Optimizing Chemical Recycling Business Models through Stakeholder Engagement – Assessment of Challenges and Success Factors in the European Chemical Industry

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Abstract

Title: Optimizing Chemical Recycling Business Models through Stakeholder Engagement – Assessment of Challenges and Success Factors in the European Chemical Industry

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The management of plastic waste represents a heavily discussed sustainability issue. About one third of post-consumer plastic waste is recycled in the EU, with the remainder split evenly between energy recovery and landfill. As an upstream player in the industrial plastics value chain, the chemical industry plays a key role in the transition to a circular economy through its research into recycling processes. In tandem with conventional recycling methods, a collection of new technologies under the umbrella term "chemical recycling" is expected to broaden the spectrum of plastic polymers eligible for inclusion in the recycling loop.

By applying a qualitative-empirical research methodology, involving 17 semi-structured interviews, this study contributes to the existing scholarly discourse. First, it explores the motivations behind engaging in chemical recycling. Second, the study addresses the challenges and success factors of implementing chemical recycling business models (CRBMs), focusing on stakeholder-specific and cross-stakeholder engagement. The findings underscore the importance of stakeholder engagement in implementing and managing CRBMs, taking a closer look into relationships with policymakers, suppliers, customers, NGOs, and technology certification bodies. Theoretical and managerial contributions include participation in multi-stakeholder platforms such as associations to facilitate cross-stakeholder collaboration to jointly educate society on chemical recycling to gain broader acceptance as well as stakeholder-specific engagement practices. Ultimately, the study contributes to bridging the gap between academic research and industry practice, providing insights into the complex landscape of CR and stakeholder engagement in the European chemical industry.

Keywords: Chemical Recycling, Circular Economy Business Models, Circular Economy, Sustainability, Stakeholder Engagement

Resumo

Título: Otimização dos Modelos de Negócio de Reciclagem Química através do Envolvimento das Partes Interessadas - Avaliação dos Desafios e Factores de Sucesso na Indústria Química Europeia

Autor: Lukas Braun

A gestão dos resíduos de plástico representa uma questão de sustentabilidade muito debatida. Cerca de um terço dos resíduos de plástico pós-consumo são reciclados na UE, sendo os restantes divididos equitativamente entre a valorização energética e a deposição em aterro. Enquanto interveniente a montante na cadeia de valor dos plásticos industriais, a indústria química desempenha um papel fundamental na transição para uma economia circular. Em conjunto com os métodos de reciclagem convencionais, espera-se que um conjunto de novas tecnologias, sob a designação genérica de "reciclagem química", alargue o espetro de polímeros plásticos elegíveis para inclusão no ciclo de reciclagem. Ao aplicar uma metodologia de investigação qualitativa-empírica, envolvendo 17 entrevistas semi-estruturadas, este estudo contribui para o discurso académico existente. Em primeiro lugar, explora as motivações subjacentes à participação na reciclagem química. Em segundo lugar, o estudo aborda os desafios e os factores de sucesso da implementação de modelos empresariais de reciclagem de produtos químicos, centrando-se no envolvimento das partes interessadas. As conclusões sublinham a importância do envolvimento das partes interessadas. Os contributos incluem a participação em plataformas multi-intervenientes, para facilitar a colaboração entre as partes interessadas, a fim de educar conjuntamente a sociedade sobre a reciclagem de produtos químicos para obter uma aceitação mais ampla, bem como práticas de envolvimento específicas das partes interessadas. Em última análise, o estudo contribui para colmatar a lacuna entre a investigação académica e a prática industrial, fornecendo informações sobre o complexo panorama da reciclagem química e do envolvimento das partes interessadas na indústria química europeia.

Palavras-chave: Reciclagem de Produtos Químicos, Modelos de Negócio da Economia Circular, Economia Circular, Sustentabilidade, Envolvimento das Partes Interessadas

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The completion of this master thesis marks the end of my academic journey at Católica Lisbon. Although the two years have passed quickly, I can state with absolute certainty that they will have a long-lasting positive impact on my life. Not only have they broadened my academic and personal horizons, but they also introduced me into a new culture and challenged me to learn a new language. An experience, I'm happy to share with all the friends, I made along the way.

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List of Abbreviations

BM	Business model
BMfS	Business model for sustainability
CBM	Circular business model
CE	Circular economy
CEBM	Circular economy business model
Cefic	Conseil Européen des Fédérations de l’Industrie Chimique (European Chemical Industry Council)
CoC	Chain of custody
CR	Chemical recycling
CRBM	Chemical recycling business model
EMF	Ellen MacArthur Foundation
GHG	Greenhouse gas
ISO	International Organization for Standardization
KPI	Key performance indicator
LBM	Linear business model
MB	Mass balance
MR	Mechanical recycling
MSP	Multi-stakeholder platform
NGO	Non-governmental organization
SE	Stakeholder engagement
SLR	Systematic literature review
ST	Stakeholder theory
VCI	Verband der Chemischen Industrie e.V. (German association of the chemical industry)

1. Introduction

Until the last century, chemical production was driven mainly by economic considerations, with little regard for the environmental impact outside the boundaries of the plant gates (Martinez-Hernandez, 2017). Consequently, the invariable use of fossil-based raw materials such as coal, natural gas or refined crude oil (Ang et al., 2021) combined with the associated high level of greenhouse gas (GHG) emissions makes it a “dirty” industry (Isella & Manca, 2022). Worldwide, the totality of chemical-based products including petrochemicals as well as industry-specific product portfolios such as fertilizers, resins, refrigerants, pharmaceuticals, and plastics accounts for approximately 7-9% of global GHG emissions (Isella & Manca, 2022; Martinez-Hernandez, 2017).

In light of the research topic, special attention is drawn towards "plastics", which typically refer to synthetic polymers that are nowadays unavoidable in modern society. Globally, 18.5% of the plastic production is located in Europe (Horodytska et al., 2022) and on average 50 kg per capita are consumed by individuals in the EU per year (Thiounn & Smith, 2020). Meanwhile, approximately 91% of this plastic remains unrecycled on a global scale. An extrapolation based on current trends in plastic waste treatment shows that 12,000 megatons will be accumulated in landfill or the environment by 2050 (Geyer et al., 2016) This detrimental man-made development endangers entire ecosystems (Kibria et al., 2023), e.g., through soil, maritime and air pollution (by open waste dumping) (Paletta et al., 2019).

The statistics indisputably reveal the extent of the problem and simultaneously highlight the responsibility of the industry. While lacking technical expertise, insufficient reversed infrastructure and shallow regulations are stated in literature, the list of causes for inadequate waste management seems endless (Kibria et al., 2023). As a response, plastic packaging waste became subject to progressively stringent sustainability targets, exemplified by the European Commission's mandate for recycling rates to attain 55% (Meys et al., 2020). Both, science and industry agree that the change cannot be achieved only through established recycling processes, which are often referred to as mechanical recycling (MR) of, e.g., PET bottles. There is a clear call for research into new recycling processes to expand both the currently recyclable scope of plastic (waste) and the possible applications in order to keep the valuable material in the production circle and to manufacture in a more climate-friendly way (Meys et al., 2020).

To realize the vision of a circular economy in the chemical industry, the nascent and complementary chemical recycling (CR) technologies are advocated as a "large-scale avenue to decrease fossil resource depletion" (Meys et al., 2020, p. 1). Simultaneously, the complexity of the plastic waste landscape emphazises the imperative for proactive measures and collaborative efforts among stakeholders (Kibria et al., 2023). The combination of CR, and respectively circular economy business models (CEBMs) within the chemical industry, and stakeholder engagement (SE) forms the transition to the underlying research gap.

First, the focus on stakeholder influence is inspired by Hina et al.'s (2023, p. 6196) systematic literature review phrasing the existing research gap as "Exploring the role of stakeholders in adopting the CEBM to drive sustainability". Hence, the analysis of responsibilities and importance of partnerships within CEBMs tend to be scarce (Lüdeke-Freund et al., 2019). Second, current research on CEBMs and SE lacks context sensitivity in terms of outcomes regarding future strategic implications and CEBM implementation mechanisms for specific industries, such as the chemical industry (Lüdeke-Freund et al., 2019). This thesis aims to shed light on both under researched topics by answering the following research questions:

1 *What are the benefits and challenges influencing practitioners to engage in CR?*
2 *How can stakeholder engagement address the challenges of designing and implementing chemical recycling business models (CRBMs) in the European chemical industry?*

In summary, this master thesis aims to gain insights on managers' motivation behind CRBM engagement. It further aims to explore the challenges faced by emerging CR technologies and identify key success factors, with a specific focus on stakeholder engagement as a crucial criterion of successful CEBM implementation.

By employing a qualitative research methodology, the dissertation adheres to an academic research format, structured as follows: Chapter 2 presents the literature to provide a knowledge foundation about the overarching themes sustainability, business models and stakeholder engagement. Chapter 3 establishes the methodological framework and rationale for the study, outlining procedures for sampling, data collection, and analysis. Chapter 4 synthesizes the primary findings, delineating three aggregated dimensions. Chapter 5 elucidates significant theoretical contributions and managerial implications, before chapter 6 summarizes the main finding in the conclusion.

2. Literature Review as Theoretical Foundation

The literature review is addressing the three overarching themes - sustainability, business models (BMs) and stakeholder engagement (SE) -, which form the foundation of the context-specific research question. First, the academic perspectives on sustainability and business models are discussed and different definition approaches are presented. Both themes are set in context to each other under the interface topic of business models for sustainability (BMfS), before narrowing the scope further by focusing on circular economy business models (CEBMs). Second, the topic of stakeholder engagement is examined, and the general impact of individual stakeholder collaboration is identified. Finally, the choice of the chemical industry, and in particular chemical recycling, as a research frame is explained, and key characteristics of this industry are highlighted. For all three themes, the current state of research is summarized and subject to critical reflection.

Figure 1 illustrates the inter-connectedness of the three themes and the underlying research gap of this master thesis is illustrated as their intersection. Other intersections resemble the keywords used in the search engine Google Scholar to identify adequate journals and research papers. The keywords include: *Chemical Recycling, Circular Economy Business Models, Business Models for Sustainability, Circular Economy, Stakeholder Engagement*. Please note that the Journal of Cleaner Production, ranked three according to the Academic Journal Guide 2021 (Chartered Association of Business Schools, 2021), published the most cited articles. However, due to its recentness and the practical nature of the CR technologies, the theoretical foundation has inevitably been supplemented by findings from lower ranked journals and has been complemented by three industry reports.

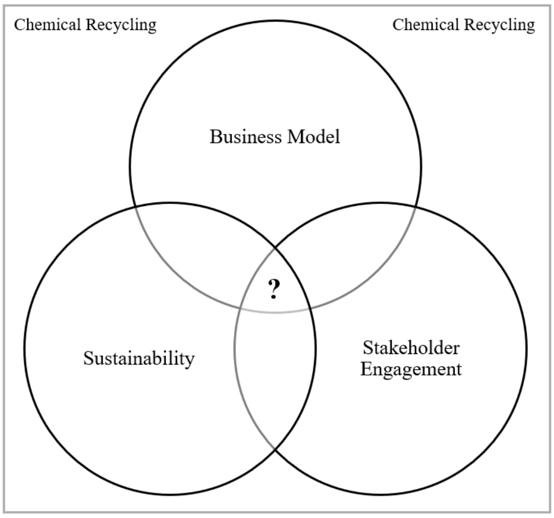

Figure 1: Thematic overview of literature review themes and research gap

2.1 Sustainability and Business Models

2.1.1 The Concept of Sustainability

While there are numerous approaches to define the concept of sustainability (Borland, 2009), the UN Commission on Environment and Development recommended in its so-called "Brundtland Report" that sustainability should be understood as the "development that meets the needs of present (species) without compromising the ability of future generations to meet their own needs" (UN Commission on Environment and Development, 1987). This rather broad definition of sustainability has been further conceptualized by Elkington in 1997, who introduced the "Triple-Bottom-Line" dividing sustainability into an economic, an ecological and a social pillar that require balance (Kristensen & Mosgaard, 2020). This classification of the sustainability concept is well accepted by most members of the scientific community as basis for its typology and further conceptual research, e.g., through systematic literature reviews (Glavič & Lukman, 2007; Purvis et al., 2019). While more context-specific research articles tend to review only one pillar, typically ecological sustainability (Borland et al., 2016), economic success, social considerations, and environmental resistance are equally important by definition (Geissdoerfer et al., 2017).

However, it is important to note that there is no consensus in academia on the origin of the sustainability terminology. This is one reason, why no universal conceptualization of sustainability has yet emerged (Purvis et al., 2019). This ultimately leads to criticism of the concept as a 'buzzword' for both, scientists and practitioners (Borland et al., 2016; Kirchherr, 2023; Kotler, 2011).

2.1.2 The Concept of Business Models

Establishing a generally recognized, holistic definition of the term "business model" remains an unsolved challenge in academia, simply due to the "explosion of articles" (Massa et al., 2017) in peer-reviewed journals using this term. Thus, academic literature tends to be fragmented, as researchers focus on their specific interests, leading to disciplinary silos hampering cumulative development of the terminology (Zott et al., 2011).

However, Zott et al. (2011) conceptualized the term in a systematic literature review (SLR) (Zott et al., 2011) and declared four widely acknowledged characteristics of BMs:

(1) BMs are perceived as a new unit of analysis (clearly distinguishable from terms such as product, firm or industry) that
(2) explain in a holistic approach, how firms “do business”.
(3) Value creation and value capture are considered a “centerpiece” (Wirtz et al., 2016) and shall be explained in accordance with
(4) the activities of the focal firm and its partners.

In addition, other authors have identified technology and innovation, strategy, and environmental sustainability as important application areas for the concept of business models (Massa et al., 2017; Schaltegger et al., 2012). This thesis focuses on the latter research area referred to as “sustainable business models” or “business models for sustainability” - BMfS in wide parts of academia.

2.1.3 Business Models for Sustainability

BMfS extent the traditional BMs since they facilitate the process of “describing, analysing, managing and communicating a company’s sustainable value proposition to its customers, and all other stakeholders” (Schaltegger et al., 2016). Authors also tend to combine the defining aspects with the triple-bottom-line concept (Freudenreich et al., 2020) and emphasize that in a BMfS economic, environmental, and social value are created and captured equally (Pinkse et al., 2023; Schaltegger et al., 2016; Stubbs & Cocklin, 2008).

Creating a BMfS requires companies to overcome their boundaries and to consciously interact with a broad stakeholder network (Pinkse et al., 2023), since multi-stakeholder collaboration is considered a necessity to accumulate expertise (Hörisch et al., 2014). Consequently, BMfS differ from traditionally applied BM frameworks such as Osterwalder’s and Pigneur’s (2010) business model canvas that originally places the value proposition for the customer in the center. Regarding the transition from BM to BMfS, Pinkse et al. (2023) conceptualized a framework describing the change processes within BMfS. Two pathways effectuate the transition of business models towards sustainability. *Discursive pathways* involve reshaping discourse to gain support and legitimize sustainability initiatives, e.g., by managing stakeholder expectations and facilitating alignment (Pinkse et al., 2023; Vernay et al., 2022). *Cognitive pathways* aim to reconfigure stakeholders' individual mental models to foster innovative thinking and envision BMfS without cognitive barriers (Pinkse et al., 2023). Established preconceptions in the minds of managers about how BMs have to be designed in their respective industry in order to maximize success (Baden-Fuller & Morgan, 2010) make BMs relatively inflexible (Bohnsack et al., 2014), calling for a synergistical integration of both pathways (Pinkse et al., 2023).

2.1.4 Transition from Linear to Circular Economy Business Models

Nowadays, the linear economy model still largely represents the status quo of how the current socio-economic framework operates (Michelini et al., 2017). Production entities manufacture goods and consumers subsequently use and discard them in a system, where mainly virgin resources serve as primary feedstock for the value chain (Michelini et al., 2017). This key characteristic of linear business models (LBMs) has been criticised by academia for many years due to the relentless depletion of finite virgin resources, dwindling biodiversity, and the acceleration of climate change (Buchmann-Duck & Beazley, 2020; Fritz & Koch, 2014).

However, over the past two decades, there has been a growing recognition of the impact of existing manufacturing practices on both, environment and society as a whole (Garbie, 2014). One way to address this socio-economic problem is to apply circular economy (CE) practices and circular economy business models (CEBMs) (Ünal et al., 2019).

As the concept of CE is increasingly gaining traction in scholars, policymaking and by practitioners, several definitions emerged. Due to the rapidly advancing development of CE terminology, the author of this thesis refers to the leading SLRs by prominent researchers when conceptualising the definition. Kirchherr et al.'s (2018) SLR collated 114 definitions of CE and was revised by the same authors in 2023, providing a terminology based on 221 definitions that exemplifies the challenging dynamics of holistically defining the term. Geissdoerfer et al.‘s (2017) widely acknowledged summary of CE as “a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops (which will) be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling” (Geissdoerfer et al., 2017, p. 759), can thus be adapted in terms of CE *core principles*, *aims* and *enablers*.

- The *core principles* describe CE as a regenerative system which reduces, reuses, recycles and recovers materials (4R).
- C *aims* include the promotion of value maintenance and sustainable development in terms of environmental quality, economic development, and social equity for current and future generations.
- The *enablers* differ since they refer to technological innovations and capabilities of a wider range of stakeholders (consumers, policymakers, academia, and industry) (Kirchherr et al., 2023).

Figure 2 visualizes the complex interaction of core principles, aims and enablers by depicting Kirchherr et al.'s (2023) definition according to their graphical coding framework.

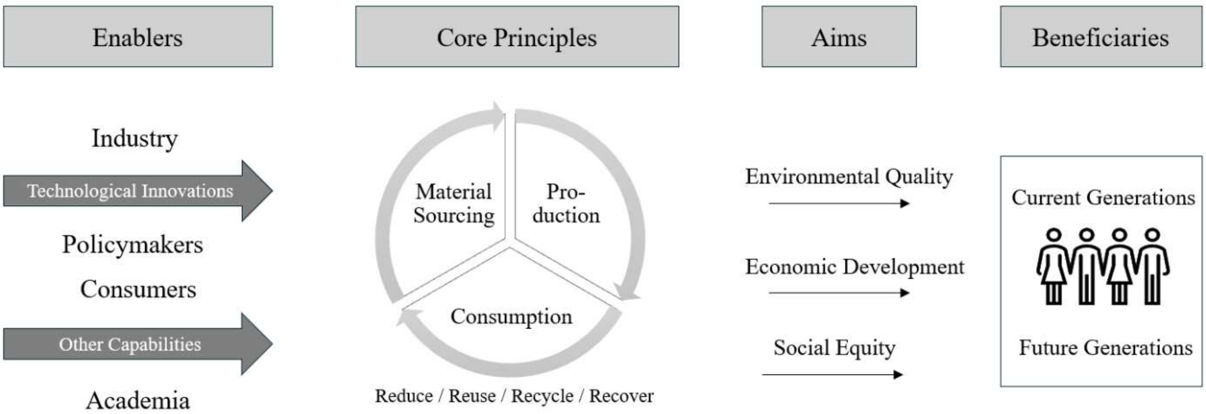

Figure 2: Visualization of the CE conceptualization, adapted from Kirchherr et al. (2023)

Literature further differentiates between the terminologies of CE and CEBM by highlighting different potential levels of implementation. Whereas CE serves as an umbrella term for micro- (product, companies, consumers), meso- (eco-industrial parks) and macro- (city, region or national) level integration, CEBM was often used to primarily refer to the micro-level of individual organizations (Ghisellini et al., 2016). However, more recent SLRs do not emphasize this differentiation (Geissdoerfer et al., 2020) and include a macro-level perspective as current trend in their definition (Kirchherr et al., 2023). Therefore, a CEBM or CBM (circular business model) is described as holistic approach involving managerial practices that target value proposition, creation, delivery, and capture (Geissdoerfer et al., 2020; Lüdeke-Freund et al., 2019) by decoupling it from consumption of virgin resources resulting in sustainable solutions" (Blaschke et al., 2017; Manninen et al., 2018; Ünal et al., 2019). However, at this stage, CEBM remains a broad and intangible term. Both, scientists and practitioners are heavily invested in designing frameworks to typologize CEBMs and thus make them more comprehensive for users. From an academic perspective, Geissdoerfer et al. (2020) distilled four generic strategies for implementing CEBMs, namely cycling, extending, intensifying, and dematerialising.

Lüdeke-Freund et al. (2019) consolidated existing models in a morphological analysis to identify and build clusters facilitating sense-making of predominant rationales behind value creation. Six CEBM patterns (namely *1) repair & maintenance, 2) reuse & redistribution, 3) refurbishment & remanufacturing, 4) recycling, 5) cascading & repurposing* as well as *6) biochemical feedstock extraction)* have been identified and offer a more in-depth characterization based on generic dimensions of the researcher`s morphological box. This typology shares similarities with the practice-inspired and widely known ReSOLVE framework (see figure 3 below) of the Ellen MacArthur Foundation (EMF), whose consideration in the CEBM implementation has proven to be beneficial for sustainability (Reim et al., 2021).

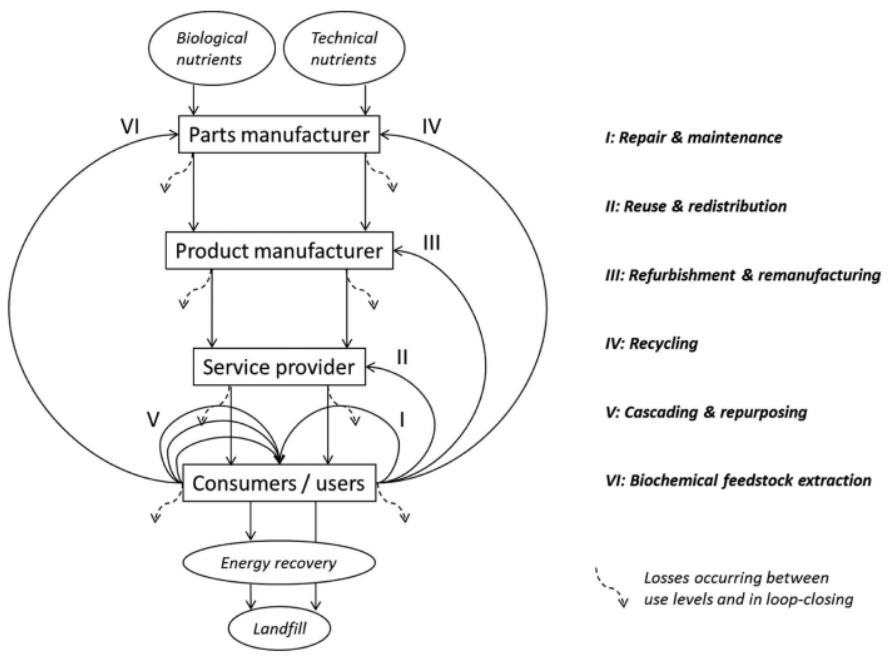

Figure 3: Depiction of major reversed cycles and CEBM patterns (Lüdeke-Freund et al., 2019)

The positions of academia and industry suggest that CR can be placed into CEBM pattern VI (Cefic, 2022; Quicker et al., 2022), although it was not explicitly categorised in the EMF framework by researchers.

Benefits

While it's recognized that CEBMs can offer substantial sustainability benefits (Ünal et al., 2019), it remains subject to clarification, how exactly these benefits are expressed on a more detailed level. Typically, encompassing economic, environmental, and social aspects, the latter dimension is less studied and lacks a solid theoretical foundation (Corvellec et al., 2022; Hina et al., 2023; Lüdeke-Freund et al., 2019; Murray et al., 2017). Therefore, this dimension is not included in the scope of the literature review. From an economic perspective, the benefit assessment heavily depends on the BM or recycling technology applied and is mainly related to diverse ways of cost saving (Lüdeke-Freund et al., 2019).

Environmental benefits prevailing in literature can be categorized into the following four groups described below. To which extent these benefits are interrelated and influence each other is subject to context-specific analysis.

1) *Eliminating waste and pollution*. In an optimal scenario, waste can be eliminated through reuse, while relying solely on renewable energy sources. Achieving this goal requires a comprehensive examination of the input, transformation and output components inherent in business models (Lewandowski, 2016; Lifset & Graedel, 2002).
2) *Substituting fossil virgin material.* Ultimately, resource efficiency and value recovery of products and by-products via recycled and reused alternatives (Sauvé et al., 2016) makes CE the perfect substitute for the current linear economy (Howard et al., 2019; Linder & Williander, 2017).
3) *Reducing greenhouse gas (GHG) emissions.* CEBMs can potentially address environmental sustainability by GHG emission reduction (Ünal et al., 2019)
4) *Improving energy efficiency.* Energy efficiency is intricately linked to the reduction of GHG emissions (Karakutuk et al., 2021). Therefore, incorporating energy loops into CEBMs designed to minimize energy loss are yielding beneficial effects on the environment (Ünal et al., 2019).

Challenges

In line with the systematic approach applied, it should be stressed that the challenges, which CEBMs currently face, are of an economic nature except for the first point. Arguments of criticising the "romanticised" perspective (Corvellec et al., 2022) on CE include:

1) *Scientific evidence from nature science is ignored*. In most CE technologies, new materials or energy must be added to the circular material loop to compensate for losses along the process (Cullen, 2017). Therefore, without the use of renewable energy, substantial amounts of GHG can be emitted (Haas et al., 2015).
2) *Limitations due to complexity of (waste) material specifications.* Certain types of waste feedstock provide industry-specific hurdles to entirely closed material-loops, e.g., due to contamination (Baxter et al., 2017).
3) *Uncertainty of recycling markets***.** Traven (2019) argues that recycling markets are characterized by high price volatility and unpredictable supply chains, which are often caused by the escalating scarcity of resources (Lieder & Rashid, 2016; Traven, 2019).
4) *Unclear policymaking***.** The implementation efforts towards single centralised systems (Corvellec et al., 2022) without thorough inclusion of stakeholders and a punctured regulatory framework (Jesus & Mendonça, 2018) leads to unclear implementability from a policy perspective (Corvellec et al., 2022).
5) *Technological feasibility***.** Particularly in complex application areas working with large volumes, technical barriers can decelerate implementation and may only be addressed through technical support or training programs (Corvellec et al., 2022).
6) *Economic feasibility*. As CEBMs represent a disruption of the status quo in most industries, there is a high degree of uncertainty in terms of profitability. In addition, high capital expenditure as initial costs lead to financial risks (Jesus & Mendonça, 2018).
7) *Customer awareness.* Although customers take sustainability aspects more and more into consideration, some scholars argue that circular solutions, particularly in dematerialization services, are confronted with relatively small customer awareness / interest (Kirchherr et al., 2018).

The accumulation of these implementation hurdles decelerates progress and as a result “to date, most firms are failing in translating the [circular economy] concept into their business operations” (Khan et al., 2021).

Finally, the concept of CEBMs offers a certain target for criticism. This is reinforced by the proximity of CEBMs to practice, making them subject to political and economic simplifications (Corvellec et al., 2022), which do not address the complexity of the issue and blur a holistic view on scientific sustainability contributions (Völker et al., 2020). Hina et al. (2023) further address a common misconception arguing that there is no scientific evidence that CEBMs are automatically entirely sustainable due to missing long-term perspectives and stakeholder engagement (Geissdoerfer et al., 2018) as well as the conflict of globally satisfying human needs while respecting planetary boundaries (Schröder et al., 2019).

2.2 Stakeholders

2.2.1 Concept Definition and Stakeholder Theory

The research paper applies the widely used academic understanding of the term "stakeholder" (Fassin, 2009) as any group or individual that "can affect or is affected by the achievement of an organization's objectives" (Freeman, 1984, p. 46). Accordingly, the term is often associated with Freeman's stakeholder theory (ST), which places stakeholders at the center of analysis and strategic decision-making (Freeman, 1984). Thus, it serves as explanation of how and why managers respond to external pressures from stakeholders, including government bodies, industry partners, consumers and NGOs (Allen et al., 2021; Guay et al., 2004; Mitchell et al., 1997). While many scholars re-conceptualised ST over the past two decades, Mitchell et al. (1997) defined *identification* and *salience* as the two main components. The former describes individuals or groups that the company should take into consideration in its decision-making based on legitimacy claims, e.g., if individual or group is impacted by company actions. The relevance or salience of stakeholders is assessed either by their power or by the urgency of a time-critical action related to that stakeholder (Mitchell et al., 1997).

Academia has recently focused on bridging CE and ST (Schultz et al., 2024) breaking with the traditional perception of ST as "pro-business" with little consideration of systemic impacts (Dmytriyev et al., 2021).

2.2.2 The Concept of Stakeholder Engagement

As a way of operationalizing the ideas of ST (Greenwood, 2007; Sachs & Rühli, 2011), the construct of stakeholder engagement (SE) started to gain prominence in the stakeholder literature at the beginning of the 2000s (Kujala et al., 2022). Based on 90 stakeholder engagement articles, Kujala et al. (2022) define SE as *"the aims, activities, and impacts of stakeholder relations in a moral, strategic, and/or pragmatic manner (Kujala et al., 2022).* In addition, SE shows parallels to "stakeholder collaboration" which emphasizes more on joint activities "to pursue goals that would otherwise be difficult to achieve internally" (Desai, 2018, p. 220) and to solve wicked problems (Savage et al., 2010). In addition to SE, these aspects of stakeholder collaboration might thus be relevant to this study and the research-specific context of this thesis.

Several authors confirm the importance of SE on organizational activities such as strategic planning, decision-making or sustainability (Arenas et al., 2009; Kujala et al., 2022). The latter is commonly analyzed in a more practice-oriented approach compared to other research streams (Papagiannakis et al., 2019). SE focuses on explaining inclusion processes of stakeholder groups, simultaneously referencing decision- and policy-making to the environmental and sustainability issues addressed (Kujala et al., 2022).

2.2.3 Stakeholder Engagement Practices in the Context of Circular Economy

Academics call for a more systematic approach to stakeholder interaction analysis to facilitate business operations beyond the companies' immediate supply chain actors (Blomsma et al., 2023). In line with Mitchell et al. (1997), Reed et al. (2009) defined the identification of the relevant stakeholders as the starting point of the application phase in their conclusive summary of various stakeholder analysis models. This phase is followed by a clear process of differentiation and categorisation (Reed et al., 2009). Historically, Freeman’s first stakeholder model visualization commonly included seven stakeholders (competitors, customers, employees, civil society, suppliers, shareholders, government). In line with the underlying research context, Schultz et al. (2024) recently published an article discussing industry-oriented governance to facilitate collaboration for CE transition in the chemical industry.

Overall, engaging in stakeholder dialogue with the aim to identify and satisfy stakeholder expectations (Salvioni & Almici, 2020) is crucial. Effective SE should be structured as "two-way" engagement, which refers to raising awareness of potentially conflicting interests before initiating decision-making processes (Belal, 2002; Burchell & Cook, 2006; Foster & Jonker, 2005). Salvioni and Almici (2020) conclude that the broader the SE, the better the environmental awareness as a prerequisite for long-term value creation.

While almost all stakeholder models remain a simplification of the reality (Fassin, 2009), figure 4 below provides a more in-depth understanding of the complex stakeholder interplay within the respective industry. As the literature review is subject to an iterative process of adaptations based on the findings from the practical part of the thesis, it follows the derived categorisation of stakeholders into suppliers, customers, policymakers, NGOs and certification bodies. In the following abstract, the literature on SE is divided into cross-stakeholder and stakeholder-specific engagement practices.

Regarding stakeholder-specific engagement, the density of available information from relevant journals varies depending on the stakeholder group.

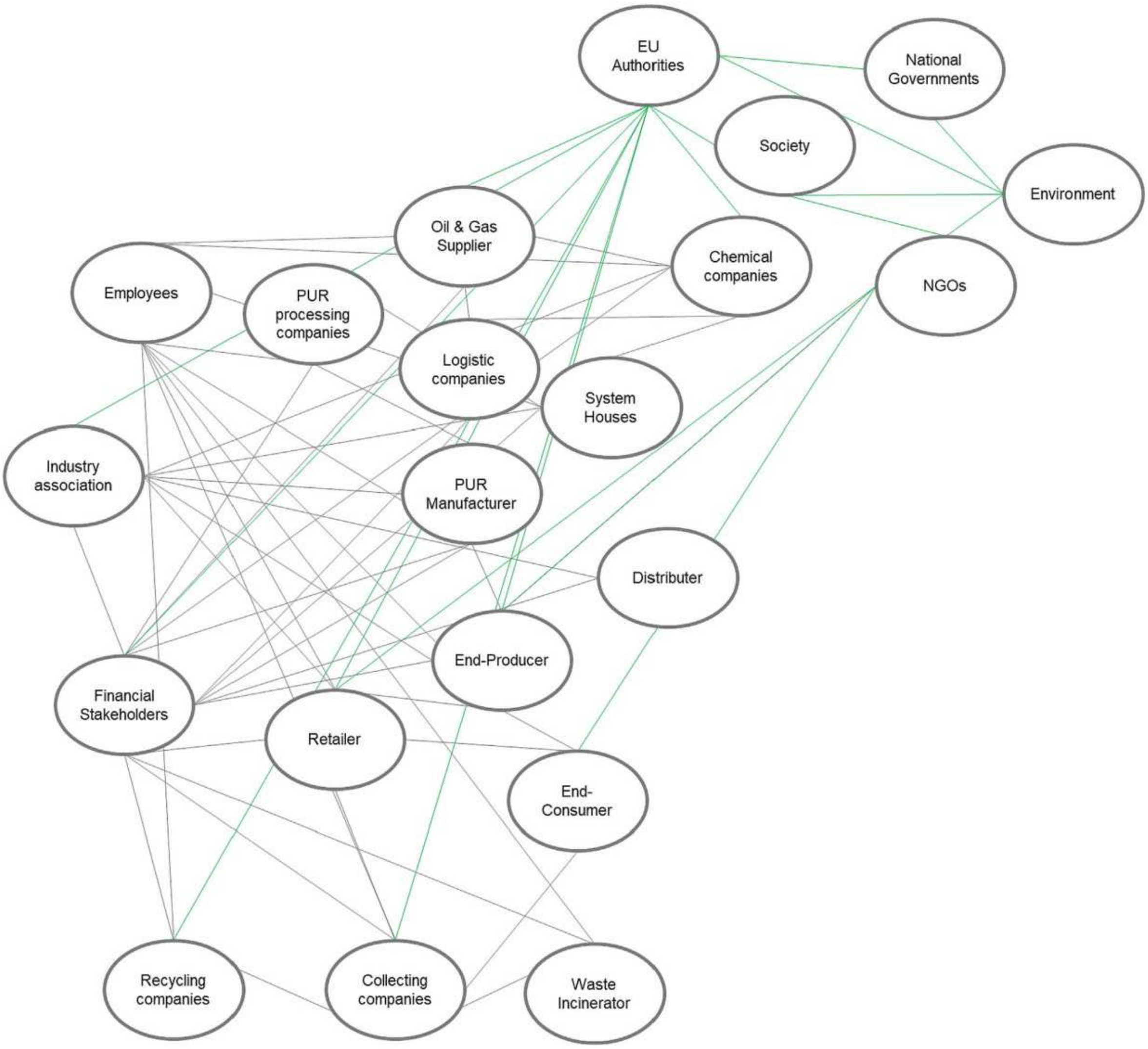

Figure 4: Network graph visualizing the stakeholder relationships in the chemical industry (Schultz et al., 2024)

1) *Policymakers and Governments*

   From a company's perspective, future generations of managers need an understanding of strategic objectives of the governing bodies as well as their own social interconnectivity as basis for constructive engagement with policymakers (Schepers, 2010). On the other side, policymakers should try to create favourable conditions to motivate companies, e.g., via subsidies, incentive programs, or tax breaks, to accelerate the transition (Salvioni & Almici, 2020; Schultz et al., 2024). An exemplary study about Norwegian waste management regulation draws special attention to regulatory clarity. Waste collectors faced considerable regulatory ambiguity that unintentionally promoted landfill over mechanical recycling (Deshpande et al., 2020).

2) *Consumers*

   Understanding expectations and communicating information to uncover optimal material utilization practices are equally important as jointly building reversed logistic infrastructure. Additionally, companies are advised to raise awareness about the interrelationship between customer behavior and circularity (Salvioni & Almici, 2020).

3) *Suppliers*

   In their article about the impact of SE on sustainability, Salvioni and Almici (2020) highlight value alignment and mutual circularity objectives to build on renewable material utilization most efficiently.

4) *NGOs*

   Close engagement and advocacy partnerships towards the adoption of pro-sustainability regulation frameworks (Schultz et al., 2024) is vital since NGOs can operate as intermediaries to facilitate collaboration across the entire stakeholder network (Antikainen & Valkokari, 2016).

5) *Certification bodies*

   The number of corresponding peer-reviewed publications is relatively scarce. However, multi-stakeholder initiatives (such as the Forest Stewardship Council), are occasionally created around certifiers. These differ from international standard-setting bodies, e.g. the International Organization for Standardization (ISO) since they often intersect with both, public institutions and private organizations (Salvioni & Almici, 2020).

2.3 The Research Context – Introduction of Chemical Recycling

With more than 60,000 chemical products and various production processes, the chemical sector is characterized by a high degree of heterogeneity (Mohan & Katakojwala, 2021). Due to the upstream positioning in cross-industry value chains, chemical-based products exemplify a diverse customer profile consisting of various sectors such as agriculture, energy, health, transportation, food and consumer goods (Mohan & Katakojwala, 2021). Within the EU, approximately 1.2 million people are directly employed in chemical companies and 4.6 million additional jobs indirectly depend on them (Elser & Ulbrich, 2019).

The chemical industry and its stakeholders are increasingly recognizing the issue, with a growing momentum observed in the emergence of recycling technologies for plastic waste. A simplification of a typical value chain in the chemical industry is shown in figure 5. It illustrates the main steps in the value chain, from raw materials via chemicals and customer-specific applications to the end user. It also highlights five molecular loops, characterised by the different ways in which plastic waste / circular feedstock can re-enter the value chain.

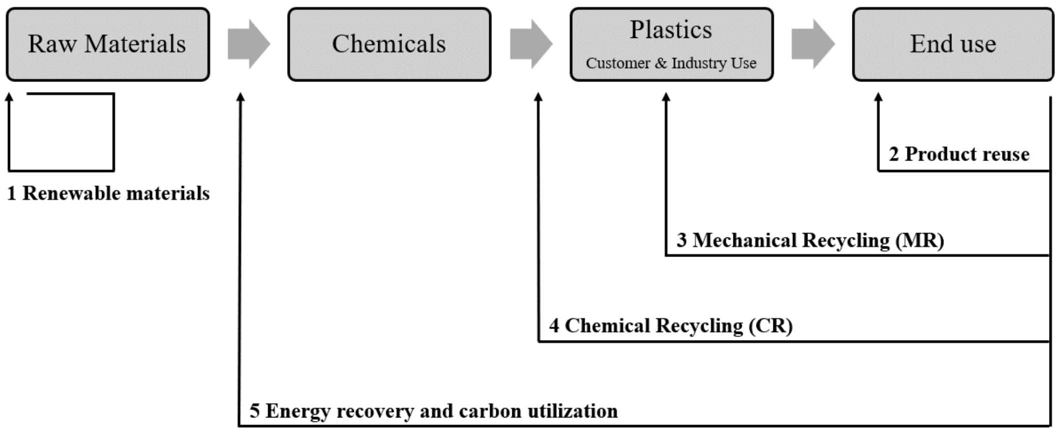

Figure 5: Depiction of the value chain in the chemical industry and the five molecular loops, adapted from Elser & Ulbrich (2019)

The fourth molecule-circulating loop is based on the modification of molecules and can be summarized under the term "chemical recycling" or "advanced recycling", which represents the focus of this thesis. Although the process is not yet defined, scientists and practitioners agree that it describes the process of breaking down plastic polymers into monomers, which are short-chain chemical building blocks (Quicker et al., 2022). Many CR technologies such as solvolysis, liquification, pyrolysis or gasification are currently researched and developed, however, none of them is officially recognised as technology pioneer, although most research is conducted in the field of pyrolysis (Maisels et al., 2021). The fragmented technology landscape influences the current definition gap and is partly responsible for the worldwide shortage of large-scale CR plants (Quicker et al., 2022).

The question of the optimal recycling method cannot be generalized. Rather, the type of plastic waste (including its degree of contamination) that is available as feedstock for recycling, and the application in which the recycled product is ultimately used, must be taken into account (Meys et al., 2020). Findings of a German research team suggest that CR has finally no positive effect on the environment compared to benchmark waste treatment, if the end-product is fuel or refinery feedstock (Meys et al, 2020). Five plastic polymers (polyethylene terephthalate (PET), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP) and polystyrene (PS)) were examined, which account for over 50% of the globally produced plastic packaging waste. In contrast, a more differentiated view identified potential when used for building monomers or value-added products (Meys et al, 2020).

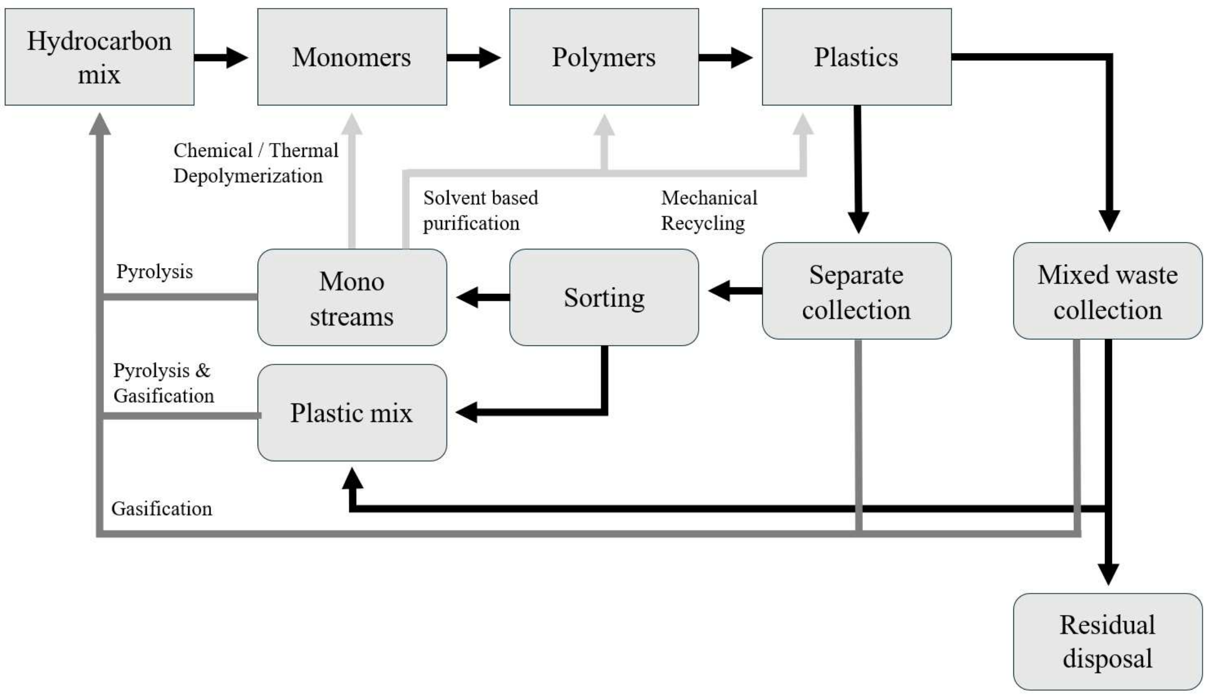

Figure 6: Depiction of plastic waste recycling routes adapted from Zero Waste Europe (2019)

To balance the technological details necessary to understand the initial scope of the paper, figure 6 provides an overview of the most common CR paths in the value chain. Which path is technologically feasible for the most prominent plastic waste category may be subject to change due to the dynamics of technology development. An in-depth discussion about the multiple factors influencing the optimal recycling loop for the different plastic molecules exceeds the scope of this thesis.

In the discourse on CR, the topic of feedstock allocation via a mass- balance (MB) approach as chain of custody (CoC) model should be explained as well. According to the International Organization for Standardization (ISO), CoC can be defined as a process by which inputs, outputs and related information are transferred, monitored and controlled as they move through each stage of the supply chain (International Organization for Standardization, 2020). Due to the complexity and interconnectedness of the established chemical production sites as well as the physical condition of the feedstock material, chemical companies are relying largely on MB. In this model, recycled and fossil materials and products are no longer considered separately, but are deliberately mixed. Certification is then credited to a portion of the output that is proportional to the certified input materials (Mol & Oosterveer, 2015).

Table 1 below summarizes, academic articles and industry reports on benefits and challenges, the young technology is currently facing. Some of the technological benefits are particularly evident in terms of the complementarity of CR to traditionally applied mechanical recycling (MR) as part of achieving a holistic waste treatment solution (Zero Waste Europe, 2019).

Industry-wide prevails the perspective that full independence from fossil resources as source for e.g. hydrocarbons is not yet possible (Elser & Ulbrich, 2019). The assessment of CR advantages and disadvantages is not exhaustive. On the contrary, it is pointed out that the complexity of the subject inevitably leads to a multitude of arguments from different points of view. It is important to note that the presented recycling options are fairly new technologies, for which analytical data is mostly generated from industry itself, respectively the number of independently conducted environmental analyzes from academia is still scarce (Zero Waste Europe, 2019).

Table 1: Overview of benefits and challenges of CR

Benefits of Chemical Recycling	Challenges of Chemical Recycling
Keep carbon in the loop Unlike MR, CR does not induce structural degradation in polymer compositions, commonly referred to as “downcycling”. Therefore, it does not limit the number of viable recycling cycles (Zero Waste Europe, 2019) and thus decelerates the path to incineration or landfill (Hong & Chen, 2017).	**Missing financial viability** Industry experts claim that industrial-scale implantation of plants faces technological hurdles and that the current technologies lack economic viability (Elser & Ulbrich, 2019). This issue is intertwined with the complicated challenges of separating and purifying real-world waste streams, encompassing mixed plastic waste, e.g., of municipalities (Thiounn & Smith, 2020).
Extended plastic waste recyclability With reference to figure 6, CR contributes to the recovery of hydrocarbons from previously incinerated or landfilled waste streams (Zero Waste Europe, 2019).	**Sorting complexity** State-of-the-art sorting technologies that rely on physical or optical properties of polymers are limited in their ability to effectively distinguish between different polymers, particularly when dealing with complex materials that have undergone partial degradation, such as those exposed to environmental stress (Rahimi & García, 2017).
Broader product applicability CR separates additives and better prevents unintentionally added substances from plastic waste, making it suitable for high-value applications such as food contact materials (Zero Waste Europe, 2019).	**Legal acceptance** Although CR is becoming increasingly well known, in Europe, for example, it is so far only recognised as a form of recycling at a national level, but not officially by the European Commission (Quicker et al., 2022).

3. Methodology

3.1 Expert Interviews as a Qualitative-empirical Study

In general, academia highlights the prevalence of quantitative, qualitative, or mixed research methods (Mulisa, 2022). Quantitative research relies on "hard" data, usually expressed numerically, while qualitative research uses "soft" data, which is conveyed, e.g., through impressions, language, images, symbols (Maxwell & Reybold, 2015). Subsequently, explorative research purposes are analyzed more with qualitative methods, while researchers largely use quantitative methods for confirmation purposes (Johnson & Christensen, 2014). The data generation and overall research approach in this paper is entirely qualitative due to the following two reasons:

First, the approach benefits from better conceptualization of new theories by understanding the person's individually constructed rationale, taking into account both the individual circumstances and dynamics (Mulisa, 2022). Therefore, it fits the purpose of this research, since CR faces a dynamic environment, e.g., due to an early stage in the market development and influence of different stakeholders (Lee et al., 2021). Conclusively, the process of CR remains yet under-researched (Quicker et al., 2022), hence the exploratory nature of the research methods can lead to novel findings that may complement or contradict current assumptions in academia.

Second, interviews provide valuable insights for establishing causal relationships, particularly in elucidating the underlying patterns of a phenomenon (Sandelowski, 2000). Instead of focusing solely on outcomes (Maxwell & Reybold, 2015; Mulisa, 2022), it facilitates the examination of SE in a CR environment as a process rather than a state.

Given its alignment with the research objectives, qualitative methods, particularly those that emphasize primary data collection through interviews, can be considered appropriate for this study. The approach allows researchers to gain a comprehensive understanding of the interdependencies of stakeholders and stakeholder engagement with current challenges and success factors for CR.

3.2 Selection of Interviewees

The interviewees were selected based on a non-probability sampling method. Initially, the goal was to create a more homogeneous sample, solely interviewing experts from (petro)chemical companies that are directly involved in the processing of chemically recycled feedstock. However, due to the recentness of CR, the number of companies engaging in these technologies is relatively scarce. By employing a purposive sampling strategy, the author addressed the relative scarcity of suitable experts and tries to optimize the use of limited research resources (Campbell et al., 2020).

Furthermore, the low number of companies currently operating in this specific position within the CR value chain forced the author of this thesis to expand the sample criteria. This allowed for a reasonable number of expert interviews with varying companies and for capturing the perspective of producers directly involved in using chemically recycled feedstocks. However, this inevitably led to a more heterogeneous sample, which complicated achieving theoretical saturation, marking the stage in which additional interviewees are not generating new relevant insights (Busetto et al., 2020).

The pre-defined sampling criteria (as part of the targeting strategy) were that the expert must have worked for at least one year in the field of chemical recycling within a company operating in Europe that is either:

- technology provider, e.g., a pyrolysis oil producer, operating small-scale plants.
- petrochemical company directly feeding the recycled material as feedstock into the production plant.
- chemical company involved in the treatment of chemically recycled feedstock.

The most suitable companies were identified via association memberships in, e.g., "Chemical Recycling Europe" or industry reports about CR. The respective experts were researched and contacted via LinkedIn or their company email address. In addition, the snowball sampling approach, where "the researcher accesses informants through contact information that is provided by other informants" (Noy, 2008, p. 330) was applied and led to the identification of additional four CR managers. In all cases, the contacts came from the same company to enrich the thesis with further insights from the perspective of another functional unit.

In total, 19 out of 99 contacted experts from 13 companies participated and 17 interviews were conducted throughout the thesis. Appendix 2 shows a comprehensive overview of the interviewee patterns. For confidentiality purposes, the interviewees' names have been abbreviated and only the respective job grades, the years of experience with CEBMs, the companies' names as well as the interview duration and the geographic location are listed.

3.3 Data Collection Method

Semi-structured expert interviews were chosen as form of primary data collection and conducted either in English or German depending on the interviewees' preferences. To provide the interview partners with a high level of comfort and flexibility and to transcend geographical limitations, all interviews were conducted via the video conferencing application Microsoft Teams.

The interview process followed an interview protocol, which balanced the need for structure with exploratory, non-leading questions to aid the interviewee to share new insights openly and impartially (Gioia et al., 2013). The interview protocol contained the following five sections and can be reviewed in appendix 2.

1) *Introduction:* The interview started by establishing common ground, discussing and assessing the degree of agreement on Geissdoerfer et al.'s (2017) academic definition of CEBMs. The other questions in this section aimed to gain knowledge about the interviewee's experience, responsibilities and the project-specific CR objective.
2) *Characterization of the CRBM:* The second section served to better comprehend the prevailing CRBMs regarding the diverse CR technology landscape. The characterization was inspired by the dimensions set out by Lüdeke-Freund et al.'s (2019) morphological analysis.
3) *Motivation and Benefits:* In this section, the researcher aimed to understand the interviewee's perspective on advantages and disadvantages of CRBMs.
4) *Stakeholder Engagement:* The interviewees identified and categorized relevant stakeholders before describing the nature, challenges and success factors for the interaction with each stakeholder group.
5) *Outlook and Closing:* Interviewees were given the opportunity to discuss relatable aspects and to clarify questions about the underlying research methodology as well as the analysis.

Throughout the initial interview phase, the interview protocol was partially re-structured to better address the newly gained insights. In addition, it was intended to streamline the questions in the SE section with the aim to improve the rigor and to avoid redundancies (Gioia et al., 2013). Special care has been taken to ensure that the comparability of the interview protocol was not compromised by these adjustments.

3.4 Data Analysis

The data analysis followed the methodology of Gioia et al. (2013) and was initiated at an early stage of the interview process, supplemented with new insights from later interviews in an iterative circle. The inductive research scheme can be divided into three phases of analysis, which are subject to a coding process (Gioia et al., 2013). Before that, each transcript was broken down into smaller units by selecting those quotations that were relevant to the research question. Depending on their length, these direct quotations were summarized and pre-grouped according to the similarity of the insights to which they referred.

First, each quote was assessed and grouped into a wide set of 59 subcategories. During the initial phases of data analysis, the approach placed considerable emphasis on the perspective of the interviewee. Hence, this "informant-centric" coding is referred to as "1st-order analysis" (Gioia et al., 2013) and faithfully adheres to the interviewee's wording with comparatively little effort to categorize. Secondly, the "2nd-order analysis" was applied by taking into consideration the researcher's perspective. By establishing relationships between academic background (displayed in the literature review) and the interview content, the "1st-order concepts" were further clustered into comparatively more abstract "2nd-order themes" to enhance qualitative rigor (Gioia et al., 2013). This process of axial coding condensed the number units analyzed to a more manageable amount of 16 "second-order themes" to identify hidden relationships, ultimately leading to a more comprehensive understanding of the phenomenon under research (Gioia et al., 2013). Summarizing the quotations is important because by conducting this "get in there and get your hands dirty" research (Gioia et al., 2013), researchers risk ‘‘going native'', namely, being too close and essentially adopting the informant's view, thus losing the higher-level perspective necessary for informed theorizing. In a third step, the "second-order themes" were distilled into "aggregated dimensions" that enable novel concept theory building (Gioia et al., 2013). The process of narrowing down direct quotations into aggregated dimensions is visualized in table 2 - 4 in the following chapter. As pointed out by Gioia et al. (2013), several scholars question the standards in demonstrating scientific soundness of inductive research approaches, e.g., due to the often limited sample size (Kelle, 2006). Historically, qualitative research also has long been criticised for not adequately substantiating its claims, because their creative theories appear to be developed based "on rather thin evidence" (Gioia et al., 2013) and therefore often lack representativeness and transferability (Magnani & Gioia, 2023). The iterative analysis process intended to minimize the risk of subjectivity, e.g., in the form of potential biases.

4. Results

Based on the accumulated data from all 19 industry experts, the thematic analysis uncovered numerous insights and emerging themes, resulting in three aggregated dimensions. Following the structure of the interview protocol, these dimensions are 1) benefits (B), 2) challenges (C) and 3) success factors (S) of (implementing and operating) CRBM. This thesis adheres to a particular structure since the challenges and success factors can largely be categorized according to the same stakeholder groups, which also serve as "second-order themes". Table 2-4 below exemplifies the underlying data structure and lists the corresponding "first-order" and "second-order" per dimension based on Gioia et al. (2013). For a detailed overview of all analyzed quotations, please refer to the table in appendix 4.

For the sake of clarity, the author has chosen to not present the results of the analysis in the traditional way of describing each dimension in turn. For dimensions 2) and 3), this chapter is divided into sub-chapters according to the stakeholders identified. This allows for a more illustrative comparison of stakeholder-specific challenges and success factors.

Stakeholders are listed in descending order based on the frequency with which they are mentioned in direct quotes. Please note that this is only an indication of the "importance" of the respective stakeholders, as the methodological approach does not target and therefore is not suitable for a scientifically sound assessment of stakeholder salience.

4.1 Findings on the Benefits of Chemical Recycling

The analysis of the benefits of CR technologies is devoted to describing the motivations and business rationale, ultimately justifying the current relevance of the topic. Organizationally, technology aspects complement the structure of the three pillars of sustainability.

From an **ecological perspective**, CR is "reducing dependency from fossil feedstocks [and keeps] materials in circulation for longer" (IS). Additionally, experts argue that "defossilization is the greatest benefit" (CS), since it subsequently leads to a reduction of environmentally harmful excavation practices (CS, NF, IS), while limiting and preventing plastic pollution and landfill (NF, IS, AB). However, the benefit of reduced GHG emissions (MM, BV, RE) needs to be considered in a more nuanced way, as the energy intensity can vary depending on the CR technology, thus affecting the associated CO_2 emissions (BV, FB, JM, AB, CM).

By comparison, the **economic benefits** tended to be more dispersed. Increased attractiveness for young employees in an ongoing "war for talents" (FB, CM), improved financing opportunities due to better performance in sustainability rankings (RE), reduced expenditure on waste disposal (YE) and the possibility of telling a compelling marketing story (YE) were occasionally mentioned. “The opportunity to shape the market [and] even legislation” (MM) that catalyses the industrial transition is mentioned more frequently (CM, NM, MM, NF). Other benefits, such as less dependence on fluctuations in raw material prices and the [favourable] supply-demand situation, as well as the acquisition of new long-term customers, have been assessed in part contradictorily by the experts (AB, YE, BV, BO, NM, MM). The same applies to the perception of recycling programs as a "licence to operate" (OB) in the future due to the adaptation of consumer attitudes and regulations (FM, OB, MM, CM).

Social benefits were less mentioned during interviews and were described from a business perspective as improving public perception of plastic (waste) from polluter to solution provider (IS, YE).

Finally, **technological benefits** included the complementary expansion of both recyclable input (feedstock) and recycled output, as CR "provides a catalyst for waste streams that cannot be mechanically recycled" (NF). Furthermore, the technology expands the range of potential customers of products made from recycled plastic feedstock to "contact-sensitive applications" (BV) such as "food packaging" (FB).

4.2 Findings on Challenges and Success Factors of Chemical Recycling

4.2.1 Policymaker Engagement

Evidence suggests that the main challenges relate to companies facing high bureaucratic hurdles due to unharmonized regulations while legislative uncertainties (such as the pending acceptance of CR and MB) and missing incentive programs decelerate progress. Many practitioners reported a lack of harmonization of national (hazardous) waste treatment and transport regulations within Europe, leading to "huge bureaucratic processes" (DK). Besides that, "the biggest disadvantage at the moment is that chemical recycling is not included in the [mandatory] recycling rate” (SS) as part of the Green Deal by EU-Commission due to pending legal acceptance of MB as chain of custody model (CM, NF, NM). Hence, products based on chemically recycled feedstock don’t count towards mandatory recycling quotas (BV, NM, FB, SS). In this sense, “the free markets and the free play of forces [is] poison for a company, because [one] cannot calculate anything reliably" (SK). These "huge uncertainties" (NF) ultimately decelerate the CR development. Counteracting "regulatory [approaches contain] the risk that well-intentioned is not always well done" (AB) referring to the fact that corresponding legal frameworks often lack a holistically beneficial approach taking into account the far-reaching sustainability facets within the entire value chain (CM, SH, FB, OB).

Regarding success factors, interviewees referred to a two-sided dialogue to enable fact-based information exchange and realizable, practice-oriented regulations and incentive programs (to secure predictability in an international levelled playing field). Securing practice-oriented applicability and holistic sense-making of legislation "involves governments, both the […] European and national governments, with whom companies collaborate to ensure that the legislation aligns" (MM). Hence, to address the challenges it is crucial to provide two-sided feedback mechanisms. Both, "[governments and companies] need to keep up the dialogue" (CM), e.g., via advocacy teams to articulate CR capabilities (BO, FB, OB, YE, CM, NM, RE), while "politicians [are supposed to be] proactive and go out and say: 'we want to talk to stakeholders from the industry'" (NF). Furthermore, successful implementation depends on the dissemination of factual information, "so that legislators have the opportunity to familiarize themselves with a wide range of perspectives" (CM) providing the basis for a fruitful discussion. Finally, targeted advocacy to unambiguously define MB and CR is vital for the acceptance of the technologies, e.g., by encouraging "regulators [to] do more with technological openness, but still create and maintain clarity and clear framework parameters" (CM).

4.2.2 Supplier Engagement

Company representatives described encountering volatile feedstock markets with ambiguous specifications leading to scarcity of correct feedstocks and sourcing unpredictability. Compared to linear counterparts, where companies "are in a commodity market with corresponding margins" (MM), CR "is a much more immature industry [mostly] done on experimental basis" (FB) resulting in volatile and untransparent feedstock markets (MM, CS). On average, the sourcing predictability is limited in terms of "quality and quantity of raw materials that you can process" (BO). Feedstock scarcity, related to sorted plastic or purified pyrolysis oil depending on the specific CR technology applied, can be a bottleneck for BM upscaling (BO, NF, CS, SK, NM) and will result in a "competition for feedstock" (YE) in the future. In addition, several experts referred to a lack of large-scale and efficient reversed logistics infrastructure (DK, OB, RE, SH).

To counteract, interviewees requested close collaboration with upstream and value chain partners from the beginning for multi-directional know-how transfers. To systematically optimize the management of these challenges, operating companies need close collaboration since “traditionally expertise is on the supplier side" (AB). A holistic transfer of know-how to develop waste management expertise along the entire upstream value chain must be implemented as early as possible in the CRBM process to be able to anticipate potential hurdles and to act accordingly. Additionally, reconceptualizing industry infrastructure towards a jointly established, decentralized, fully utilized waste treatment infrastructure (RE, CS, OB) was mentioned as part of a successful transition.

4.2.3 Customer Engagement

Some customers seem to lack clear sustainability plans and communicate ambiguous needs, compounded by a low willingness-to-pay for more sustainable products. Some customers lack clear sustainability transition roadmaps, which do not direct their efforts towards an explicit sustainability goal, but rather leave the question open whether "they want CO_2 reduction or [...] circularity, or both?" (AB). As a result, experts reported a degree of inconsistency, both in their own communication and in expectations of pricing. Particularly in price-sensitive industries, customers "are not prepared to pay higher prices, because they do not want to impose them on their customers" (AB), resulting in a low willingness to pay.

Experts advocated for close collaboration with downstream value chain partners from the beginning to align strategy, motivation and values to foster successful long-term partnerships. To lay the foundations for thriving long-term partnerships, managers should "spend a lot of time with customers and customers' customers" (NF). Other experts recommended to “meet production, understand their needs and future capabilities and [to] agree on the formalities to sell at a later date” (JM). Finally, clarification of customer motivation, alignment of strategy, targets and distinct “value communication” (BO) form the basis of long-term commitment.

4.2.4 NGO Engagement

Concluding from the interviews, NGOs resorting to ideology-based campaigns instead of fact-based discussions harm the public perception of CR. Ideology-based campaigns without the possibility of a “scientifically sound, educated discussion” (NM) that “lack the openness to compromise from a technical, scientific [view]” (CM), cause frustration among managers (SS, FB, CM) and can negatively affect public CR image. However, it is important to note that a “NGO focused solely on GHG emissions will have a different opinion than an NGO focused on biodiversity or on human rights" (MM). Therefore, it is difficult to generalize the engagement challenges because of diverse purposes of different interacting NGOs (IS, YE, BO, BV, MM).

The distinction between disregarding ideological NGOs versus engaging in fact-based discourse cooperating with NGOs to educate society on CR is key. Differentiated NGO engagement is crucial, e.g., by not responding “to those really emotional challenges where they use selected facts to serve their purposes rather than telling the whole story" (IS). Especially if the attitude of “everything leads full throttle into climate hell" (SK) prevails, it is recommended to stay “rather reactive [and only invite] selected ones” (BV). On the other side, cooperating in fact-based discussions can work as a catalyst for educational work on recycling (FB, CS).

4.2.5 Certifier Engagement

According to some experts, scarcity of non-government related certification bodies and third-party auditors leads to potential profit-driven motives and thus to additional costs and bureaucracy for companies. In the cross-stakeholder comparison, the role of certifiers is less discussed. While expert OB argued that “today, there is not enough certification in the market”, others emphasized a lack of competition between non-government certifiers making space for monopolization and "money-making" (NM, CS, SS). Moreover, CR and MB certification require high bureaucratic documentation efforts and are therefore cost-intensive (SS).

Third-party certification based on harmonized standards to provide credibility and transparency for stakeholders based on clear standardization could address the challenge. Experts seemed to be on the same page regarding certification as success factor. The certification of e.g., CR feedstock and the MB allocation process, to gain credibility, reliability, transparency, and accountability, helps ultimately to establish a trust-base with other stakeholders involved, because it makes “clear that everyone is playing by the same rules" (FB). More specifically, one expert (SS) advocated for a clear standardization guideline (e.g., via ISO standards) to prevent privatized certifiers from "money-making". Based on these ISO standards, a variety of different third-party auditing companies should certify the CR technologies and the MB approaches as CoC system.

4.2.6 Cross-Stakeholder Engagement

This subchapter summarizes aspects that apply across all stakeholders. Due to the large number and complexity of the quotes, the important points are listed in a structured manner based on the respective second-order themes for challenges and success factors. In summary, recentness and technological complexity create a new, less efficient business environment for all value chain actors requiring time for adaptation leading to current knowledge gaps and slowly advancing CR and MB acceptance. From a technical perspective, “many technologies still [need to] become established industrially, so the commercial upscaling is still to come” (CM). Associated with this, the recyclability of (contaminated) mixed plastic waste with unclear feedstock specifications “demands robustness from technology" (YE), which multiplies the technological complexity (AB, LD, RE, OB, CS, DK, SK, CM). Moreover, the coordination and virtual allocation of varying waste management streams remains challenging (DK, MM, NF, SS, RE, CS, AB). Finally, some experts concluded that “CR is not yet the holy grail” (BV), since CR alone cannot substitute linear BMs, because “most recycling applications today actually involve downcycling” (SK). Therefore, virgin feedstocks will remain a necessity. Mutual obstruction via advocacy channels instead of cross-competitor collaboration within the limits of competition law summarizes complications related to “engagement” with competitors. Friction points on the advocacy level arise both among the various CR technologies and between CR and MR. For instance, the MR lobby in Germany “is very critical to advanced recycling, because they have a quite big industry in mechanical recycling.” (BV). This is mainly due to feedstock supply concerns according to specifications. Companies tend to bet on “several horses, simply because there is uncertainty which technologies will prevail” (CM) instead of joining efforts, within the boundaries of competition law, to enhance one technology frontier.

Overall, many experts reported on adaptation difficulties related to “fossil value chain, where the facilities run 365 days a year, 24/7, [compared to] very fresh companies that have a new technology that hasn't been tested for a long time” (MM). Furthermore, the common lack of knowledge, communication and awareness about CR and MB across all stakeholders “is definitely a challenge on the acceptance side" (AB). Finally, accumulating the above challenges creates the overarching wicked problem of building a viable BM and remaining competitive compared to LBM and MR. This finding was explicitly stated by 12 out of 19 industry experts.

Empirical data supports participation in multi-stakeholder platforms (MSPs) such as (trade) associations or project-specific industry roundtables to facilitate cross-stakeholder collaboration, within the boundaries of competition law, to jointly educate society on CR to gain broader acceptance. Wider acceptance by all stakeholders can be achieved by raising awareness and redesigning educational channels "to give knowledge to consumers" (BV). In this regard, industry should "recognize the opportunity to influence society via various social media platforms" (CM) to "pick up society and say no, this is not greenwashing and it's just getting started" (SS). Companies "should also position in this area and really talk openly about the difficulties, but also about the potential that chemical recycling or mechanical recycling has to offer in terms of sustainability" (CM). Honesty is perceived as the key to maintain trustworthiness in the face of critical attitudes towards the chemical industry (SS, IS, SH).

A frequently quoted lever is the participation in MSP such as (trade) associations or project-specific industry roundtables to facilitate cross-stakeholder collaboration. From the managers' point of view, MSPs function as an umbrella term for exchange opportunities in various constellations with the stakeholder groups already described. Overall, the referenced exchange models can be divided into (trade) associations such as "Plastic Europe, VCI, and Cefic" (SK) and project-specific industry roundtables. Value chain partners can "simply exchange ideas" (NF) and discuss "problems (in) implementing something that a law, a regulation, or a society demands" (SS). "Under the umbrella of trade associations, the peer companies get together" (IS) within the boundaries of competition law (AB, SK, LD, MM). Simultaneously, companies should establish cross-stakeholder roundtables "either for closed-loop projects, that include various stakeholders or for different waste streams such as hospital waste" (BV). This describes the need to "look very closely at industry solutions, including shared IP" (AP). Experts further advised to initiate the discussion as early as possible and to "spend time, money [and] resources on the believers, on the innovators that want to continue with (CR) in order to create a kind of a pull instead of a push" (BV). Additionally, collective efforts of all CE actors, e.g., via joint positioning statements, are needed to accelerate the transition and they should actively be promoted since "there is space for everybody at the moment for chemical recycling" (IS).

Table 2: Overview of the thematic analysis based on Gioia et al. (2013) - First Aggregated Dimension: Benefits of CRBMs

Overview of the thematic analysis based on Gioia et al. (2013) - First Aggregated Dimension: Benefits of CRBMs		
Direct Quotations	**First-Order Concepts**	**Second-Order Themes**
[...]	B1 - Reduction of GHG emissions to mitigate climate change. *	**Ecological** Contribution to defossilization, decarbonization and mitigation of (environmental) plastic waste pollution.
[...]		
[...]	B2 - Replacement of fossil raw materials makes environmental destruction due to excavation practices obsolete.	
[...]		
[...]	B3 - Limiting and preventing plastic pollution and landfill	
[...]		
[...]	B4 - Company performs better in sustainability rankings and is therefore also more attractive for financing options based on sustainability KPIs.	**Economic** Positive monetary implications on various areas within the company (financing, marketing, sales, recruiting, waste disposal) as well as a beneficial supply-demand situation in a volatile environment due to adapting consumer mindsets and regulations.
[...]		
[...]	B5 - Increased company/ industry reputation and thus attractiveness for young employees in the current "war for talents".	
[...]		
[...]	B6 - Regulatory / legislative framework is currently evolving and still influenceable and thus will help to catalyse transition.	
[...]		
[...]	B7 - Costs for waste disposal gets eliminated because plastic waste gets a price tag.	
[...]		
[...]	B8 - Closed-loop projects with chemically recycled feedstock enable good marketing stories.	
[...]		
[...]	B9 - Less dependency on price fluctuations of fossil raw materials. *	
[...]		
[...]	B10 - Comfortable pricing situation because market demand is outpacing supply. *	

[...]		
[...]	B11 - Acquisition of new (long-term) customers because of improved support opportunities with their recycling targets. *	
[...]		
[...]	B12 - Recycling programs are perceived as "license-to-operate" for the chemical sector in the future because of adapting consumer mindset and changing regulations. *	
[...]		
[...]		
[...]	B13 - Increased awareness for pollution and corresponding solutions of / for plastic (waste).	**Social** Enhanced awareness and public perception of plastic (waste) from the image as environmental polluter to solution provider.
[...]		
[...]	B14 - Reshaping the perception on plastic (waste) to a material that contains value.	
[...]	B15 - CR helps to acquire new and diverse customer markets for products made from recycled plastic waste, e.g., food applications and pharma.	**Technological** Complementary extension of both, recyclable input (feedstock) and recycled output (product application options), due to constant (plastic waste) feedstock quality enabled by different CR technologies.
[...]		
[...]	B16 - Chemically recycled plastics maintain quality (no downcycling), hence carbon molecules stay in the loop.	
[...]		
[...]	B17 - CR poses a complementary approach to MR and thus expands the scope of recyclable (waste) feedstock.	
[...]		

Table 3: Overview of the thematic analysis based on Gioia et al. (2013) - Second Aggregated Dimension: Challenges of CRBMs

Overview of the thematic analysis based on Gioia et al. (2013) - Second Aggregated Dimension: Challenges of CRBMs		
Direct Quotations	**First-Order Concepts**	**Second-Order Themes**
[...]	C1 - Missing harmonization of country-specific (hazardous) waste treatment and transportation regulations inside Europe leads to bureaucracy efforts.	**Policymakers** Companies face high bureaucratic hurdles due to unharmonized
[...]		
[...]	C2 - Pending acceptance of MB as chain of custody model and CR by EU-	

[...]	Commission affects recycling quota, green claims etc.	regulations while legislative uncertainties (such as the pending acceptance of CR and MB) and missing incentive programs decelerate progress.
[...]	C3 - Uncertainties in legislation and regulation decelerate R&D progress and CR market development.	
[...]		
[...]	C4 - Lack of holistically beneficial policy-making and incentive programs.	
[...]		
[...]	C5 - Recentness of volatile, untransparent feedstock market leads to unpredictability in sourcing for companies.	**Suppliers** Companies encounter volatile feedstock markets with ambiguous specifications leading to scarcity of correct feedstocks and sourcing unpredictability.
[...]		
[...]	C6 - Feedstock scarcity (in terms of sorted plastics or pyrolysis oil) can be a bottleneck for BM upscaling.	
[...]		
[...]	C7 - Lack of large-scale and efficient reversed logistics systems.	
[...]		
[...]	C8 - Customers lack clear sustainability transition plans resulting in unambiguous communication of which sustainable aspects are needed.	**Customers** Customers lack clear sustainability plans and communicate ambiguous needs, compounded by low willingness-to-pay for more sustainable products.
[...]		
[...]	C9 - Contradictory expectations regarding low willingness-to-pay for optimized product.	
[...]		
[...]	C10 - Ideology-based campaigns instead of fact-based discussions negatively affect public CR image.	**NGOs** NGOs resorting to ideology-based campaigns instead of fact-based discussions harm the public perception of CR.
[...]		
[...]	C11 - Difficult to generalize the engagement challenges because of diverse purposes of different interacting NGOs.	
[...]		
[...]	C12 - Lack of certification makes space for "green-washing“.	**Certifiers** Scarcity of non-government related certifiers and third-party auditors lead to potential profit-driven motives and thus to additional costs and bureaucracy for companies.
[...]		
[...]	C13 - Lack of competition between non-government certifiers makes space for monopolization and "money-making".	
[...]		
[...]	C14 - CR and MB certification requires high bureaucratic documentation efforts	

[...]	and is therefore cost-intensive.	
[...] [...]	C15 - High technical complexity to develop industrial-scale CR plants results in long plant development times.	**General** Recentness and technological complexity create a new, less efficient business environment for all value chain actors requiring time for adaptation leading to current knowledge gaps and slowly advancing CR and MB acceptance.
[...] [...]	C16 - High technical complexity to recycle (contaminated) mixed plastic waste due to unclear feedstock specifications.	
[...] [...]	C17 - Challenge to oversee and coordinate different waste management streams.	
[...] [...]	C18 - High energy-intensity can lead to high GHG emissions compared to alternatives such as landfill. *	
[...] [...]	C19 - Recycling alone cannot substitute linear business models because virgin feedstock will remain a necessity.	
[...] [...]	C20 - MR and different CR technologies advocate against each other due to feedstock concerns.	
[...] [...]	C21 - Broad technology landscape instead of collective efforts (within the boundaries of competition law) to enhance one technology frontier. *	
[...] [...]	C22 - All value chain actors have difficulties to adapt to new (less efficient) processes and environment.	
[...] [...]	C23 - A common lack of knowledge, communication and awareness about CR and MB hinders CR acceptance among all stakeholders.	
[...] [...]	**C24 - Challenge to build a viable BM and to stay competitive compared to traditional BM and MR.**	

Table 4: Overview of the thematic analysis based on Gioia et al. (2013) - Third Aggregated Dimension: Success Factors of CRBMs

Overview of the thematic analysis based on Gioia et al. (2013) - Third Aggregated Dimension: Success Factors of CRBMs		
Direct Quotations	**First-Order Concepts**	**Second-Order Themes**
[...] [...]	S1 - Secure practice-oriented applicability and holistic sense-making of legislation and (incentivising) projects by providing feedback mechanisms.	**Policymakers** Two-sided dialogue to enable fact-based information exchange and realisable, practice-oriented regulations and incentive programs (to secure predictability in an international level playing field).
[...] [...]	S2 - Engage in a two-sided dialogue via advocacy teams to articulate CR capabilities and perspectives for the future.	
[...] [...]	S3 - Spread fact-based information to familiarize policymakers with the different CR technologies to build a base for discussion.	
[...] [...]	S4 - Advocate for EU regulations and acceptance of CR and MB since this is the main driver for CR process in an international level playing field.	
[...] [...]	S5 - Built on know-how transfer to develop expertise in waste management from the beginning.	**Suppliers** Close collaboration with upstream and value chain partners from the beginning for multi-directional know-how transfers.
[...] [...]	S6 - Engage in establishing a decentralized, fully utilized waste treatment infrastructure.	
[...] [...]	S7 - Understand customers' motivation and internal processes to successfully establish CR projects.	**Customers** Close collaboration with downstream value chain partners from the beginning to align strategy, motivation, and values to foster successful long-term partnerships.
[...] [...]	S8 - Clarify and align customer strategy, targets and values as base for long-term commitment.	
[...] [...]	S9 - Differentiate NGO engagement and don't interact with "sensational" (IS) / ideological NGOs but rather cooperate in fact-based discussions.	**NGOs** Distinction between disregarding ideological NGOs vs. engaging in fact-based discourse cooperating with NGOs to educate society
[...]	S10 - Partner with NGOs and use them as a catalyst for educational work on	

<table>
<tr><td>[...]</td><td>(chemical) recycling.</td><td>on CR</td></tr>
<tr><td>[...]</td><td rowspan="2">S11 - Certify CR feedstock etc. to gain credibility, reliability, transparency, and accountability to establish a trust base with stakeholders.</td><td rowspan="4">Certification
Third-party certification based on harmonised standards to provide credibility and transparency for stakeholders based on clear standardization.</td></tr>
<tr><td>[...]</td></tr>
<tr><td>[...]</td><td rowspan="2">S12 - Advocate for a clear standardization, (e.g., via ISO guideline) to prevent privatised certifiers from "money-making".</td></tr>
<tr><td>[...]</td></tr>
<tr><td>[...]</td><td rowspan="3">S13 - Engage in associations as multi-stakeholder platforms for value chain actors / peers to collaborate and share information within the boundaries of competition law.</td><td rowspan="13">General
Participation in multi-stakeholder platforms such as (trade) associations or project-specific industry roundtables to facilitate cross-stakeholder collaboration (within the boundaries of competition law) to jointly educate society on CR to gain broader acceptance.</td></tr>
<tr><td>[...]</td></tr>
<tr><td>[...]</td></tr>
<tr><td>[...]</td><td rowspan="2">S14 - Collective effort / positioning statements of all CE actors to accelerate the transition since the market is currently big enough for everybody.</td></tr>
<tr><td>[...]</td></tr>
<tr><td>[...]</td><td rowspan="2">S15 - Establish collaborations with players ("CR believers") along the value chain starting from the beginning of the CR planning phase.</td></tr>
<tr><td>[...]</td></tr>
<tr><td>[...]</td><td rowspan="2">S16 - Establish "stakeholder roundtables" where representatives of different stakeholder groups work together for industry- / customer-specific solutions.</td></tr>
<tr><td>[...]</td></tr>
<tr><td>[...]</td><td rowspan="2">S17 - Raise awareness and educate customers / society as well as other stakeholders on (chemical) recycling to gain broader acceptance.</td></tr>
<tr><td>[...]</td></tr>
<tr><td>[...]</td><td rowspan="2">S18 - Communicate benefits / potentials of CR technology honestly to maintain trustworthiness against the critical attitude towards the chemical industry.</td></tr>
<tr><td>[...]</td></tr>
</table>

*Indication that the first-order concept is subject to contradicting statements from experts.

5. Discussion

5.1 Theoretical and Managerial Contributions

The chapter highlights academic contributions and managerial implications related to benefits, challenges and success factors and compares the extent to which the study validates existing literature. The technology under consideration remains relatively novel, which partly explains the scarcity of academically rigorous articles on the subject.

Subsequently, this study contributes to new academic insights by showcasing (1) the importance of cross-stakeholder collaboration via multi-stakeholder platforms as a way of addressing the complexity of the global plastic waste issue. In contrast to parallel LBMs, the nascent and fragmented technology is currently perceived to create a market big enough for all players. Similarly, the associated sustainability problem can only be solved collectively by the entire value chain of the industry, advocating for a less competitive and more collaborative environment. More precisely, academics and managers would be well advised to be attentive towards political conflicts of interest that still exist between individual parties within the recycling sector. Additionally, new contributions related to cross-stakeholder collaboration refer to honesty in external communication to maintain trustworthiness.

Contrasting to Salvioni and Almici (2020) recommending supplier engagement practices that focus primarily on value alignment and mutual circularity objectives, the study is increasingly outlining (2) a need for know-how transfer and joint infrastructure development from the beginning of the CRBM creation process.

By suggesting (3) a clear distinction between ideological and rational, technologically open NGOs, this study contributes with a novel insight to the existing literature. The question of how and according to which criteria differentiated engagement should be managed in practice requires further research. However, this study validates the potential of NGOs to operate as facilitator (Antikainen & Valkokari, 2016) and to catalyse education on CEBMs, and therefore indirectly on CR (Schultz et al., 2024).

(4) Certification of, e.g., mass- balance as chain of custody model is key to gain broad acceptance for CRBMs. Adequate literature on engagement with certification bodies in the CEBM, let alone in the CR context, is non-existent. Challenges related to financial and bureaucratic burdens and demands for clear standardization (e.g., via ISO) as result of the study thus contribute to a novel academic perspective on CR. However, for this specific stakeholder, additional interviews could have enhanced the degree of theoretical saturation.

(5) Furthermore, the in-depth analysis of economic benefits surpassed the described ones in the literature. Financial benefits typically refer to cost reductions, e.g., via enhanced material utilization and decreased waste treatment costs (Da Cruz et al., 2014). However, expert interviews have introduced a more nuanced perspective, differentiating between indirect financial benefits for functional divisions such as marketing, HR, or financing. Furthermore, the number of different arguments and partially contradicting statements (e.g., for B9 – B12) suggests that insights generated so far are not exhaustive and thus theoretical saturation has not been reached.

Finally, figure 7 provides an (6) assessment of stakeholders' challenges and success factors, synthesized in a visual tabular framework. It presents a good overview of new contributions and literature confirmations at the level of second-order concepts. The table in appendix 4 serves as a supplementary overview of the thematic comparison from the literature and the study. Additionally, it includes a reflection on the degree of theoretical saturation achieved for the analysis of each stakeholder group based on the number of experts quoted. The framework can serve as a starting point for further academic work, as potential research questions can be derived. For industry, the success factors constitute a systematic catalogue of potential actions. Although this work relates to a niche technology, the challenges and success factors can be transferred to the assessment of similar CEBMs.

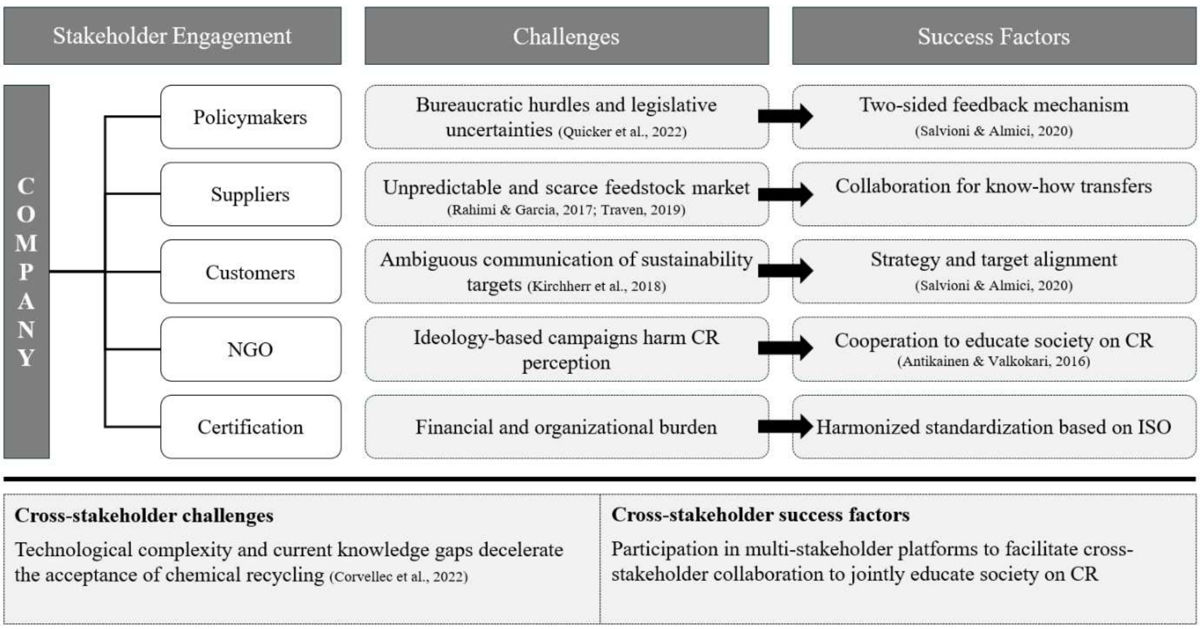

Figure 7: Framework for cross-stakeholder and stakeholder-specific engagement challenges and success factors

Figure 7 above also shows where the study confirms existing literature. The comparison not only relates to the concept of CR, but also refers to the benefits, challenges and success factors for CEBM prevailing in literature.

Challenging factors in the collaboration with policymakers have been widely acknowledged in academic circles. This accounts for the pending legal recognition of CR as a form of recycling by the European Commission (Quicker et al., 2022) correlating to a generally limited predictability due to uncertainties in policymaking and partially ambiguously designed incentive frameworks (Deshpande et al., 2020; Salvioni & Almici, 2020; Schultz et al., 2024). Bureaucratic burdens due to missing harmonization of country-specific waste treatment regulations partially represents a newly gained insight. The same applies for the spreading of fact-based information to familiarize policymakers with CR as success factor. Other success factors mentioned can largely be understood as direct conclusions from the literature and are thus indirectly included. Given the pervasive and consistently addressed nature of the issue across the majority of stakeholders, it is reasonable to posit that theoretical saturation was attained. Closely connected to technological complexity, the volatility and scarcity of feedstock is heavily discussed in both literature and study. Research on CEBM (Corvellec et al., 2022; Lieder & Rashid, 2016; Traven, 2019) confirms that these challenges in the supplier-company relationship are also prevailing in a CR environment. Here, especially the sorting capabilities limit sourcing predictability. Regarding customers, the interviewees specified the relatively small customer awareness for CE solutions and provided a more in-depth description of engagement challenges. In practice, challenges reported include the lack of clear transition roadmaps and contradictory expectations regarding low willingness to pay. The study largely confirms CEBM literature regarding success factors, namely in terms of unequivocal communication to optimize expectation management on strategy, targets, and values (Salvioni & Almici, 2020).

Observing the benefits of CR technologies, the literature review and the findings from the interviews coincide in three of the four subcategories (second-order themes). The *technological* and *ecological* advantages of CR are congruent with the already presented arguments prevailing in academia and industry reports (Cefic, 2022; Zero Waste Europe, 2019). *Social* benefits are scarcely mentioned compared to other benefits. This is in line with the current state in academia, criticized by a lack of social considerations in the CEBM and CR discourse (Corvellec et al., 2022; Hina et al., 2023; Lüdeke-Freund et al., 2019; Murray et al., 2017).

5.2 Limitations and Further Research

Although the underlying research question calls for a qualitative research design, it is inevitably subject to limitations. Interviews are to some extent subject to risk of bias. As the issue of recycling is emotionally charged and generally perceived in society as a desirable behavior, the risk of e.g. an underlying social desirability bias (Lee & Sargeant, 2011) could not be eliminated. Confidentiality assurance at the beginning of each interview served to mitigate this effect.

Furthermore, there was a heterogeneous spectrum of professional backgrounds and current positions within the respective CR project among the interviewees. While some experts argued through a marketing or sales lens, others shared their experiences from a procurement, advocacy, or process engineering perspective. This inevitably led to a different prioritisation of sub-content and ultimately to a broad spectrum of different results, which is showcased by the high number of first-order concepts in the study. While this diversified observation was explicitly desired, it hampered achieving theoretical saturation. This research thus offers a good overall view of the different perspectives. Theoretical saturation can potentially be improved by only using experts from similar functions within the companies. However, this was difficult due to the short time horizon of the thesis and the scarcity of experts.

The advantage of methodological flexibility is accompanied by a lack of reliability (Babbie, 2016), because of the iterative adaptation of the interview protocol due to step-by-step analysis and inclusion of findings. According to Gioia et al. (2013) this resembles a trade-off between effectively deriving new scientific concepts and a lack of standardization and consistency compared to traditional research. The results of this study could have benefitted from the addition of quantitative research methods, which would enhance the external validity and objectivity of the findings.

This research can be complemented in the following ways to gain additional insights. First, the limited scope of the thesis did not allow an integrated perspective on the topic of SE in the context of CR. By interviewing representatives from other stakeholder groups, interdependences of the entire stakeholder network could be multi-prospectively researched and thus provide more accurate practical implications based on more perspectives. Second, the geographical focus of the research could be expanded to capture the macroeconomic differences potentially resulting from differing political systems or cultural contexts. Third, the quality of the implications is limited due to the consideration of various technologies. Further research should conduct this study based on a structured technology categorization with an even number of interviewees representing the currently most promising CR technologies. Fourthly, figure 4 indicates the complexity of the stakeholder network in the chemical industry. Applying a more granulated stakeholder categorization might potentially enhance the depth of challenges and effectiveness of success factors of SE. Fifthly, the fast-moving CR environment is influenced by a fragmented technology provider market and regulations. Abrupt developments can have drastic implications which is why this momentary observation should be continued as a longitudinal study. Finally, this approach could be used to evaluate the effectiveness of the success factors and thus adding value, in particular for managers.

6. Conclusion

The chemical sector is currently in a transitional phase, investigating into new technologies, ultimately seeking to shift towards a more sustainable industrial model. While only a combination of technologies can successfully drive change, CR, despite its far-reaching technical limitations, is a beacon of hope and has therefore moved to the forefront of scientific research and industry considerations in this decade.

The literature review vividly sheds light on the progress of academic research bridging the topics of CEBM and SE, underscoring the indispensability of efficient collaboration between stakeholders for successfully implementing CEBMs. By conducting this qualitative study, the current trend in academia is transferred to the specific application of CR. Conclusively, the goal was to obtain an in-depth expertise on challenges, the nascent technology is currently facing, as well as success factors for implementation, both under the umbrella of SE as provider of methodological structure.

The thematic analysis of 17 expert interviews representing 13 companies identified three dimensions, dividing the key results into 1) benefits 2) challenges 3) success factors of CR. Novel contributions were further categorized according to the stakeholder groups involved. They refer to a different perspective on cross-stakeholder collaboration via MSPs as well as stakeholder-specific engagement practices for such as multi-directional know-how transfer with suppliers, differentiated NGO engagement and the necessity to investigate the role of certification bodies. Benefit-related findings largely corroborate the existing literature but provide a more nuanced perspective on the financial benefits. The heart of the thesis is the visualisation of the comparison of stakeholder-specific and cross-stakeholder challenges and success factors. The synthesis of novel contributions and established literary findings is restructured within the context of the typical circumstances of the chemical industry.

Contemporary policymaking often leaves space for bureaucratic hurdles and legislative uncertainties. Success factors describe a two-sided feedback mechanism, aiming to streamline communication channels and navigate regulatory complexities. Supplier challenges are related to an unpredictable and scarce feedstock market, mitigatable by fostering collaboration for know-how transfers, enhancing resilience and adaptability within the supply chain. Ambiguous communication of sustainability targets of customers require clarification through strategy and target alignment. The complexity of some certification schemes results in financial and organizational burden, potentially alleviated through harmonized standardization such as ISO. For NGOs, a distinction between disregarding ideological NGOs and engaging with fact-based NGOs to educate society on CR is crucial.

Cross-stakeholder engagement to tackle lacking CR acceptance can be achieved through the utilization of MSPs to facilitate collaboration within the boundaries of competition law. In essence, the journey towards effective stakeholder engagement in the described recent environment practices necessitates a continuous technology scouting and monitoring of regulatory changes.

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Appendix

Appendix 1: Interview Participants

#	Identification	Company	Seniority	Years of Experience	Interview Duration (min)	Country
1	DK	Henkel	Head	4.5	45	Germany
2	MM	BASF	Lead	1	35	Germany
3	NF	Evonik	Director	7	30	Germany
4	NM	BASF	Manager	4	65	Germany
5	OB	Solvay	Head	5	30	Belgium
6	BV	SABIC	Leader	6	80	Belgium
7	BO	Neste	Manager	5	55	Germany
8	FB	Borealis	Manager	3	45	Sweden
9	IS	Eastman	Director	8	45	UK
10	SS	Borealis	Manager	4.5	52	Germany
11	YE	Clariter	Head	5	75	Israel
12	CM	Evonik	Manager	4	47	Germany
13	JM*	Elkem	Leader	5	53	France
14	RE*	Elkem	Manager	8	53	Norway
15	CS	LyondellBasell	Manager	4	35	Luxembourg
16	AB	Covestro	Head	4	53	Germany
17	LD*	Röhm Chemie	Director	2.5	65	Germany
18	SK*	Röhm Chemie	Not available	2.5	65	Germany
19	SH	Eastman	Manager	3	55	Germany

*Two interview partners have been interviewed together in one interview session.

Appendix 2: Semi-structured Interview Protocol

Optimizing Chemical Recycling Business Models through Stakeholder Engagement –Assessment of Challenges and Success Factors in the European Chemical Industry	
Interviewee:	**Date:**
Company:	**Years of Experience:**
Position/ Job Title:	**Interview Duration:**

#	Topic	Questions
1	Introduction	One definition of CE that is often referred to in academia is: *CE may be defined as "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling*" (Geissdoerfer et al., 2017). *Consequently, CEBM are often described as the way companies create value by adhering to these CE principles* (Lüdeke-Freund et al., 2019). Is this definition in line with your personal definition of CEBMs or would you add/change certain aspects? How long have you been working in the field of circular economy/ in chemical recycling in the chemical industry? Can you describe your experience and your responsibilities in establishing/participating/supporting one CRBM project at the company? *To narrow down & specify the scope of the interview, I ask you to focus on one CE program related to the process of chemical/ advanced recycling.* What are/were the goals of this project, you are currently or have been involved in?
2	Characterizing the Circular Economy Business Model	Can you describe the typical value chain in the chemical industry that is relevant for your business? Can you describe the position in the value chain of the respective project? Can you characterize your chemical recycling business model? The following circular economy business model dimensions from academia can serve as a starting point. *Product / Service / Target Customer / Value Delivery Process / Value creation process / Revenues / Cost* Can you comment on the impact of chemical recycling on the chemical industry in the next 10 to 20 years?

3	Motivation & Benefits	From your experience, what are the benefits/ disadvantages of CEBM in comparison to the traditional linear counterparts you already experienced and hope to experience in the future? How would you evaluate the impact of CEBMs to tackle sustainability problems or concerns associated within the chemical industry?
4	Stakeholder Engagement – Challenges & Success Factors	What are the main stakeholder groups (other than internal employees) involved in designing and implementing the CRBM? Please describe the individual relationship and the way of engagement with each stakeholder you mentioned. 1. **Way of Engagement** How did you involve or engage with each stakeholder group in the design or implementation process (directly vs. indirectly or proactive, reactive, or passive engagement)? 2. **Challenges & Disadvantages** Can you please elaborate on the challenges and disadvantages of the involvement of each stakeholder group? 3. **Success Factors** In your experience, what were the key success factors from involving these distinct groups of stakeholders? What have you learnt and what would you do differently for each stakeholder group? What kind of engagement style or collaboration structure would have been practical to have in place at the beginning of the project? Can you add other success factors and challenges for implementing CE business models?
5	Outlook & Closing	From your perspective, what advice or recommendations would you give your successor working with chemical recycling in terms of stakeholder engagement to manage the respective chemical recycling project etc. as efficiently as possible? Which questions did I forget to ask you? Do you have any additional questions or remarks? Do you know anyone else (colleagues, competitors, technology partners) involved in CEBM in the chemical industry who might be able to add insights on this topic?

Appendix 3: Comparative Content Analysis of Literature on CEBMs and CR with the Study

Stakeholders	**Challenges (number of experts quoted)**	**LR**	**TS**	**Success Factors (number of experts quoted)**	**LR**	**TS**
Policymakers	Bureaucratic hurdles and legislative uncertainties (14)	F	H	Two-sided feedback mechanism (12)	P	H
Suppliers	Unpredictable and scarce feedstock market (12)	F	H	Collaboration for know-how transfers (8)	P	M
Customers	Ambiguous communication of sustainability targets (5)	P	L	Strategy and target alignment (8)	F	M
NGOs	Ideology-based campaigns harm CR perception (9)	N	M	Cooperation to educate society on CR (6)	F	M
Certifiers	Financial and organizational burden (4)	N	L	Harmonized standardization such as ISO (7)	N	M
General	Technological complexity and CR acceptance (18)	P	H	MSP to facilitate collaboration (15)	N	H

LR = Discussed in Literature Review

F = Fully discussed in LR

P = Partially discussed in LR

N = Not discussed in LR

TS = Theoretical Saturation (number of experts quoted)

L = Low TS (1-5)

M = Medium TS (6-10)

H = High TS (> 10)

Appendix 4: Overview of the Quotations for the Thematic Analysis based on Gioia et al. (2013)

Quotations for the thematic analysis based on Gioia et al. (2013) - First Aggregated Dimension: Benefits of CRBMs		
Direct Quotations	**First-order Concepts**	**Second-order Themes**
"The purpose is that you link it to two drivers. So, circularity and decarbonization or carbon neutrality." (BV)	B1 - Reduction of GHG emissions to mitigate climate change. *	**Ecological** Contribution to defossilization, decarbonization and mitigation of (environmental) plastic waste pollution.
"Yes, alongside the advantage of reducing greenhouse gas emissions" [...] (MM)		
" [...] comes to silicones on the climate roadmap, we emphasize that the big milestone has to be done on the silicone metal industry, because it's a big part of our carbon footprint." (RE)		
"We'll have of course better LCAs, better carbon footprints and experience, and this will be the advantage of using chemical recycling." (CS)		
"So most of the time if you replace a natural product, then it's super because then it gives economical value, but you have also sustainability value." (OB)	B2 - Replacement of fossil raw materials makes environmental destruction due to excavation practices obsolete.	
"I would say that defossilization is the greatest benefit." (CS)		
"So the aim of the circular economy is always to avoid fossil raw materials. For us, I'd say that's the huge lever" (NF)		
"This is just trying to secure and keep the natural resources which have been excavated long time ago" (IS)		
"So in 10 years time I'd think we can proudly look back [...] and say, yes, we have made a difference. We are reducing dependency from fossil feed stocks for example, and we are keeping materials in circulation for longer." (IS)		
"The purpose of chemical recycling is to ensure that recycling is really possible, even of materials that are currently not recyclable, no landfill stories, but that we can really say that resources can really be recycled" (NF)	B3 - Limiting and preventing plastic pollution and landfill.	
"Benefits to the environment that [are] really tackling waste. What do you do with waste? You can't forever landfill it or just burn it away" (IS)		
“So, chemical recycling is an enabler to make the chemical industry able to [...] deliver what is needed [to reduce pollution]." (CS)		
“We are of course aware of our social responsibility and polymers that end up in the environment unchecked are a bad thing. We naturally want to counteract " (AB)		
"Banking, investors, they're very, very concerned about sustainability, [of] which certainly economy is a big portion of that. So basically, you will not be able to invest without sustainability programs." (RE)	B4 - Company performs better in sustainability rankings and is therefore also more attractive for financing options based on sustainability KPIs.	**Economic** Positive monetary implications on various areas

"I think chemical industry doesn't have the best reputation, sometimes unfairly." (FB)	B5 - Increased company / industry reputation and thus attractiveness for young employees in the current "war for talents".	within the company (financing, marketing, sales, recruiting, waste disposal) as well as beneficial supply-demand situation in a volatile environment due to adapting consumer mindsets and regulations.
"Of course, it also makes sense to present yourself as a sustainable employer in the so-called war of talents, because you can simply see that more and more young professionals are focussing on this topic and you naturally want to show that you are a sustainable employer." (CM)		
"Rubber granules, which are normally used in artificial turf, are gradually being banned. This creates the problem that a market like the rubber recyclers, a large market, will need to adapt." (CM)	B6 - Regulatory / legislative framework is currently evolving and still influenceable and thus will help to catalyse transition.	
"Now you have the opportunity to shape the market, even to shape legislation. So, in the direction that it's balanced, so that you can continue to function within a certain setup." (MM)		
“The coalition agreement even includes the topic of chemical recycling, which was explicitly mentioned, keyword technology openness, but the implementation is a long time coming, but will ultimately help to catalyse the transition." (NM)		
“Of course, depending on which market it is, let's take packaging or automotive, the whole thing is primarily driven by regulation, So, it's clear that something will change by 2030, because that's when all these requirements will be [...] switched on." (NF)		
"So, they pay a lot of money to get this [...] burned or landfill or whatever as hazardous waste. We managed to take those plastic drums and recycle them with our process." (YE)	B7 - Costs for waste disposal gets eliminated because plastic waste gets a price tag.	
"We've taken ghost nets [...] from one of the NGOs that are cleaning up the oceans, and we've made those into wax that we sold. We gave it to a manufacturer of surf wax." (YE)	B8 - Closed-loop projects with chemically recycled feedstock enable good marketing stories.	
"So, on a macroeconomic level, you naturally have a significantly lower dependency on fossil raw material flows and prices if you close it now." (AB)	B9 - Less dependency on price fluctuations of fossil raw materials. *	
“We're also much less dependent on the price of crude oil, because as a typical chemical recycler [...] you're making [...] plastic into plastic.” (YE)		
"I signed an agreement about two and a half years ago with a Dutch trader to sell everything that we will manufacture from the first four plants in Europe and the Middle East. For the first five years of production, everything is sold." (YE)	B10 - Comfortable pricing situation because market demand is outpacing supply. *	
"Financially, recycled feedstock is triple the price. However, demand is still outpacing supply by far." (BV)		
"In this respect, in a developing market like this, [...] I think we are very, very good at recognising opportunities that arise and retaining customers in the long-term." (BO)	B11 - Acquisition of new (long-term) customers because of improved support opportunities with their recycling targets. *	
"The only thing that you change is that you meet a possible recycling quota, and		

you meet a reduction in the product carbon footprint." (MM)		
"Unique Selling Proposition which[...] is the recycling quota and the PCF." (MM)		
"We have the Green Deal, it's just about avoiding additional carbon emissions, so [...] benefits are all the sustainability attributes that we also have as core messages, including circular content for their recycling quota." (NM)		
"There is this social responsibility component. The responsibility towards our customers to offer products with which they will be successful long-term." (AB)		
"We can create real value in the world, doing something that is helping out and helping transform society. And [...] if you don't do that, would you even have a seat at the table the next decade?" (FB)	B12 - Recycling programs are perceived as "license-to-operate" for the chemical sector in the future because of adapting consumer mindset and changing regulations. *	
"What would be the situation [...] in 20 [years], I mean, industry players can disappear quickly." (FB)		
"Whether the chemical industry in Europe exists in the next 50 years as it currently does, with players of the same size and so on, chemical recycling doesn't have an impact on that, right?" (MM)		
"What are the levers today [...], it's really the value of the CO_2, the value of the material, the license to operate that we have on site, that's really the key engine." (OB)		
"We believe that through the Product Carbon Footprint or recycling quotas and stricter environmental regulations, your business model must adapt, because it's practically your license to play." (MM)		
"if you are not positioned because you cannot provide a solution, because you have procured something, then you may become obsolete as a supplier or as a business partner." (CM)		
"[...] being able to deal with waste more effectively, [...] there will be positive social impact [...] if nothing else." (IS)	B13 - Increased awareness for pollution and corresponding solutions of / for plastic (waste).	**Social** Enhanced awareness and public perception of plastic (waste) from the image as environmental polluter to solution provider.
"But I think there are also social benefits, because [...] it's important for us as a race, as a human race to treat the environment better, not just for the environment, but so that the next generations can still benefit from the environment also." (YE)		
"To make sure that we have streams that can be recycled. And cause no headaches for coming generations." (RE)		
"CR technology is providing proof points that the chemical industry actually can make a change and can address plastics waste issue that is there because the society will need plastic one way or the other" (IS)	B14 - Reshaping the perception on plastic (waste) to a material that contains value.	
"Even if the world stopped making plastic today, we can still go into existing landfills and the plastic in the ocean. So, we're never running out." (YE)		

"Target customers are the customers in contact-sensitive applications meaning food and beverages, because this is not allowed for mechanical recycling." (BV)	B15 - CR helps to acquire new and diverse customer markets for products made from recycled plastic waste, e.g., food applications and pharma.	**Technological** Complementary extension of both, recyclable input (feedstock) and recycled output (product application options), due to constant (plastic waste) feedstock quality enabled by different CR technologies.
"Generally, the product in chemical recycling is not different from the fossil product. It has the exact same properties, can go to the exact same markets, to the exact same customers." (MM)		
" [...] medical or [those] who have food contact when you work in mechanical recycling, that's not possible." (BO)		
"I think food packaging, because today it's very hard to do mechanical recycling to food packaging." (FB)		
"Example, the biggest cosmetics company in the world, and all of our products have passed FDA standard testing for food contact." (YE)		
"And they passed, which means that you can use the R wax, for example, to wrap cheese or to apples and oranges or chocolate or as wax paper between the slices of cheese, things to wrap hamburgers." (YE)		
"So, it could be construction, automotive, cosmetic. We do have a lot on, for example, as well the paper industry and the textile industry." (RE)		
"It is no end of life or plastics. We need to give it a second life. We need to assure that the carbon is kept into the loop." (BV)"	B16 - Chemically recycled plastics maintain quality (no downcycling), hence carbon molecules stay in the loop.	
"So, with the plastic waste that was purposed for land filling or incineration with energy recovery, we say advanced recycling is bringing opportunity in order to keep the carbon in the loop, because if you burn it, it's gone." (BV)		
"You then create a product that is the same but from a property perspective." (FB)		
"So only [...] by actually reusing instead of incinerating or using a landfill, that upgrade creates also value, right?" (FB)		
"In other words, how long these materials can be used. Which means that chemical recycling is like squaring the circle, because that's exactly when you want to break these materials down again." (AB)		
"Monomers that I can bring back to a purity with chemical process steps that I can control perfectly. For us and our customers, that nobody here has to fear the risk of finding a banned substance in their product at some point." (LD)		
"Because some mechanical recycled PETs look good, but many have [...] aesthetic problems, i.e., they're a bit grey and, [...] a bit hazy." (SH)		
"And the fact that we have, more or less, virgin-like pads again, we have, an advantage over the mechanical recycled material, because we don't have this contamination in our material." (SH)		
"[...] PET recycling, where we again provide a catalyst for waste streams that cannot be mechanically recycled. But PET should actually always be mechanically	B17 - CR poses a complementary approach to MR and	

recycled in the best-case scenario." (NF)	thus expands the scope of recyclable (waste) feedstock.	
"Chemical recycling is, [...] that we have a relatively broad raw material base and that we can go into all different applications." (BO)		
"Make sure that we can reach our products on spec even with a varying feedstock, because if you're using waste, you never really know what you're going to get." (YE)		
"That we can utilize materials that we couldn't before." (JM)		
"There is no waste, there is just the right substance in the wrong place at the wrong time." (LD)		
"And the good qualities are for mechanical recycling, what we say. And it's important also in your thesis, it's a complementary solution." (BV)		
"So, [...] from my point of view, these things are complementary." (BO)		
"[CR] must be embedded in mechanical recycling." (NF)		
"In principle, our perspective is that the different recycling methods are, of course, complementary. So, [...] mechanical recycling, gasification and[...] liquefaction, they all have their right to exist." (BO)		
"[For] plastic waste you can't do mechanical recycling for ever. You can go to chemical recycling. That makes more sense also from an environmental perspective."(FB)		
"There are always two ways, chemical and mechanical. And I believe they have to go hand in hand. And then, in my opinion, it also goes into the future." (SS)		
"And you can't just take polyethylene and polypropylene and PPC and PT and melt them all together." (YE)		
"Right now, we say that we don't compete with mechanical recyclers. Anything that can be recycled mechanically should be recycled. Mechanically, it's better for the environment and it's cheaper." (YE)		
"Buzzword, is complementary to mechanical recycling." (CM)		
"Mechanical recycling plastics not being diverted to chemical recycling due to its quality, because then it's not the best way to be circular" (CR)		

Quotations for the thematic analysis based on Gioia et al. (2013) - Second Aggregated Dimension: Challenges of CRBMs		
Direct Quotations	**First-order Concepts**	**Second-order Themes**
"Spanish market regulator is accepting CR but does have its doubts on mass balance. And in UK it's more difficult." (BV)	C1 - Missing harmonization of country-specific (hazardous) waste treatment and transportation regulations inside Europe leads to bureaucracy efforts.	**Policymakers** Companies face high bureaucratic hurdles due to unharmonized regulations while legislative uncertainties (such as the pending acceptance of CR and MB) and missing incentive programs decelerate progress.
"If you look at the outside of the EU or the countries and regulations as a whole, then there is too much stuff coming at you as a company that is not harmonised and is not somehow goal-oriented, just a huge bureaucratic effort." (DK)		
"The regulatory system is so fragmented, because it's different in every country, then it's different for every substance you have and then it's not only different at country level but also at municipal or federal state level in Germany [...]." (DK)		
"Local authorities can classify different repellents differently, so as soon as you approach the matter from a regulatory perspective [...], [with] all these speculated stakeholder groups, you are very quickly in long bureaucratic paths." (DK)		
"[...] producing competitively in Europe[...], everything [...] plays a role, because ultimately these are all cost factors that also affect us with our project and our technologies." (NM)		
"[...] complicated to go to some level at the European level for industries like cement, plaster, board [...] they need to harmonize." (OB)		
"And it should be made, symbols for everybody. Like also the people, who enter with some product in Europe, they don't have the same constraints like us." (OB)		
" [but] every country is very different, right?" (YE)"		
"So, then you need huge bureaucratic processes, because you're not allowed to or it's not desirable that you actually transport hazardous waste from one country to another." (DK)		
"[A] hazardous substance is actually [a] big challenge in chemical industry [...]in Europe the hurdle to push hazardous waste (even packaging of hazardous waste) across national borders is extremely high." (DK)		
"This means that we as a company do not have a waste assessment licence. We are not even allowed to take the material back to our company premises." (LD)		
"Then of course every industry might be different. But on the other hand, I would say that every country is even more different than it is on industry level." (FB)		
"[...] today chemical recycling is not, or not yet, fully approved according to European regulations or directives." (BV)	C2 - Pending acceptance of MB as chain of custody model and CR by EU-Commission affects recycling quota, green claims etc.	
"You have something that is not yet mandated by legislation." (MM)		
"I don't know if you've ever heard of EU green claims, a regulation that the EU has		

tightened up in terms of communicating sustainability and ultimately it's primarily about consumer protection." (NM)		
" [I need to] also have appropriate proof points for what I write there that it is comprehensible, but it must also be technically and factually correct." (NM)		
"Chemical recycling doesn't count as recycling yet: So, we're still working hard to make sure […] that [it] also counts as part of it, but that's precisely why we have to be careful." (NM)		
"The chemical recycling isn't counted for sustainability or this sort of quotas." (FB)		
"But as long as chemical recycling is not really officially accepted as recycling from a legal point of view, it's probably going to be a longer road." (FB)		
"The biggest disadvantage at the moment is that chemical recycling is not included in the recycling rate." (SS)		
"When you see that the countries, accept chemical recycling, they recognize fuel exempt as one of the ways to deliver the commitments." (CS)		
"[mass balance awareness as big challenge] have to be communicated as the main driver that fossil resources are replaced." (NM)		
"Yes, mass balancing must be accepted. It is not possible without it."(NF)		
"So, either fuel exempt mass balance, which means anything that goes into fuel, we don't even count and just the rest will be allocated to the ensuing products." (YE)		
"Need mass balance, because you cannot only apply CR product, because of the small quantities." (BV)		
"It is pretty tough since it's not widely accepted, and we have to bear also in mind that it's worldwide." (CS)		
"And if you take a look at the legislation, then a lot of the legislation is in the end market, i.e. in packaging, automotive." (BO)		
"But of course about scalability, without recognition and quotas, it's also difficult." (NM)		
"I think if the legislation comes this year or next year, then you'll really be that cool, right? Without upscaling [it] will be difficult, because there is no market push." (NM)	C3 - Uncertainties in legislation and regulation decelerate R&D progress and CR market development.	
"I mean, the only thing I can give as advice to anyone, would be that there is a huge part of unknowns. And this can be an unusually uncomfortable amount of uncertainty." (FB)		
"Everything is still open at the moment. And from the company's point of view, that simply creates huge uncertainties. You can count on a bad investment case, if you don't know where it will go." (NF)		

"[An] important point that you don't yet see in the legislation, [are] for example, the quotas that you can achieve through recycling." (BO)		
"Because it really depends upon European legislation. You can send products everywhere in Europe, but waste is a problem." (FB)		
"When you look at regulation, it's still ongoing. It's still in the construction process, compared to mechanical recycling or recycling in the metal industry. Chemical recycling is still new to everyone." (RE)		
"There is regulatory pressure. In start-up phases, this ensures that you have risk capital."(YE)		
"So, I can see ways, in which the regulator can create more clarity without regulating things in detail, [e.g., by …] simply not allowing certain things. Just burning, for example, is not an option." (AB)		
"Then there is a great deal of legal uncertainty, also worldwide. If I feed a small amount of recycled material into my plant - we have huge plants - can I lose my food-grade approval, for example, for all products from this entire large plant?" (LD)		
"Can any company in the world that has [upcoming] investments […] in the hundreds of millions or [even] billions, [be] able to handle it without knowing that what it is doing is worth 50 euros per tonne of CO_2 or 250?" (SK)		
"The free market and the free play of forces. In reality, that's poison for a company, because I can't calculate anything reliably." (SK)		
"In most of Europe, there are still landfills (like France and Spain) or incineration plants (like Germany). To get rid of a ton of waste, you pay anywhere from a hundred to 250 euros a ton. So, if you take out a ton of plastic before you incinerate it, you just saved on average, 150 euros." (YE)	C4 - Lack of holistically beneficial policy-making and incentive programs.	
"17 million euros that the South African government helped us with. So, they took some of the financial burden of this, which was very helpful." (YE)		
"You have to set some kind of incentives to encourage investment and you also need planning security for the industry and the players, and that's always a bit of a chicken and egg game" (NM)		
"But today there are also competitors and most of the time [we] are lacking a little bit of consistency, on regulation." (OB)		
"So for example, if we have taxes in Europe and restrictions in Europe, it's tough if someone can export into Europe who doesn't have to go through this." (FB)		
"It's good for plastics, but then it could simply be that certain companies will simply switch to materials where there are no high regulatory requirements." (CM)		
"But you can see that some regulations and laws still fail to reflect the reality of the industry. And the issue of feasibility is not always well thought through." (CM)		

"[the] regulatory approach has the risk that well-intentioned is not always well done." (AB)		
"CO_2 is not always congruent with the circular economy. That means you either have to set target corridors for both and then you have to bring them together in such a way that they are still realistic." (AB)		
"But it's not about politicians' opinions, it's about laws. BMWK has made subsidy laws." (LD)		
"We cannot pay for this program to this extent from our own funds. We are dependent on funding. And everyone realises that. Otherwise, Mr Habeck wouldn't have proposed spending 70 or 100 billion to promote it." (SK)		
"And I think, we have realised that the people, who write the laws, are not necessarily the experts, when it comes to the topics about which the laws are written." (SH)		
"PPWR was a law and I think the problem was that the people, who wrote the law didn't really understand what the limitations were in the packaging sector." (SH)		
"[A commodity market] is completely predictable, right? You can see that both from the customer side and from the producer side. So, you are in a commodity market with corresponding margins." (MM)	C5 - Recentness of volatile, untransparent feedstock market leads to unpredictability in sourcing for companies.	**Suppliers** Companies encounter volatile feedstock markets with ambiguous specifications leading to scarcity of correct feedstocks and sourcing unpredictability.
"I guess, the more mature markets, if you look for us, it's not that mature." (CS)		
"Availability and quality, because if the world is great and everything is there, I don't believe everybody will have the spec that the crackers or the polymerization units need. So, besides availability, also quality [is important]." (CS)		
"Chemical recycling today is done on [an] experimental basis." (FB)		
" [...] the sourcing side is not yet well developed. So it's not an established market. NAFTA, oil, gas are traded. That means the markets are very liquid, very transparent, and the specifications are very comparable. You don't have all of that with pyrolysis oil." (MM)		
"Raw materials in the quality and in the quantities, that you can virtually process them" (BO)	C6 - Feedstock scarcity (in terms of sorted plastics or pyrolysis oil) can be a bottleneck for BM upscaling.	
"What we do have, or what we will have probably is competition for feedstock. " (YE)		
"That's also the fear of the European Commission that advanced recycling is cannibalizing part of the plastic waste, the good waste." (BV)		
"High quantities and constant supply are not provided" (NF)		
"The problem is that there's simply not enough sorting plants […] even in Germany. More and better sorting would allow us to use a lot more plastic." (YE)		
"But we know that comparing to the fossil world, it's not a commodity yet." (CS)		

"We don't have enough. The quantities that can come back are a fraction of all the monomers that are produced, that's four million tonnes." (SK)		
"We don't have a commodity market for pyrolysis oil, so the shortage and high demand is keeping the price high." (NM)		
"That you put [waste materials] on a truck and drive 1000 kilometres through the area that's all costs, so you have to think twice about what you do with it now." (DK)		
"[trucks and ships] but there we are not so good, because we are better for logistics on pure commercial product also in terms of CO_2." (OB)		
"The difficulty is, many of these projects involve a lot of transportation. So, we move material from A to B to C to D, a lot of trucking." (RE)		
"It's about the logistics. So, we are discussing about a few euros per ton, but then you need to pay the logistics." (OB)	C7 - Lack of large-scale and efficient reversed logistics systems.	
"The problem is that there's simply not enough sorting plants […] even in Germany. More and better sorting would allow us to use a lot more plastic." (YE)		
"But we know that comparing to the fossil world, it's not a commodity yet." (CS)		
"We don't have enough. The quantities that can come back are a fraction of all the monomers that are produced, that's four million tonnes." (SK)		
"And, the infrastructure for such things is simply still lacking. I think that's still a bit of a problem." (SH)		
"Customers don't really know exactly what they want either. So do they want CO2 reduction, or do they want circularity or do they want both?" (AB)	C8 - Customers lack clear sustainability transition plans resulting in unambiguous communication of which sustainable aspects are needed.	**Customer** Customers lack clear sustainability plans and communicate ambiguous needs, compounded by low willingness-to-pay for more sustainable products.
As long as a customer himself does not know what kind of product he wants, i.e. this classic phenomenon, the customer wants a sustainable product, it must not cost more, but he also does not know exactly what kind of sustainability aspect he wants" (LD)		
"Some want their own washes to change into their own raw materials. Some want them to have a recycling sale, and others want them to reduce their carbon footprint " (AB)		
" [...] and our customers honestly don't know either, do I need, am I allowed to do post-industrial recycling? " (LD)		
"But the customers, at least in my company, are not willing to pay more than general cost deals. Whether it's based on value or coal, unfortunately. Hopefully that will change in the future. But for now, we don't see that." (JM)		
"It's an illusion to believe that circular products are cheaper just because they don't need oil. You need a lot of other things for that. New assets, supply chain, logistics and so on. So our assessment is that the cost points will not change significantly now," (AB)		

"Firstly, that you really understand the driver of your customer. Because for every case, open round, closed round, for every business model, the display is different." (RM)		
"What is interesting is that many companies set themselves sustainability targets, but are not prepared to pay higher prices, because they do not want to impose them on their customers." (AB)	C9 - Contradictory expectations regarding low willingness-to-pay for optimised product.	
"Many [customers] had 2025 targets and if you talk to them now, they're already going back, so when it comes to the climate targets, it's also about the plastic reduction targets and, less recycled material, it's going back everywhere." (SH)		
"Because, the recycled material is too expensive, and at the end of the day, you have a lot of companies that just say," Yes, it would be nice if we could do that, but we can't spend any more money on it now." (SH)		
"So, NGOs' focus is on lowering the use of fossil resins and to [just] move back to alternatives [… like] paper [which has a higher CO_2 footprint]." (BV)	C10 - Ideology-based campaigns instead of fact-based discussions negatively affect public CR image.	**NGOs** NGOs resorting to ideology-based campaigns instead of fact-based discussions harm the public perception of CR.
"NGOs are different, [with some] there is simply not scientifically sound, educated discussion possible at all." (NM)		
"The worst criticism I ever got, was [that I once] had to leave the head office in Austria and I couldn't leave the main exit, because "Fridays for future" we're having a demonstration outside." (FB)		
"[it] also made my veins throb a little again, because I was so annoyed that the reporter completely ignored everything that is being done in this economy." (SS)		
"What I often miss with NGOs is a certain openness towards newer things. The arguments are not always technically sound." (CM)		
"I simply lack this openness, this openness to compromise from a technical, scientific perspective." (CM)		
"A personal opinion. An NGO focusing solely on greenhouse gas emissions will have a different opinion than an NGO focusing on biodiversity or one focusing on human rights." (MM)	C11 - Difficult to generalize the engagement challenges because of diverse purposes of different interacting NGOs.	
"Because the NGOs, they have different agendas, they have different focus on different things." (IS)		
"[Generally good relationships] but one of the NGOs, they didn't criticize us, but they didn't really want to help us." (YE)		
"What is an NGO for you?" (BO)		
"NGOs are more complex, because they rely on public relations, while as a chemical industry, you might not necessarily have such a public-facing approach." (MM)		
"But today there is not enough certification in the market. So that's something we [are] still lacking." (OB)	C12 - Lack of certification makes space for "green	

"So, everybody called it green but at the end it's greenwashing most of the time." (OB)	washing“.	
ISCC is currently beginning to gain the upper hand and a dominant position in the certification market. So, if you […] say that everyone is simply following an ISO standard, then it doesn't matter whether TÜV Nord, ISCC etc." (NM)	C13 - Lack of competition between non-government certifier makes space for monopolization and "money-making".	**Certifiers** Scarcity of non-government related certifiers and third-party auditors lead to potential profit-driven motives and thus to additional costs and bureaucracy for companies.
"In the beginning it was a cool idea. And now it's just a scam and a money-making scheme." (NM)		
"So, if I may give you a tip, open an auditing company and become filthy rich, because everything that goes on here is certified." (SS)		
"The more sorters you have supplying the input stream, the more difficult certification becomes, because our auditor also has to go to 10 suppliers [of us] annually." (SS)		
"Currently we just have ISCC+. So, they are currently the only one that I'm seeing being super proactive in the market." (CS)		
"I'm always very surprised why so many people say that. It's greenwashing or something else. It's an unbelievable mess to be certified" (SS)	C14 - CR and MB certification requires high bureaucratic documentation efforts and is therefore cost-intensive.	
"I have to start planning my audit three months in advance, otherwise I will end up with no valid certificate and the volume flow will stand still until I have a valid certificate again." (SS)		
"However, I also believe that this bureaucratic effort also serves to protect a certification company, so that it is not vulnerable." (SS)		
"I think in 10 years it would still be [a] smaller niche, but it might be an issue just like wind farms [for which it] took a decade or two before they were actually generating more energy than [was] used to create them" (FB)	C15 - High technical complexity to develop industrial-scale CR plants results in long plant development times.	
"We started a very long time ago. We're a very old startup, 21 years ago, rare for a startup. " (YE)		
"We said, you can't scale up from a pilot, from a pilot that does a few kilos a day to a huge plant that does 50,000 tons a year. It is just too risky." (YE)		
"I believe [...] many technologies have still to become established industrially, so this commercial upscaling is still to come." (CM)		
"[...] but I think the main challenge is also to apply R&D results more quickly into industrialization." (JM)		
" Today the technology is in place to run, on a yearly basis, assets of 20 to 40 kilotons. But it's small." (BV)		
"It would probably explode within hours or something, right? It's just that nobody has [large-scale production facility]" (NM)		
"you're really just starting out with pilot plants and it will go through a		

development and at some point, economy of scale things will materialise and your prices will go down." (NM)		**General** Recentness and technological complexity create a new, less efficient business environment for all value chain actors requiring time for adaptation leading to current knowledge gaps and slowly advancing CR and MB acceptance.
" There is still a lot to be developed on the technical side so that we simply have a good raw material base in order to achieve chemical recycling." (BO)		
"Of course, this also raises the fundamental question of whether the circular economy might be an inherent driver of inflation, because you might then go for smaller assets, go for new assets" (AB)		
"The reverse supply chain is characterised above all by the fact that you need a certain quality, so the question is what specifications you actually need in the new input material and how robust your chemical recycling is." (AB)	C16 - High technical complexity to recycle (contaminated) mixed plastic waste due to unclear feedstock specifications.	
"There are substances that are banned from circulation, so if they are detected in one of our products, we're in real trouble."(LD)		
"And especially, if you're a chemicalist who isn't always used 100% [...] sometimes it's just a very thin contamination, to know what led you and why you're being used as a raw material or as a challenge." (RE)		
"Because to give value in the circularity, you need to give some specification of the product." (OB)		
"If you talk about disadvantages, then of course [a] disadvantage is that our feedstock is not always the same, right? Demands robustness from technology" (YE)		
"But companies are still struggling to deliver, and achieve these specifications that are needed." (CS)		
" [...] monomaterial because you use an adhesive for this, so gluing actively prevents recycling, so it's simply a search for an optimal material for recycling processes" (DK)		
"The main challenge [is] to find a feed stock that can fit to what's needed. This is for the purchase part" (CS)		
"From my experience, I would say that [CR technologies] are not really finished yet." (SK)		
"And then you have the issue afterwards, suddenly it's a huge mixed bag of plastics. And that's where the sorting issue comes in." (LD)		
"This takes place at the PVC level. And PVC in recycling is a really difficult polymer. It's actually bad." (SK)		
"From our point of view, there is currently no technology that can really take the yellow bag as it is. In fact, all technologies today suffer from the fact that immense effort has to be put into pre-sorting." (SK)		
"Accordingly, all recycling plants are in danger for gluing, which has negative		

consequences." (DK)	
"With pyrolysis I know that you can't just pour everything in, it will be pyrolysed." (CM)	
"The challenge is that companies do not differentiate themselves by not being entirely clear about what they put into these materials." (AB)	
"But because everything is so new, you might also make [allocation] mistakes. And will you then be held accountable for that?" (MM)	C17 - Challenge to oversee and coordinate different waste management streams.
"One of my biggest demands is to build a module that goes out at the push of a button, then we save 10 employees who are currently tracking the whole thing in Excel spreadsheets." (SS)	
"It's that today we're more on internal and post-industrial wastes. We're building the foundations, while the scheme is already on post-industrial. Today, it's not so easy to exploit their potential." (RE)	
"Local solutions [… are] not the same at every site and everywhere in the world it's different." (DK)	
"I believe that companies will also have to adapt to the fact that they will very soon reach their limits when it comes to the complexity of movements and material flows." (SS)	
"I think we need to have better understanding on post-consumer mixed plastics. What is considered what?" (CS)	
"We are actually talking about many [aspects] to us and itis a complexity that we are very unlikely able to handle." (AB)	
"Considering LCA, advanced recycling is slightly higher than conventional that is going to landfill. But with technology upscaling, these effects will decrease." (BV)	C18 - High energy-intensity can lead to high GHG emissions compared to alternatives such as landfill. *
"[explanation of LCA analysis graph from website …] depending on the way the LCA is calculated, carbon emissions are not necessarily better because of high process energy[…]" (BO)	
"Secondly, on terms of carbon footprint, it's not close to mechanical recycling." (FB)	
"I would say one thing would actually be electricity, if you look into the whole sustainability change." (FB)	
"And when it comes to the chemical recycling plant here, which we postpone, because we would not have the energy for it." (FB)	
"We did an LCA lifecycle analysis that showed that we have a negative carbon footprint. So it's not that we take out greenhouse gases from the atmosphere, we don't." (YE)	

"I don't see the chemical recycling as a license to operate issue yet. It's more the efficiency, the energy." (JM)	
"So, there are always LCA analyses of pyrolysis that are supposed to confirm that the whole thing is not so good." (CM)	
"What must not be concealed is that chemical recycling also requires energy [and therefore CO_2 emissions]." (AB)	
"Chemical recycling is not yet the holy grail." (BV)	C19 - Recycling alone cannot substitute linear business models because virgin feedstock will remain a necessity.
"Only 70% or 60% of that pyrolysis oil becomes ethylene and propylene that goes into making polypropylene and polyethylene." (YE)	
"And you can't circulate unnecessarily. There simply comes a point where you say, let's burn the whole thing and create fossil fuels or primary raw materials again." (CM)	
"It will be probably a mix of linear and recycled, because there is still a portion that we won't be able to recycle there." (RE)	
"That will never work completely, because you always have a little bit of loss." (AB)	
"That most recycling applications today actually involve downcycling. So, no matter how much effort I put into collecting, sorting, reprocessing and decontaminating." (SK)	
"Paint is a mixture of 20 products, how am I supposed to get it back?" (LD)	
"So, the idea that there's a silver bullet that can solve all environmental problems probably should have come before, I don't know, 1800 something, right?" (MM)	
"But you can see in advance that in 2025, for example, when all PET bottles should contain at least 25% recycled material that the pool of material in Europe […] will simply no longer be sufficient." (SH)	
"I think one danger is that at some point CR and MR are both competing for the same feed materials." (CM)	C20 - MR and different CR technologies advocate against each other due to feedstock concerns.
"If your customers see a product and it says 100% recycled and it's really only 10% recycled [because of MB …], they're never going to believe anything they read on any label. So. I think the industry is shooting itself in the foot." (YE)	
"Different view on chemical recycling, which is very negative, which doesn't match our view on chemical recycling, because the recyclers of Europe are very much focused on mechanical recycling." (FB)	
“The Germans are very critical to advanced recycling, because they have a quite big industry in mechanical recycling. And Mechanical Recycling Association has a strong lobby." (BV)	
"We don't need any mass balance, because 100% of our product is made from	

plastic waste." (YE)	
"We also have a certain hierarchy here in the circular economy as to how waste should be treated. At the top is first avoid, then reuse, then comes recycling, which means mechanical recycling." (CM)	
"I think for a long time the Plastic Recyclers Europe [especially] some of the old school people still see us as the enemy." (SH)	
"Nobody dares to come out of the woodwork. But it's accepted on the customer side, right?" (NM)	C21 - Broad technology landscape instead of collective efforts (within the boundaries of competition law) to enhance one technology frontier. *
"[Companies rely on each other's efforts does not work] everybody has to do a fair share regarding advocacy work." (OB)	
"So, there's liquification, gasification, solvolysis [...] because you somehow produce an oil, and then gasification, that you produce the gas, everything deserves attention" (BO)	
"This [technology] uncertainty, i.e. when do I do the right thing? I think that's a big issue here." (SS)	
"At the moment, it's a bit difficult to focus on a specific technology because many things are emerging. It's still a very dynamic market" (JM)	
"But the same manufacturer has to back several horses, simply because there is a certain uncertainty as to which technologies will prevail, which means that there is a certain disadvantage involved." (CM)	
"So, there's a competition potentially amongst the peer companies but also with other technologies like energy from waste" (IS)	
"There are other technologies that we know with gasification, microwaving. There are others that are also in early stages similar to pyrolysis" (CS)	
"It's also starting to, how do you say, change the practices" (IS)	C22 - All value chain actors have difficulties to adapt to new (less efficient) processes and environment.
"[petrochemical companies] biggest problem, [...] now you suddenly have to build up expert knowledge, they all sit in the companies, everyone knows it, but nobody has any idea about waste." (SS)	
"I think that's the biggest challenge, this understanding of waste, how waste is created, […] and now my product simply has to come back in as feedstock" (SS)	
"As a chemical company, you're used to dealing with people who have a lot of experience in your fossil value chain, where their facilities run 365 days a year, 24/7, when you suddenly deal with small, very fresh companies that have a new technology that hasn't been tested for a long time, it certainly poses a lot of potential for conflict, right?" (MM)	
"Most of projects are currently startups with low yields and inefficient processes." (CS)	

"And the third disadvantage in this sense is that it is very difficult to create a complete supply chain." (AB)	
"So, you have very opaque, well, you can't even call them markets yet, but you have the specifications." (MM)	
"One challenge here is that the product and innovation cycles are very different. Developing a new product, with all the approvals and construction of large plants, usually takes ten or more years" (AB)	
"So working with different people, different parts in the value chain. We have never really had waste management [or] dealt with waste management companies in the past other than disposing our waste" (IS)	
"What I'm learning is [that] the most difficult part is explaining mass balance." (BV)	C23 - A common lack of knowledge, communication and awareness about CR and MB hinders CR acceptance among all stakeholders.
"So, advocacy naturally wants to work towards the fact that this is part of recycled content, right. That's why they always like to talk about Attributed Recycled Content." (NM)	
"It's people's perception [that] becomes the truth in a way. And it's not really based upon real numbers. And as a chemical engineer, sometimes you can be frustrated about that." (FB)	
"Now our technologies have been lumped into the same thing and virology. Unfortunately, [it] doesn't have the most positive reputation in Europe because of many reasons. Ours is very different." (IS)	
"I would say that [the] way of engagement, it's clients understanding the value of the product, and it's not a switch on and off. Now I'm going from fossil to chemical recycling." (CS)	
"Our difficulty is that all plastics are lumped together." (LD)	
"But we also realise that the chemical industry does not always enjoy the best reputation in the political landscape. This means that there is definitely a challenge on the acceptance side." (AB)	
"And from this story, who is in the value chain to extract money? Is it (the company, customer, the retailer)? That is the big question." (MM)	**C24 - Challenge to build a viable BM and to stay competitive compared to traditional BM and MR**.
"Financially [chemical recycling] is not competitive in comparison to fossil business." (NF)	
"It's material with no big value, I would say. And that's what makes the [profitability] challenging." (OB)	
"Most challenging situation [is] in terms of commercial marketing, because it's new business." (OB)	
"So, if you compare that with fossil fuels, then of course the current costs are	

higher." (BO)		
"This requires investment, because there's a change, [...] there's a cost somebody has to pay." (IS)		
" I think that in general, for something to be sustainable, it has to be profitable. If it's not profitable, it's not sustainable." (YE)		
"Even if we talk a lot about the sustainability side, but it only works if it also makes economic sense somewhere." (CM)		
"How can you pass on the potentially higher costs in the value chain? That is of course always the question, how can you commercialize it if it is a little more expensive?" (BO)		
"Coordination and costs, because you have to understand that in order to utilize, you have to be prepared somehow, which means you always need money depending on your partner's materials." (DK)		
"The cost aspect is an issue, if it has not been fully realised." (CM)		
"And as you can imagine, sustainable materials are always more expensive to purchase." (JM)		
"We are a listed for-profit company and we naturally expect that the money and resources that we invest in such topics are better utilised here than in other investment opportunities." (AB)		
"I think, at the end of the day, you have to be a bit honest. So, sustainability is our commitment, but somewhere you have to have a business case." (NM)		

Quotations for the thematic analysis based on Gioia et al. (2013) - Third Aggregated Dimension: Success Factors of CRBMs

Direct Quotations	First-order Concepts	Second-order Themes
"To somehow get this Circular Economy Act on track. And there is precisely this multi-stakeholder platform where people are saying that we need to organise this together now." (NF)	S1 - Secure practice-oriented applicability and holistic sense-making of legislation and (incentivising) projects by providing feedback mechanisms.	**Policymakers** Two-sided dialogue to enable fact-based information exchange and realisable, practice-oriented regulations and incentive programs (to secure predictability in an international level playing field).
" [...] involves governments, with whom we collaborate to ensure that the legislation aligns." (MM)		
"And then on the other side, you have the Israeli government who says that they want to help us, but the bureaucracy is terrible." (YE)		
"Well, here the purpose is to try to apply the framework and give feedback. Is it applicable? How actually are we challenging the framework they are proposing in the questionnaire? " (RE)		

"And I think the engagement at the policymakers' level is also important as well to continue ensuring that they get facts, their questions are answered." (IS)		
"Some regulations and laws still fail to reflect the reality of the industry. And the issue of feasibility is not always well thought through in the holistic aspect" (CM)		
"In other words, we are also asked and consulted on certain regulatory issues. And then we also try to create sensible incentive systems for the chemical industry" (AB)		
"Of course, a lot of lobbying experience, because [the company], who is involved in various committees, has always had lobby people" (NM)	S2 - Engage in a two-sided dialogue via advocacy teams to articulate CR capabilities and perspectives for the future.	
"We need to be able to provide the impetus to deal with these framework conditions or, where they have not yet been defined, to shape this environment together with others. That's how I would put it." (NM)		
"Yes, I would say that most of what we do is proactive. Because it's about building understanding, both for the topic and for what each value chain partner can actually control there." (NF)		
"They can help decide, where they can bring in corporate interests or stakeholder interests are exchanged." (SS)		
"[Colleagues in Brussels look for dialogue with policymakers, but separate division]." (CM)		
"So, we are more in a situation where we give feedback when they try to implement through projects or other link." (RE)		
"If I could start over, one of the things that I would do is I would engage [...] with a lobbying company a lot earlier." (YE)		
"The legislative mills seem to grind very, very slowly. That's why we need to keep up the dialogue." (CM)		
"Politicians are also very proactive and go out and say we want to talk to stakeholders from the industry." (NF)		
"[proactive engagement with policymakers and NGOs]? We have some persons inside the company who could and should do that, but they are already full with all the other aspects." (OB)		
"We do have a person responsible for public affairs and she sits in Brussels." (FB)		
"If you talk about it, the engagement is good, helpful, efficient" (YE)		
"Organizations educate politicians about various industries and opportunities. Exactly, there are many industry associations where we develop positions together through dialogue." (BO)		
"But that's exactly how we've organised it at [our company], so there's a public affairs team that works for all business units." (BO)		

"And again, it comes back to education and explaining that each [technology] has a place and it's not just one is going to solve everything [...] you need the different technologies." (IS)	S3 - Spread fact-based information to familiarize policymakers with the different CR technologies to build a base for discussion.	
"I believe that sustainability education in society should also be directed towards politics. Simply so that legislators have the opportunity to familiarise themselves with a wide range of perspectives." (CM)		
"And in politics in particular, it's not usually the experts who are out and about. And that's why it takes the greatest effort to make it really clear what it is, what it can do and what it can't do." (NF)		
"Politics is different, there is also duty from the industry to supply the facts from the technologies that are there. Try to build trust in a transparent way." (IS)		
"But I think it's also education and to make sure that the legislators, understand that it's not that easy and what can be done to enable that to happen, to enable the circular economy." (CS)		
"Of course, the legislation should also somehow be such that, for example, certain technologies are not simply deprioritised" (NF)	S4 - Advocate for EU regulations and acceptance of CR and MB since this is the main driver for CR processes and international level playing field.	
"When is waste no longer waste? Something like that is not defined." (NF)		
"And I do believe that the regulators could do more with technological openness, but still create and maintain clarity and clear framework parameters." (AB)		
Therefore, the target parameters must actually be set by a regulator." (AB)		
"Everyone has their own view on mass balance or non-mass balance." (MM)		
"I think it's also important to ensure we have a level playing field between Europe and non-Europe." (FB)		
"So, regulation also has the positive effect of offering a certain degree of reliability in the end." (AB)		
"At the moment, the regulatory pressure is simply that the regulatory requirements are increasing." (CM)		
"It's really on how we drive the acceptance of chemical recycling forward" (IS)		
"How do we get the legislators on our side in such a way that they will incentivize the investments?" (IS)		
"When the EU was considering in which domains or which industries to start with, to force them to use a minimum recycling rate in their products." (YE)		
"So really the collaboration between different players, in order to then bring together technologies and the competencies of the individual players." (BO)	S5 - Built on know-how transfer to develop expertise in waste management from the beginning.	**Suppliers** Close collaboration with upstream and value
"Challenges that, at least what we now have, is this understanding of waste. This understanding of how this dirty process works beforehand and working together to		

get it moving in the right direction." (SS)		chain partners from the beginning for multi-directional know-how transfers.
"That means that you have the right stakeholders from the beginning and those with appreciation to co-develop it." (JM)		
"Of course, you need reversed logistics and traditionally our expertise is on the supplier side" (AB)		
"The most important stakeholders are other companies, waste disposal companies/ reconditioning companies who can do something with our waste." (DK)		
" [to work effectively it must be] decentralized and local" (YE)	S6 - Engage in establishing a decentralized, fully utilized waste treatment infrastructure.	
"So closer is your customers more chains, your business case will fly as usual." (OB)		
"It's much better to have small units that are 24 hours, 7 days a week [...] and installing locally, with new industrial practices." (RE)		
"Decentralization, being close to waste-sorting-companies is something you also need" (CS)		
"[...] they go directly to the side, they put the safety shoes, and they look at the process and they try to understand." (OB)	S7 - Understand customers' motivation and internal processes to successfully establish CR projects.	**Customers** Close collaboration with downstream value chain partners from the beginning to align strategy, motivation, and values to foster successful long-term partnerships.
"And, and we are also very strong in communication. And that also means that customers come to us." (BO)		
"We spend a lot of time with customers and customer's customers to ensure success" (NF)		
"So, you need to well understand the final user, what he really needs. And it's not just by a small discussion, it's never clear." (OB)		
"What's important for us, is to meet production, understand their needs and future capabilities, and agree on the formalities to sell at a later date." (JM)		
"[Explain to customers] chemical washes are always harder to treat, to imply that they have no solution" (RE)		
"We have the same customers than before, so for customers, we use the existing structures. But it works because they want the same product but more sustainable" (NM)		
"The one that fits your own strategy, that fits the strategy of the customer, that fits the strategy of the stakeholder, with whom you can really get to grips with the subject of chemical recycling" (CM).	S8 - Clarify and align customer strategy, targets, and values as base for long-term commitment.	
"What is key is really alignment. Alignment between the different stakeholders to find a common benefit. "(OB)		
"I think that's a very important point, […] the target alignment is the value communication." (BO)		

"Of course, the commitment to engage customers in a circular economy and the end customers, that the value that goes with it is not communicated too little and is communicated sufficiently. " (BO)		
"So, from my point of view, the common target corridor is the overall challenge and can actually only be achieved via a regulator." (AB)		
"There is still no clarity as to whether or not mass balancing will be permitted. This means that the customer side, which unfortunately does not yet know what it wants." (SK)		
"[No] interaction with sensational NGOs for which everything is bad]" (IS)	S9 - Differentiate NGO engagement and don't interact with "sensational" (IS) / ideological NGOs but rather cooperate in fact-based discussions.	**NGOs** Distinction between disregarding ideological NGOs vs. engaging in fact-based discourse cooperating with NGOs to educate society on CR
"I would say that sometimes they do challenge us and often industry chooses not to respond to those really emotional challenges where they use selected facts to serve their purposes rather than telling the whole story. " (IS)		
"NGOs is broad, normally its rather reactive, specific ones we invite" (BV)		
"We engage with NGO or the key European NGOs on a regular basis, but it's more education, it's responding to their questions, and it is also trying to have a dialogue and see where we might have commonalities. " (IS)		
"In fact no matter what you do, everything is not enough. So, what is done is not honoured at all, everything leads full throttle into climate hell. " (SK)		
"I can't imagine, they will probably never say, yes, chemical recycling is great, do it now, but at least they won't say, yes, chemical recycling is terrible and will destroy the environment." (SH)		
"I think you really have to look at [which NGO] you're talking to." (SH)		
"So, I would say that NGOs have to do a lot of educational work. " (FB)	S10 - Partner with NGOs and use them as a catalyst for educational work on (chemical) recycling.	
"Education together with non-profit organizations, because it is easy to criticize, but you don't know everything, so it's not like this." (CS)		
"Of course, there is also credibility and trust if a third party gives his approval and of course you work hand in hand." (NM)	S11 - Certify CR feedstock etc. to gain credibility, reliability, transparency, and accountability to establish a trust base with stakeholders.	**Certification** Third-party certification based on harmonised standards to provide credibility and transparency for stakeholders based on clear standardization.
"But of course, [certification schemes] also play a role, because I would say that transparency and reliability are at the top of the list." (NF)		
"We are already voluntarily using them, but it comes back to the credibility" (IS)		
"I think overall it's good to have standards so that it's clear that everyone is playing by the same rules" (FB)		
"So, if we say that this recycled content would be created by mass balance, nobody will believe chemical industry because chemical industry already the word chemical is bad for most of the people." (IS)		

"For me, what I realized very quickly is that the Blue Angel is a mark of quality throughout Europe." (SS)		
" [certification] is a factor for success, in the sense that it shows reliability in a space or environment where sustainability doesn't always know what's behind it. And now people are accountable and want it to be right and done."(YE)		
"Certification authorities with uncertain development, so if the market decides for ISCC, someone else might come in, different markets might choose different certification schemes, everything's open and needs more harmonization." (MM)	S12 - Advocate for a clear standardization (e.g. via ISO guideline) to prevent privatised certifiers from "money-making".	
"How could you counteract the fact that at some point there will be an ISO standard, whatever it is, that regulates this" (SS)		
"EMF as platform as well as Cefic" (BV)	S13 - Engage in associations as multi-stakeholder platforms for value chain actors / peers to collaborate and share information within the boundaries of competition law.	**General** Participation in multi-stakeholder platforms such as (trade) associations or project-specific industry roundtables to facilitate cross-stakeholder collaboration (within the boundaries of competition law) to jointly educate society on CR to gain broader acceptance.
"Yes, there are things like certification, ISO circles, where you can discuss within a secure framework, from a competition law perspective, how to understand mass balance."(MM)		
"At trade shows and conferences, everyone meets, and there's a lot of exchange of opinions and perspectives." (MM)		
"I would now have said: offer a platform for exchange channels. And use the presence there also for an appeal to politics" (NM)		
"Of course, many people are already talking to each other in the ISO" (NM)		
Most of the time, it actually works through associations. The other value chain partners are also involved, and you simply exchange ideas. So, it always has to be an industry approach. " (NF)		
"Plastics Europe where they have different working groups for [different plastics], that's where you meet." (FB)		
"So I think under the umbrella of trade associations, the peer companies get together."(IS)		
"I think it's very important to stay connected with the trade associations because they provide a safe place to have a dialogue on the topic" (IS)		
"[a multi-stakeholder platform] would be very helpful. (YE)		
"The Federal Association of Secondary Disposers, be it Plastics Europe. These are the associations that come to mind so quickly." (CM)		
"Global silicone council where all the competitors of silicone are sharing information, where we are also providing, the products for the competition." (RE)		
"So, competition is, helping in order to get a kind of a common understanding what advanced recycling can do" (BV)		
"European trade associations are good at mediating discussions and really keeping on a topic and not talking about being competitors or anything […]" (IS)		

“Yes, so best practice for me would actually be, that you look at the value chain or work together along the value chain.” (BO) "So, the associations, I think that's essential. A company has problems implementing something that a law, a regulation or a society demands" (SS) "Through technical conferences, we also share what we do and what we can share" (RE) "Competition law. This means that we cannot now come to a solution with similar companies, at least not now, without bringing in other players or creating a certain pricing power. So the question is, pre-competitively, yes." (AB) "There is a competition law. How am I supposed to have an open dialogue with them about cost items or technical things? I still wish it would be possible." (LD) "That it is a joint task and that there is also a need to exchange ideas with competitors." (LD) "The lobby groups that represent us, Plastik Europe, VCI, Plastic Europe are actually the big ones, we're also in the groups that deal with the issue of recycling." (SK) "In certification committees, ISO, and so on, there is a needed dialogue." (MM) "So, we are strongly involved in Cefic and the EMF " (BO) "Two or three trade organizations in Europe and normally they have a position and try to represent it in Europe and what we have done for a long time" (SH)		
"Sometimes a third party is involved. But it's very specific because it's just such a huge issue." (NF) "So, there is a lot to say what we see is that there's space for everybody at the moment for chemical recycling." (IS) "I'm encouraging competitors to position advanced recycling as an option next to fossil resources. Because again, demand is outpacing supply." (BV) "Sometimes they get mixed messages as well. We explain one thing, there might be another technology we explain slightly differently." (IS) "Addressing plastics waste, everybody's efforts are needed. There is not going to be one company who's going to solve it. So, everybody should work together" (IS) "So, I think it is important that as an industry together you can drive the change more effectively than individual companies." (IS) "To reach an agreement here, everyone has to be in the same place, because everyone wants the same thing, and we have to be honest with ourselves about everything that has to do with the circular economy" (SS) "The aim is also to organise and exchange ideas, to learn, but also to open up the legislator's perspective as a closed group" (CM)	S14 - Collective effort / positioning statements of all CE actors to accelerate the transition since the market is currently big enough for everybody	

"That they also recognise that it is not a single company that has a problem right now, but that there is also a certain group behind it that thinks the same way." (CM)		
"What we wanted to do with mass balance in chemistry, it was more about us conveying it to our customers, and then it's really a matter of aligning our thoughts with theirs, finding common ground." (MM)	S15 - Establish collaborations with players ("CR believers") along the value chain starting from the beginning of the CR planning phase.	
"In other words, don't just focus on your own product all the time and perfect it, but understand how you actually have to think about the business models of everyone else who uses it." (NF)		
"So, who will it bother and who will it benefit and how should you position it?" (NF)		
"So, first of all, the exchange from the beginning is fortunate, because it's direct customers and suppliers, the exchange is very, very close" (LD)		
"Spend your time, money, resources on the believers, on the innovators that wants to continue with advanced recycling [...] in order to create a kind of a pull instead of a push." (BV)		
"So, LinkedIn is a story, but in the end, it will be the players, Unilever, you name it, will [convey the message]" (SS)		
"Roundtables either for closed loop projects, that include various stakeholders or for different waste streams such as hospital waste" (BV)	S16 - Establish "stakeholder roundtables" where representatives of different stakeholder groups work together for industry-/ customer-specific solutions.	
"In other words, really bundling these competences, but also addressing the value chain and not always just the direct customer." (NF)		
"Plastics Recycler Europe roundtable is only focusing on the companies that put the stuff on the market, but also on the feedstock side."(YE)		
"You should look very closely at industry solutions, shared IP and therefore platform approaches, cross-partners." (AB)		
"We are involved via standardisation committees and now have the advantage of being a leading player " (AB)		
"You have to update, to teach, to explain, to give knowledge to consumers." (BV)	S17 - Raise awareness and educate customers / society as well as other stakeholders on (chemical) recycling to gain broader acceptance.	
"Not only creating awareness of the sustainability benefits of chemical recycling, but of course also sensitising people a little to [...] mass balance" (NM)		
"The customers, where it's about explaining the story of why we believe in chemical recycling and mass balance, understanding what they believe in, finding overlapping fields" (MM)		
"We also try to take an educational approach and say, what do we do with chemical recycling, why is chemical recycling a good idea? Use them as multiplicators." (NM)		
"When people hear what we do and how we do, I don't necessarily mean there [is]		

help all the time, but usually they like what we do." (YE)		
"What I always feel is that not everyone knows yet why chemical recycling is needed, there are still enough people who think, okay, with mechanical recycling" (BO)		
"So, you start with the education, what it is, what can [be done] and then transparently answer the questions what they are asking. So, I would describe it as education and then dialogue." (IS)		
"And in my opinion, which is incredibly important, our industry must manage to pick up society. To pick up society and say, no, this is not greenwashing and it's just getting started" (SS)		
"So that we can also take on this task as an industry to say that you have the opportunity to influence society yourself via various social media platforms that exist" (CM)		
"I think it's education and education of all people because people do not know what's happening and what each stamp in the packaging means and what it is. " (CS)		
"So, I think education, education, education, and this might start with kids at school" (CS)		
"And it is also very important to remain in continuous dialogue with potential partners and, to remain in close contact with the regulator via associations and standardisation in order to ensure that the solution we have (or believe we have) also has regulatory and hopefully social acceptance." (AB)		
"We would often like to see a bit more scientific discussion, both in politics and in NGOs, that doesn't say plastic is plastic, always bad." (LD)		
„Pragmatic knowledge that everyone actually needs somehow." (NF)		
"Let me put it this way: communication, communication. (BO)"		
Also, the topic of generally educating, raising awareness, giving knowledge. This is a lot of work to do." (FB)		
"Education, education, education, so a lot of educational work needs to be done with the stakeholders" (CM)		
"I think it's incredibly good here to communicate the problems. How can we solve problems that the company is thinking about and that the customers are then satisfied." (SS)	S18 - Communicate benefits / potentials of CR technologies honestly to maintain trustworthiness against the critical attitude towards the chemical industry.	
"As a chemical industry, we should also position ourselves in this area and really talk openly about the difficulties in terms of sustainability." (CM)		
"I think very few reports are really open, transparent and honest. Many simply have a certain agenda behind them, without being in favour or against." (CM)		