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Enabling Circular Economy Dynamics in the Plastics and Steel Industries: Perspectives from Multiple Stakeholders *

Xi Sun† Sophie M. Behr ‡ Merve Kücük§

Abstract

This paper investigates the perspectives of stakeholder groups in the plastic and steel value chains on transitioning toward a circular economy (CE). Through semi-structured interviews with 31 business stakeholders, we analyze business strategies, key factors, challenges and opportunities, as well as coordination and regulatory needs for a successful industry-wide CE transition. Our findings highlight the effectiveness of CE regulations in driving CE-oriented business strategies and fostering coordination within fragmented value chains. While stakeholders acknowledge the significance of product design and the crucial role of producers, differing opinions emerge on the role and adequacy of regulations. This nuanced understanding contributes to an evidence-based analysis of the distinct incentives that shape the transitional activities in these industries.

Keywords: stakeholder interview, circular transition, value chain, plastics, steel
JEL classification: D83, L61,65, Q58

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1 Introduction

Since the year 2000, the need to reduce resource import dependence and mitigate environmental pollution from resource extraction and processing has driven policy agendas on resource efficiency and the circular economy (CE) in various countries and regions (Domenech and Bahn-Walkowiak, 2019; Bleischwitz et al., 2022). There is increasing motivation toward adopting CE as a solution for multiple global challenges, including climate policy concerns associated with the primary production of materials that account for 30% of global greenhouse gas (GHG) emissions[1] ((Meys et al., 2021; Gómez-Sanabria et al., 2022; Material Economics, 2018). Furthermore, CE is increasingly seen as beneficial for economic growth and sustainable development ((Schroeder et al., 2019; Domenech and Bahn-Walkowiak, 2019; Belmonte-Ureña et al., 2021; Hondroyiannis et al., 2024; Bleischwitz et al., 2022; Ellen MacArthur Foundation, 2015).

While CE strategies obtain cross-cutting support, the slow adoption of circular practices is observed.[2] A rich and comprehensive strand of literature conceptualizes the drivers and barriers for a CE transition into frameworks. For instance, several studies identify and map the drivers and barriers into a framework comprising four categories of barriers: technical, economic, institutional, and technological ((de Jesus and Mendonça, 2018; Kirchherr et al., 2018; Grafström and Aasma, 2021).[3] On the other hand, few studies distinguish the interests of different actors across industrial value chains. Existing economic studies on waste policies have long recognized the link between the social cost of waste management and product design (Eichner and Pethig, 2001; Fullerton and Wu, 1998; Calcott and Walls, 2005) or consumer choice (Taylor and Thompson, 1982; Fullerton and Kinnaman, 1995; Walls and Palmer, 2001; Briguglio, 2021). However, the construction of economic models is typically based on hypotheses that assume rational behavior of only a few actors – producers and consumers – that are abstracted from the real economy. In contrast, the interactions among actors within or across value chains are becoming increasingly crucial for CE implementation and policy practices (European Commission, 2014; Milios et al., 2018; Kirchherr

[1]This is the case despite ongoing geopolitical challenges. For instance, the governments of the United States and China signed a statement in November 2023, in which a joint effort is agreed to develop circular economy and resource efficiency to address the climate crisis (U.S. Department of State, 2023)

[2]According to the Global Circularity Metric used in the global Circularity Gap Report (Fraser et al., 2023), global circularity of material use shrunk from 9.1% in 2018, to 8.6% in 2020, and 7.2% in 2023.

[3]Moreover, Ranta et al. (2018) applies institutional theory to specify the regulative, normative, and cultural-cognitive drivers and barriers to CE in a cross-regional comparative study. Tura et al. (2019) structures the drivers and barriers for circular businesses with respect to seven areas that also include informational and supply chain factors. More examples in this strand are found in: Masi et al. (2018); Adams et al. (2017); Liu and Bai (2014); Xue et al. (2010); Scott (2008).

et al., 2023). Constraints in such interactions can hinder a systematic transition toward a CE, particularly when innovation in products, organizational structures, or value chain relationships is necessary (European Commission, 2014; Korhonen et al., 2018; Hartley et al., 2020; Stahel, 2019).

In this study, we fill this literature gap by identifying key factors that influence firms' strategic and investment decisions through semi-structured interviews. With perspectives reflected by 31 industrial stakeholders along the value chains of plastics and steel, our results inform CE policies and economic modeling. Due to the wide range of policy instruments and regulations that actors must consider when making decisions about circularity, analyzing policies related to circularity strategies remains challenging. Through our interviews, we gain insights into what ultimately matters for private actors in this policy-rich environment, which helps us understand their impact, synergies, and trade-offs. Additionally, the identification of underlining drivers for firms' decision-making contributes to formulating hypotheses and parameters for economic modeling of the CE, thereby bridging the gap between the limited theoretical studies and the large and growing body of qualitative research in this field.

We define a circular industrial economy in line with Stahel (2019), which includes three domains: (1) extending the service life of manufactured objects through reuse, repair, refurbish, remanufacture, and technological upgrades; (2) providing local services such as renting, leasing, sharing, and quality monitoring; and (3) recycling used materials globally to recover molecules and atoms.[4] Additionally, we acknowledge the need of new inputs from the linear industrial economy to (1) upgrade existing stocks with innovative materials and components, and (2) replace obsolete or destroyed stocks, in line with Stahel (2019). Accordingly, we categorize the interviewed companies under four main stakeholder groups: primary material manufacturers, material-using producers, recyclers and waste managers, and reuse service providers (see Figure 1).

The study most similar to ours is by (Milios et al., 2018), which conducts a holistic analysis of actors in the plastic value chain. We extend their stakeholder group to include primary material manufacturers and reuse service providers as well. The inclusion of these stakeholders is important for the transition analysis because of the current incumbency of the former and a different circular economic incentive presented by the latter. Furthermore, our study presents a comparative picture in the CE transition of the value chains of two different material types: plastics and steel. While most conceptual studies of CE are neither material nor industry specific (see, Bocken et al. (2016);

[4]While a single definition of CE remains elusive, a 2023 literature review of 221 CE definitions finds that consensus has grown regarding the core principles underpinning CE (Kirchherr et al., 2023).

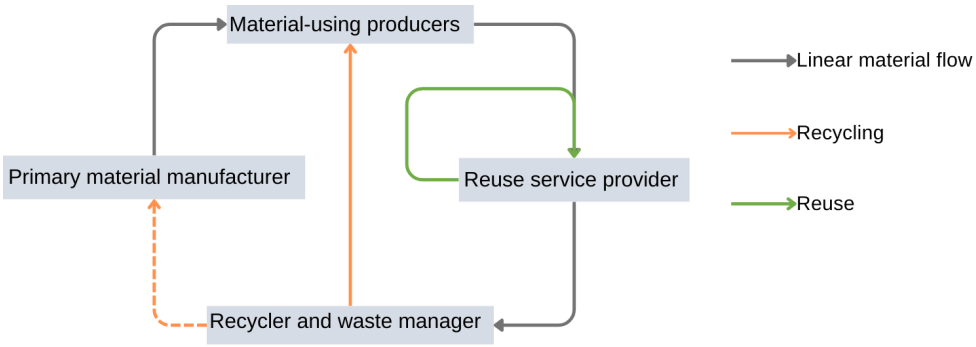


Figure 1: Four stakeholder groups in a material value chain covered in this paper.

Geissdoerfer et al. (2017); Korhonen et al. (2018), studies that lay out transition pathways typically focus on one or a few heavy material sectors, such as cement, plastic, or steel (Gallego-Schmid et al., 2020; Material Economics, 2018). In this study, we contribute to bridging this gap by identifying and comparing the drivers and challenges for CE transition of the two industries that are different in material value and waste treatment method (Daehn et al., 2017; Watari et al., 2023; Meys et al., 2021; Gómez-Sanabria et al., 2022).

We identify several insights that explain different incentives of the stakeholders for a CE transition. First, non-economic factors play a central role in decision-making for some stakeholders. Second, decisions that favor CE may be weak in economic terms, reflecting weak market resilience for recycled materials and high transactions costs associated with circular product design. Third, strategic activities have the potential to overcome the challenges of insufficient economic incentives for CE transition through long-term partnerships across actors in the industries or business model innovations. Moreover, we find the perceptions of key challenges and regulatory needs vary among stakeholders. Despite a strong consensus on the importance of product design, only a small share of material-using producers in the plastics industry prioritizes product requirements, in contrast to other stakeholders such as recyclers and primary manufacturers. This finding is coherent with the an unbalanced inclination towards down-stream waste regulations, despite the the consensus that the primary responsibility for CE transition rests on the shoulders of producers.

By comparing the narratives across industries, we find that the steel industry exhibits greater value chain integration, with downstream product companies controlling multiple stages of its production process. In contrast, the plastics industry presents a more fragmented structure, characterized by a diverse range of independent entities each specializing in different segments of the value chain. In addition, the urgency in advancing recycling technologies is perceived differently both

across sector and stakeholder groups. The entire steel industry overall and the chemical companies in the plastics industry prioritize it as a top factor. While the noncompetitive price and quality of recycled materials are regarded as common challenges to close the loop for both materials, scrap availability is considered a key challenge only for the steel industry.

This paper is structured as follows. Section 2 presents the methodology used. In Section 3, we present the findings which are organized in the sequence as our interview questions. Section four introduces the current CE policies and developments in the EU and reflects the policy recommendations based on our interview results. The last section concludes.

2 Methodology

We conduct semi-structured expert interviews with stakeholders from the plastics and steel industries by following the methodological steps of stakeholder analysis, including the identification of stakeholders and their differentiation and categorization (Reed et al., 2009). To present a comprehensive picture of the CE dynamics of these industries, we include all stakeholder groups along the entire value chain. We identify prominent companies within the stakeholder groups along the value chain of the plastics and steel industry in Europe. Our inclusion strategy comprises an inductive sampling approach, whereby we focus on the decision-makers who actively conduct or are influenced by CE activities in their businesses. This allows for better informed identification of the barriers and opportunities within their industry as our interviewees are already experienced with relevant practices and applications. This step is followed by online searches of the companies' names and keywords such as "circularity expert" with the goal of finding the most suitable person to conduct the interview with.[5] In total, 31 interviews are qualified, with 22 companies operating in the plastics and 9 in the steel industry.[6] The uneven distribution between the two industries is unintended – companies active in the plastics industry were more responsive to our requests.

We categorize the selected companies into four stakeholder groups. Table 1 provides an overview of this categorization and the number of companies interviewed from each stakeholder group. In particular, the recyclers and waste managers in the plastics value chain include private and public waste management companies, recycling technology providers, and take-back system operators.

[5]Upon the initial contact, in some cases, we were redirected to a more suitable person to answer the questionnaire within the company, which we did. A list of our interviewees' roles is given in the appendix.

[6]One company is a public transport service provider that is, however, not directly related to either industry. This sample item is therefore excluded from the analyses and results.

Material-using producers in the plastics value chain encompass intermediate product producers, such as plastic converters and ink producers, and retailers. We use this categorization to structure our analysis and results.

Stakeholder Group	Plastic Industry	Steel Industry
Recyclers	8	4
Consumer Product Producers	6	1
Reuse/Circular Service Providers	5	0
Primary Material Producers	3	4

Table 1: Number of interviewed companies by stakeholder group and material type.

Most interviews took between 45 - 60 minutes with only a few being limited to 30 minutes due to the interviewees' time constraints. All interviews were conducted online and 90% allowed us to record the interview. We used digital transcription services to transcribe the recordings. Using semi-structured interviews allow us to adjust the order of the questions in the questionnaire according to the flow of the interview as well as to ask follow-up questions upon completion of the questionnaire whenever necessary (Harrell and Bradley, 2009).

Our questionnaire is structured in four parts which enquire about 1) the stakeholders' strategy and decision-making surrounding circular processes; 2) the stakeholders' perspectives on the most important factors for a successful CE transition; 3) the perceived and experienced challenges and opportunities for a CE transition; and 4) the value chain coordination and policy needs to improve circular processes. The questionnaire contains eleven questions. Out of these, eight were open-ended and three were multiple-choice.

We evaluate the results of the interviews in several steps. First, we review all recordings and transcriptions upon completion of all interviews.[7] Second, we create an overview based on initial reviews and integrate our notes on the key takeaways from each interview in it. Third, we analyze the multiple-choice questions separately using graphical visualizations, allowing us to observe commonalities and discrepancies in responses to challenges and policy responses that were mentioned by most stakeholders. In our final step, we build on our summary of the structured open questions by assessing if stakeholders at the same stage of the value chain voiced similar opinions about the barriers and opportunities. We look for common patterns, shared opinions, and differing perspectives.

[7]For the interviews where no recording was permitted, we reviewed our hand-written notes.

3 Results

3.1 Stakeholder strategies and drivers for a CE transition

Q1. Does your company have a strategy contributing to a circular economy? How does/will this strategy influence the core business of your company? And how would you measure the success of this strategy?
Q2. Which departments in your company are involved in your company's circular economy strategy and what is the decision-making process? What are the key factors affecting this decision-making process?
Q3. Who do you think is in the main position to influence your company's circularity decision/strategy - the customers, the investor, the regulator, or other firms in the supply chain?

Table 2: Interview questions on business strategy and decision-making factors

Our results reveal that many firms have developed CE business strategies. Despite varied implementation across industries and stakeholder groups, a common theme emerges in the increasing collaboration and economic incentives driving the adoption of CE practices. Tables 3 and 4 summarize the interview results to questions given in Table 2 on CE business strategies in the plastics and steel industries, respectively. Most companies have a CE strategy or alternatively include CE in their business strategy for sustainability, especially in the plastics industry. This finding is at odds with Kirchherr et al. (2018), who find hesitant company culture as a major barrier to a CE transition. A potential reason is the limit of our inductive sampling approach and the proximity of CE to sustainability-related management roles (see Appendix B). Nevertheless, we notice a growing trend to engage various functional departments in the internal discussions for CE. Most interviewed material-using producers report that all departments participate due to their unique functions and perspectives. In the reuse business, roles such as research and development, product development, and supply chain management are more prominent. In contrast, primary manufacturing companies typically employ a top-down decision-making approach. This hierarchical structure is also prevalent in most waste management companies. A difference between stakeholders in the plastics and the steel industries is that only a few companies interviewed from the steel industry have formulated explicit CE strategies. For them, advancements in CE are perceived as a way to achieve climate neutrality rather than a goal by itself.

The implementation of CE strategies is measured in different ways across and within stakeholder

Stakeholder Group	Business Strategies for a CE
Primary Manufacturer	All companies include CE as a main strategy or as part of the corporate vision.
Material-Using Producer	All companies have a CE strategy or employ CE as their core business. Their measurement metrics, however, are diverse.
Recycler and Waste Manager	Some companies have quantitatively defined strategies, such as the share of useful materials recovered from incinerated waste. Some companies include CE as a principle in their business sustainability strategy. Some companies include CE as their core business.
Reuse Service Provider	Business models revolve around CE.

Table 3: Company CE strategies in the plastics industry

Stakeholder Group	Business Strategies for a CE
Primary Manufacturer	Some companies have strategies focused on climate neutrality rather than CE. In these cases, CE is used as a tool to achieve climate goals. Other companies have explicit CE strategies aimed at enhancing their reputation and profitability through product differentiation.
Material-Using Producer	The interviewed company does not have a strategy for CE. Current regulatory focus on product safety hinders the development of circular products.
Recycler and Waste Manager	For these companies, CE is the core of their business. Some invest in improving the quality of their recycled products.

Table 4: Company CE strategies in the steel industry

groups. Primary material manufacturers in the plastics industry, or chemical companies, measure the success of their circular strategy by the sales of circular chemical products – the share of outputs that utilize circular feedstocks, such as pyrolysis oil, biomass, or carbon dioxide. While most chemical companies incorporate this metric into their future visions, their current production still largely relies on primary fossil resources. In comparison, primary steel manufacturers already recycle a share of steel scrap in their conventional production processes.[8] New investments in

[8]For instance, scrap use accounts for around 20% of the material input in the conventional basic oxygen furnace route for metallurgical purposes, such as cooling. This information is received from interviews, but also confirmed from external sources, such as World Steel Association (2021).

production processes such as direct reduced iron (DRI) or electric arc furnace (EAF) can help these companies to process a higher share of scraps in steelmaking. A combination of basic oxygen furnace (BOF) and smart carbon usage is also mentioned as one pathway to produce low-carbon steel while coupling with other industries to achieve carbon circulation. For material-using producers in the plastics industry, some companies keep track of their ecological footprint and their products' cradle-to-cradle performances, while others develop corporate targets on minimum recycled content in plastic packaging. One interviewee in the plastic converting business mentions their adoption of lean management,[9] which greatly improves material efficiency.

Economic motivation to advance CE actions is found in several stakeholders to various extents. Recycling and waste management companies seem to share the common pursuit of value retention, although the latter is regulated with binding targets to recover more useful materials from waste.[10] Winning bids from big customers constitutes a significant income stream for waste management companies. While the sale of recyclates generates additional income streams, uncertainties in the price of plastic recyclates render this revenue stream unreliable, thereby allowing companies in this stakeholder group to generate only a small share of revenues from the sale of recyclates. Nevertheless, the economic incentives motivate the effort of some waste management companies to push their customers for better product design and waste separation. In contrast, the material-using producers typically do not have a direct economic interest in material recovery or reuse.

Interviews with the reuse service providers in the plastics industry reveal several shared economic principles despite diverse business models. First, most interviewees emphasize the role of product quality as a precondition for the profitability of a reuse business. "A reusable product with long service-life can withstand more rounds of use and washing before it breaks and requires repair," as a business founder of reusable packaging argues. Similarly, a good quality second-hand product is more likely to get sold and gain an extended service life before it gets donated, recycled, or disposed

[9]Lean management is a systematic approach aimed at reducing waste within manufacturing systems while simultaneously improving productivity and quality. It focuses on streamlining operations, optimizing processes, and enhancing efficiency by identifying and eliminating non-value-added activities (Womack and Jones, 2010)

[10]Both the waste management companies and take-back system operators are obliged to raise their recycling rates under national or regional legislation. For instance, the European Commission lays down national recycling targets of packaging wastes that EU Member States must meet in the proposal of the EU Packaging and Packaging Waste Regulation. Before this regulation repeals the former regulating legislation, the Directive 94/62/EC, it is the duty of each Member State to set binding regulations to meet self-legislated recycling targets that are supposed to at least meet EU stipulations. Under the stipulation of extended producer responsibility (EPR), take-back systems, such as the German dual systems, are obliged with binding regulations.

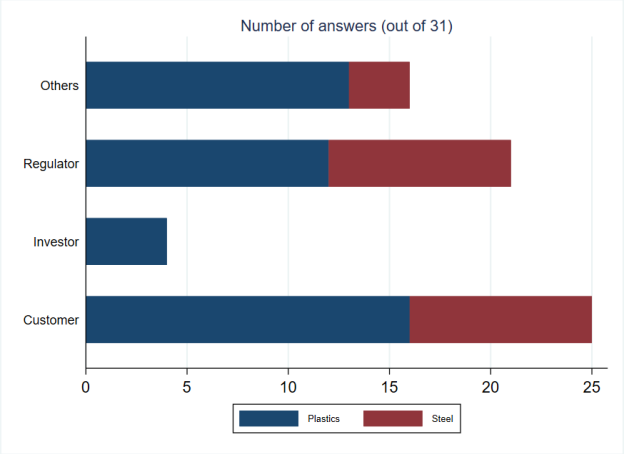


Figure 2: External drivers for a sustainable/CE business strategy

of. Second, the standardization of products and processes could enhance cost competitiveness. In this regard, several reuse service providers highlight the role of digitalized tracking systems that help them measure and enhance system efficiency. Third, most reuse businesses interviewed focus on providing a service, instead of selling a product. Altogether, these factors seem to result in close cooperation of reuse service providers with their suppliers in the product development process to minimize impurities in new designs.

Regarding external drivers, both customers and the regulator are considered important in influencing the business strategies for a CE (see Figure 2). About 76% of the interviewees mention the importance of their customers and 58% emphasize the role of regulators. When calculated for specific materials, the shares are higher for businesses in the steel industry (90% and 60%, respectively) than for businesses in the plastics industry (70% and 52%, respectively). The role of both business customers and end-consumers is reflected by interviewees in the plastics industry. In particular, the operational performance of waste management companies can be improved if product producers reduce the types of materials, avoid the use of combined materials, and if households and businesses deliver better waste separation. On the other hand, public attention to the issue of plastic pollution appears to have created significant momentum within material-using companies.

While most businesses interviewed characterize themselves as customer-driven, it is noteworthy that the demand for circular products and services from customers is influenced, at least in part, by regulations. A regulatory framework on waste collection and treatment methods determines the demand for facilities and services a waste management company must provide. Within the steel stakeholder groups, several interviewees, including recyclers and primary manufacturers, explain

that action is initiated by steel-using consumers (e.g. car manufacturers), who demand low-carbon steel due to regulatory requirements. This, in turn, increases the demand by steel mills for recycled steel, leading steel recyclers to invest in advancing their facilities to improve the quality of their scrap-based products. Broader aspects of sustainability, such as resource efficiency and CE, become increasingly reflected in new regulations, such as the Corporate Sustainability Report Directive or the End-of-life Vehicle Directive in the EU. As a result, companies in this stakeholder group start to invest in new partnerships or business models to comply with the changing regulatory trend.

A large share of the interviewees (48% overall, with 57% in the plastics industry and 30% in the steel industry) also mention other important drivers for their business strategies for a CE. These factors include public education on sustainability, attitude of employees or the business owner, the EPR systems, and structural trends in the industry such as digital infrastructure. For chemical companies, collaboration with upstream suppliers of the circular feedstock is also very important for them to deliver their strategies. The influence of investors is not emphasized by most interviewees, except for one who mentions an increasing interest of European investors in greener technologies and circular business solutions.

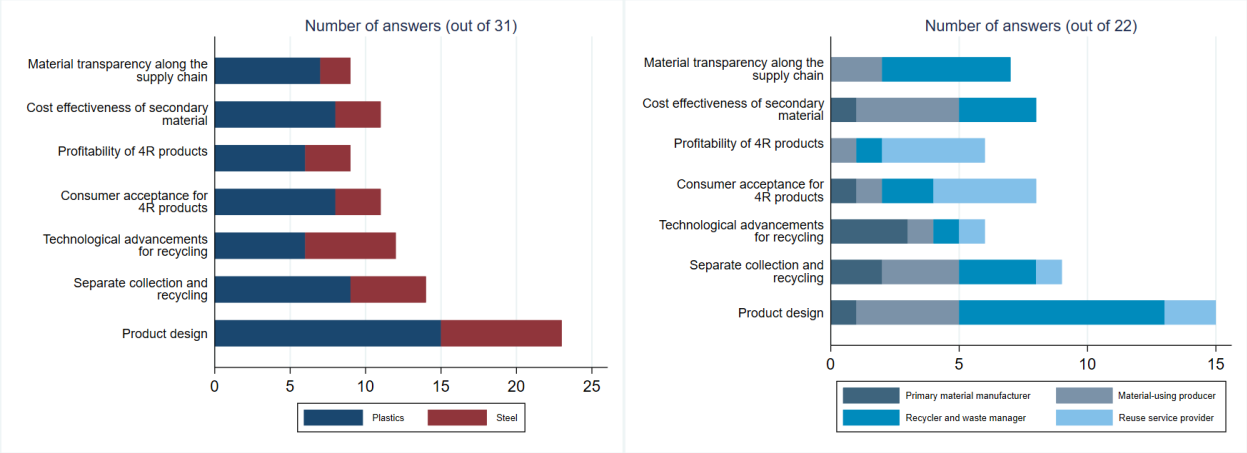
3.2 Most important factors for a successful CE transition

Q5. Could you choose 2-3 factors that are most important in your opinion to support a successful transition toward a CE, and add more if we have missed some aspects? (Multiple-choice question)

Table 5: Interview questions on the most important factors for a CE transition

We ask our interviewees a question on the most important factors for a successful CE transition (see Table 5) and find that both consensus and heterogeneous opinions across industries and stakeholder groups. Figure 3 illustrates the interview results by (a) industry and (b) by stakeholder groups in the plastics industry alone. Overall, product design and separate waste collection, sorting and recycling are considered most important, selected by, respectively, 23 (70%) and 14 (42%) interviewees. A major difference across the industries observed is that six steel-related companies, constituting 60% of interviewees from the steel industry, choose advancements for recycling technology, in contrast to only 26% of interviewees from the plastics industry. A breakdown by stakeholder group shows that within the plastics industry, recycling technology advancements are deemed most crucial by chemical companies – the primary material manufacturers in this industry,

as all interviewed companies (100%) choose this option. Therefore, our results reveal dispersion on the need for recycling technology advancements among stakeholders and across material industries. This heterogeneity may explain the conflicting findings reported in the literature. While some studies identify technical bottlenecks as pivotal obstacles hindering the transition to a CE (de Jesus and Mendonça, 2018), others do not perceive them as predominant barriers (Kirchherr et al., 2018).



(a) By industry **(b)** By stakeholder group (in the plastics industry)

Figure 3: Most important factors for CE transition

Another heterogeneity is observed across different stakeholder groups in the plastics industry. While all recyclers and waste managers regard product design as crucial, only a third of the interviewed primary manufacturers consider it important. Moreover, none of the primary manufacturers or reuse service providers opt for material transparency along the supply chain, whereas 63% of the recyclers and waste managers rank it as one of the most important factors. Approximately 80% of the reuse service providers consider both consumer acceptance for reused, repaired, refurbished, and remanufactured products and the profitability of these products as the most important factors, whereas most other stakeholders did not choose them. In comparison, two-thirds of the material-using producers opt for the cost effectiveness of recycled materials, but this factor is not relevant for the reuse service providers.

3.3 Challenges and opportunities for CE transition

In this section, we summarize the key insights we obtain for answers to the open questions given in Table 6 on the key challenges and opportunities for a CE transition (see Figure 4). We first analyze

Q4. Based on the EU CE Action Plan, where do you think are the bottlenecks and opportunities when it comes to a successfully functioning CE?
Q8. In terms of technological advancements, which technologies do you think are essential to support the transition to a CE? Is this technology already adopted in your company or in the supply chain that your company belongs to? Do you perceive any barrier or opportunity for its adoption and implementation?
Q11. Overall, what do you think are the further opportunities to move toward a circular and low-emission economy that might be overlooked or underinvested that we have not touched upon in this interview?

Table 6: Interview questions on the challenges and opportunities for a CE transition

the main perspectives on the challenges, then follow up with the observed opportunities and trends by interviewees. First, the uncompetitive price of recycled materials is voiced as a key challenge for both types of materials. When the price of primary plastics is comparatively low, for instance triggered by low demand and oil price shock during the global Covid-19 pandemic, a low demand for recycled plastics follows (Weinhagen, 2006; Issifu et al., 2021). The prevailing high energy price in Europe is also mentioned by interviewees, contributing to the persistent low demand even after the economic recovery. As a result, interviewees in the plastics industry observe recycling facilities dropping out of the market, which in turn poses a challenge for packaging producers to source high-quality plastic recyclates. Simultaneously, the weak market discourages investment in new sorting technologies, leaving the potential of higher quality plastic recyclates unexplored.

While the uncompetitive price of recycled materials can also be seen in the steel industry, the challenge here lies in the higher capital and operational costs required to process scrap to a quality comparable to that of primary steel. Due to a rising demand for high quality recycled steel in downstream manufacturers, notable efforts are mentioned by our interviewees, including investments in new scrap processing facilities and grade-separated logistics. Nonetheless, the high initial costs pose a challenge to profitability, affecting the economic incentives for scrap dealers and recyclers to make such investments. Additionally, with blending technologies already matured in steel mills for producing low-quality recycled steel, most scrap collectors in Europe lack the economic incentive to explore alternative technological paths.

Second, the high volatility of recycled material prices, including both processed scraps and plastic recyclates, also deters investment in recycling facilities, according to interviewees in both industries. Low supply elasticities of different recycled materials, combined with demand shocks,

have been identified to explain the price volatility (Stromberg, 2004; Blomberg and Söderholm, 2009). Nevertheless, less evidence is found to support a significant difference in price volatility between primary and recycled materials (Stromberg, 2004).

A third concern arises mainly in the steel industry regards scrap availability. Multiple interviewees note a trend that steel companies seek mergers and acquisitions with recycling companies to access scrap steel more easily. However, the scrap supply remains a problem, since the amount of available new scrap is limited by the level of metal production and scrap supply rarely responding to changes in scrap stocks (Blomberg and Söderholm, 2009). This is confirmed by interviewees who mention the abundant but largely "forgotten" scrap deposits of home appliances and vehicles, stressing the need for collection schemes.

Another major concern in the plastics industry is the lack of incentives for product producers to adapt their product design to rules for recyclability. Several interviewees note the high transaction cost for producers to alter product design, search for alternative material suppliers, and undergo certification processes. Moreover, the cost of recycling remains external to the business of product producers, and there is no established way for recyclers to refund producers the transaction cost of product design changes (Calcott and Walls, 2005; Milios et al., 2018). Despite the implementation of financial mechanisms to bridge costs between producers and recyclers through the concept of EPR, the strong incentive to design for recyclability is missing (Joltreau, 2022; Compagnoni, 2022). This is compounded by a lack of consumer awareness and demand for more recyclable products in some markets. Reflecting the increased cost of product design in the price of final products would reduce the competitiveness of the product in these markets and prevent consumer goods producers from placing their products in the best spots in retail stores. Several interviewees conclude that "producers are not going to deliver a solution if other stakeholders in the value chain will not put similar effort and resources into this transition."

The current policy framework is criticized for its lack of certainty and clarity as well as its long planning horizons. Consequently, municipalities' demand and investments of waste management companies in the necessary infrastructures are low. Similarly, circular plastic converters criticize the confusing signals created by uncertain regulatory restrictions on the use of recycled polymers in certain products, which could cause a mismatch between plastic converting technology investment and demand. Moreover, current policies bias toward recycling, which hinders circular business models such as reuse. Several waste management companies notice a conflict between the profitability of their core business and material reduction. Reuse service providers argue that shifting the policy

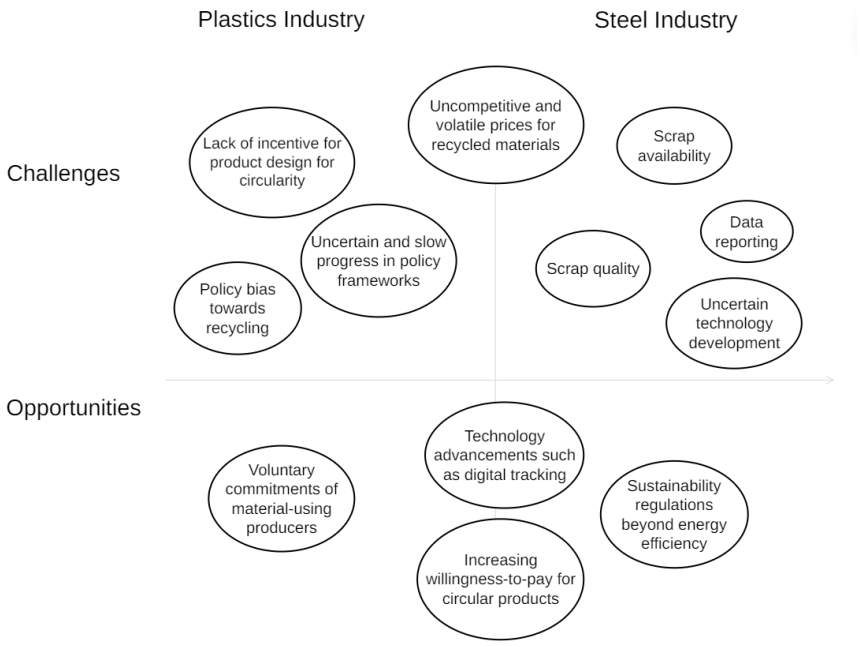


Figure 4: Summary of interview results on the challenges and opportunities for a CE transition

focus to waste prevention rather than recycling early on can save switching costs for consumers, institutions, and businesses, thereby reducing the overall investment costs for a CE transition. For instance, the heavy investment in expensive incineration facilities may hinder the policies shifted to strong promotion of recycling (Domenech and Bahn-Walkowiak, 2019; Yamamoto and Kinnaman, 2022). A transformation of how governments conceptualize CE facilitates the adoption of more holistic criteria into specific policy instruments, such as circular public procurement (Hartley et al., 2020).

The interviewees also mention opportunities that can foster the circular transition of the economy. First, recent and upcoming technological advancements, such as digital tracking, are believed to promote a circular transition. Examples are waste bin sensors or sorting facility can increasingly detect materials, including polymer types and trace elements in metal mixes. They offer the opportunity to reduce material contamination while lowering the costs for material users to inspect and ensure their material inputs' quality. Reuse service providers with digital platforms can also track their products' use and measure the number of single-use products or waste-generation avoided. Second, the increasing voluntary commitment of consumer product producers to a low-carbon and circular corporate strategy is also seen as an opportunity. Given the high transaction costs involved in altering product design, voluntary commitment to using recycled content could stabilize demand

in the recycled material market. However, in sectors where producers operate on a just-in-time basis, voluntary commitments may lack credibility. Broadening the regulatory focus beyond energy efficiency to other aspects of sustainability is also seen as an opportunity, although progress has been slow. Notably, the EU Corporate Sustainability Responsibility Directive (Directive (EU) 2022/2464) is enforcing sustainability reporting standards on environmental factors, including CE and scope 3 emissions, that companies are obliged to submit in 2029. Lastly, the willingness-to-pay for circular products varies across markets (Köveker et al., 2023). While producers in some markets still aim to sell the cheapest product on retailer's shelves, others mention a changing trend toward products with high recycled content to take the better spots.

3.4 Needs for coordination and regulation

Q6. Could you choose 2-3 stakeholders in the life-cycle value chain that in your opinion should take the key responsibility for a circular transition, and add more if we have missed some aspects? (Multiple-choice question)
Q7. Do you think systematic coordination between different players/stages in the value chain is necessary or not? If yes, who do you think should take the lead in it?
Q9. Do you think voluntary motivations are enough to provide a strong incentive for transitioning toward a CE, or are mandatory rules necessary too? Why?
Q10. Could you choose 2-3 policy instruments from the list below that you think are most important to enable the CE transition? Is there a policy that is important but missing from the list? Can you elaborate a bit further on why they are important? (Multiple-choice question)

Table 7: Interview questions on coordination and regulatory needs

We ask our interviewees questions on the need for coordination and regulation in the value chain (see Table 7). Most interviewees, 15 (65%) companies in the plastics industry and 5 (56%) companies in the steel industry, explicitly argue for the importance of value chain cooperation. In the steel industry, recyclers who have secured long-term contracts with consumer product producers to take back scraps are considered more capable of producing recycled steel with guaranteed quality. On the other hand, producers need to partner with reliable suppliers to reduce product carbon footprint and comply with regulations. Nevertheless, this process is reported have only begun in recent years. Primary material manufacturing continues to dominate the market and transitioning to a more scrap-based production process would entail importing these valuable resources from countries where they are currently recycled, which may lead to an increase in global emissions.

A similar trend in value chain cooperation is observed by the interviewees in the plastics industry. Notably, several plastic converters and consumer product producers emphasize the necessity of a partnership between them and the recyclers. An ink producer indicates a limitation not in producing sustainable inks suitable for recycling but in how their customers, the plastic converters, utilize such products. However, compared to the rather integrated steel value chain, the plastic value chain is very fragmented, which is in line with Milios et al. (2018). While some companies pioneer in initiating and maintaining cooperation with their value chain partners, most interviewees criticize the resistance of the industry to change and the lack of motivation for industry stakeholders to talk to each other without additional profit or cost cut possibility.

As a result, regulations are considered a major impulse for industry stakeholders to collaborate. Almost all interviewees (about 90%) emphasize the need for mandatory rules in parallel to voluntary market incentives. Interviewees from German take-back systems and waste management companies mention the EPR systems that create value chain cooperation, as the establishment of EPR requires a multi-stakeholder process. Several strands of literature acknowledge the effect of EPRs to encourage producer-recycler interaction, thereby stimulating collaborative downstream innovation and the setting of product standards (Micheaux and Aggeri, 2021; Massarutto, 2014). Regulations facilitating this process include enhancing information transparency and data availability and creating a level-playing field.

Specific regulations are ranked by our interviewees, as illustrated in Figure 5. We observe a consensus on the relative importance of policies but also differing perspectives. First, a notable disparity emerges regarding policy preferences among stakeholders in the plastic and steel industries. While 39% of plastic stakeholders prioritize resource policies over carbon pricing (22%), 44% of steel stakeholders emphasize the importance of carbon pricing, with only 11% favoring resource policies. This result suggests that distinct policy instruments may vary in effectiveness across different material types, despite having similar policy objectives. Furthermore, stakeholders in the plastics industry place a higher importance on the regulatory framework (61%) compared to their counterparts in the steel industry (22%). This observation aligns with the previous finding indicating a higher level of integration within the steel industry compared to the plastics industry.

Second, within the plastics industry, the prioritization of regulatory needs hinges upon the specific role of respondents in the value chain as can be seen in Figure 6. While most interviewees see product requirements as the most important and urgently needed regulation, only 17% of interviewed material-using producers in the plastics industry select this option, in stark contrast to 88%

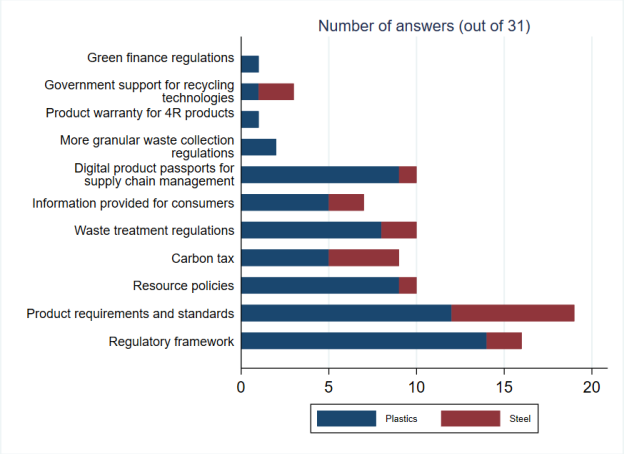


Figure 5: Selected regulatory needs for a CE transition by industry

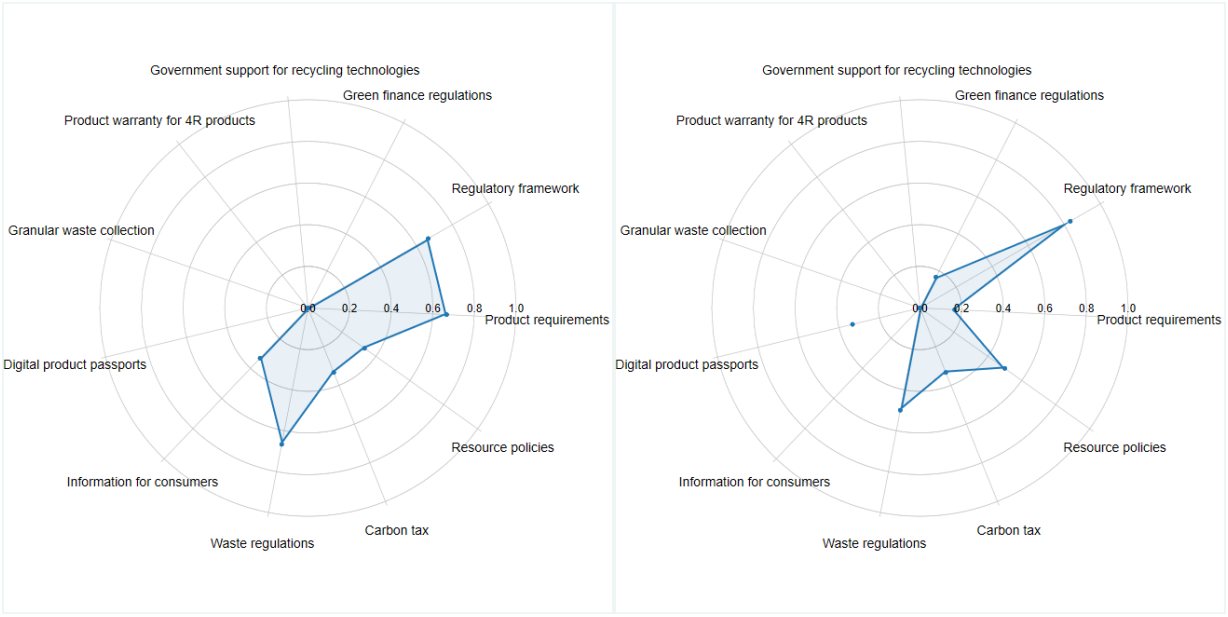
of interviewed recyclers and waste managers and 67% of primary material manufacturers. Moreover, while reuse service providers (60%) emphasize the information disclosed to consumers,[11] none of the material-using producers in the sample considers an urgent need for this policy instrument. On the other hand, waste treatment regulations are not relevant to reuse service providers, but they are considered crucial to primary material manufacturers (67%) and material-using producers (50%).[12] Overall, granular waste collection, product warranty, government support for recycling technologies, and green finance are considered less urgent by our interviewees.

Despite the heterogeneities, the clear preference for product regulation in both industries is consistent with the belief of most interviewees that producers should take the main responsibility for a circular transition (See Figure 7). Downstream companies in the supply chain, particularly waste management and treatment companies, are considered less responsible and only responsive to the choices of other market players, although these sectors are heavily regulated (Hartley et al., 2020).[13]

[11]The challenge for consumers to change their mindset and behavior to accept circular products is also reflected in the choice of some retailers who refuse to accept reusable products or fail to promote these products to their customers. As a result, policies are needed to support reuse and waste prevention.

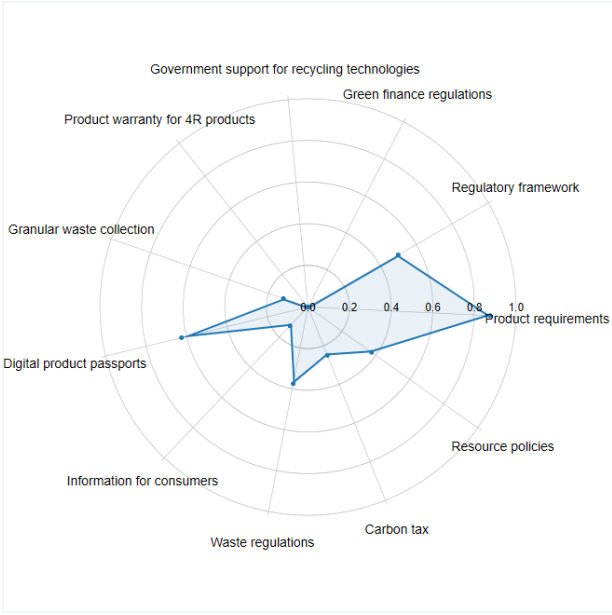
[12]We find that information disclosure to consumers seems to be interpreted by the interviewees as a supportive tool to increase consumer acceptance for reused, repaired, refurbished, and remanufactured products, rather than to enhance material transparency along the supply chain, by comparing the answers to Q5 and Q10. In Q5, 80% of reuse service providers select consumer acceptance as one of the most important factors for a successful CE transition, whereas only 17% of the material-using producers select this option. In contrast, none of the reuse service providers select material transparency along the supply chain. This result is in line with the answers to Q5.

[13]See, for example, the Landfill Directive (1999/31/EC), Waste trade policy (Regulation (EC) 1418/2007, latest amendment: 2021/1840), Waste Framework Directive (2008/98/EC), Directive (EU) 2018/850 on landfill and waste, as well as Directive (EU) 2018/851 on waste management.

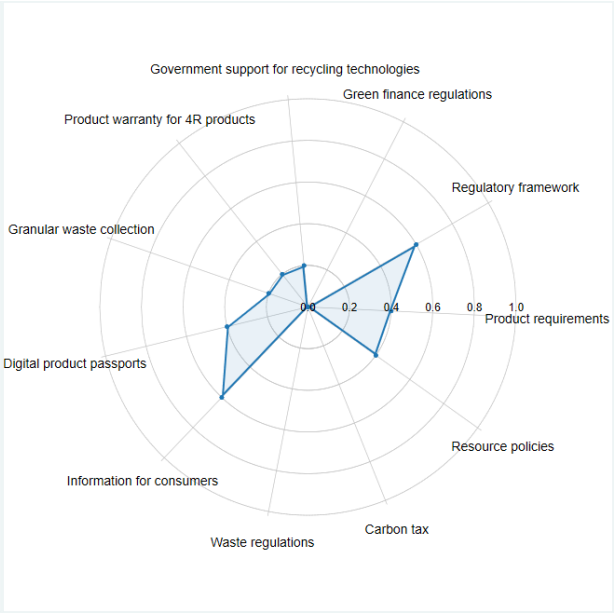


(a) Primary material manufacturer

(b) Material-using producer

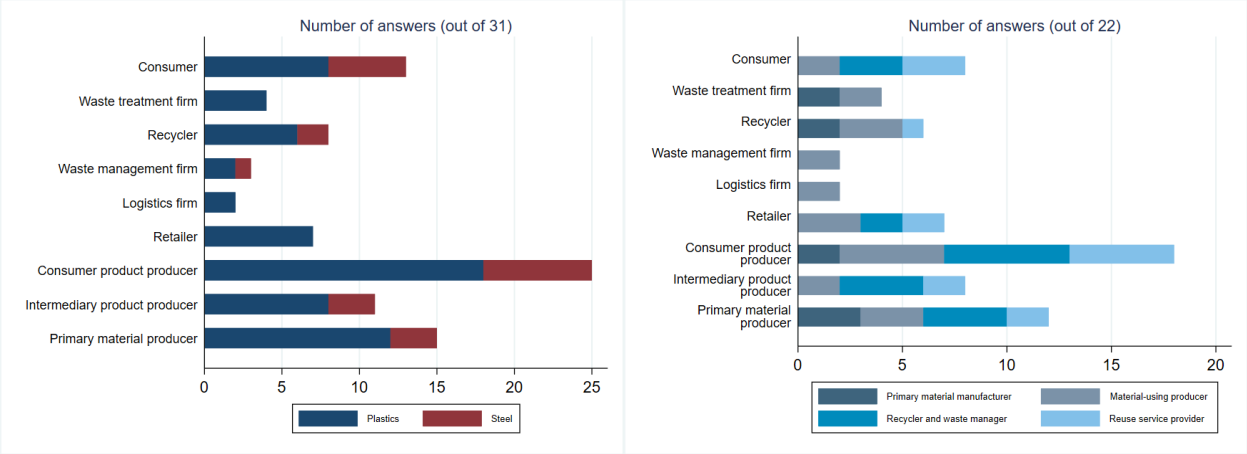


(c) Recycler and waste manager



(d) Reuse service provider

Figure 6: Selected regulatory needs for a CE transition by industry by stakeholder group (in the plastics industry)



(a) By industry **(b)** By stakeholder group (in the plastics industry)

Figure 7: Stakeholders that should undertake the key responsibilities for a CE transition

4 Current policy landscape in Europe

Resource and energy policies have been discussed in the EU since the 1970s through the implementation of environmental protection and waste management policies.[14] Subsequently, these policies became more stringent with CE first being introduced as a concept in 2014 (Mazur-Wierzbicka, 2021). The political umbrella for circular activities in the EU, the CE Action Plan (CEAP),[15] is a fundamental part of the European Green Deal (European Commission, 2020). In this section, we briefly present CE policy development in the EU, as of 2023, and the recommendations summarized from interviews (see Appendix A for an overview of policies mentioned in the interviews).

First, although CE policies have primarily focused on end-of-pipe solutions, shifts in both study and policy practices are happening, with a life-cycle view that reflects the holistic perspective needed for a CE transition being adopted (Milios, 2018; Hartley et al., 2020). This trend advances the enforcement of the waste hierarchy to recover a higher value at the end of product life.[16] A new EU Ecodesign for Sustainable Products Regulation (ESPR) proposal was adopted in 2022,[17] as a cornerstone regulation of the EU CEAP. This proposal suggests new product requirements that

[14] These were strongly integrated with the "community strategy for waste management" in 1989, which introduced common principles to protect the environment (Commission of the European Communities, 1989).

[15] Officially referred to as "A new Circular Economy Action Plan For a cleaner and more competitive Europe."

[16] A more stringent enforcement of the waste hierarchy was encouraged in directive 2008/98/EC on "waste and repealing certain Directives."

[17] See European Commission, Proposal for a Regulation of the European Parliament and of the Council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC, COM/2022/142 final.

make products not only energy and resource efficient but also durable, reusable, repairable, and recyclable. It also introduces the concept of a Digital Product Passport to pass information along the entire value chain and inform consumption choices. At product level, a clear definition of reusability and recyclability for plastic packaging and harmonized implementation of EPR systems across EU member states are proposed in the new EU Packaging and Packaging Waste Regulation (PPWR).[18] Around the same time, a new EU Regulation on End-of-life Vehicles was proposed, specifying new rules ranging from circular design of vehicles, minimum use of recycled plastic, better recoverability of raw materials to the enforcement of producer financial responsibility for the final treatment of vehicles at the end-of-life.[19]

Second, recycling quotas are increasingly used by regulators. The Single Use Plastic Directive (EU 2019/904)[20] calls for a minimum recycled content for single-use plastic bottles, while the new proposal of End-of-life Vehicle Regulation (COM/2023/451) suggests to include a minimum required content for recycled plastic as well. Based on our interview results, we find that clear legal definitions on recycling and recycled content are needed in the plastics industry to determine the prevalent recycling technology used. Opposing views of chemical companies arise with some arguing in favor of enforced minimum recycled content targets in all sectors, and others being concerned about such policies' implications on their business models. Additionally, we find that regulation must not only focus on output but also on feedstock inputs such as pyrolysis oil, biomass, and CCUS. Expanding the share of these feedstocks would also face regulatory challenges. Legislation is needed to ensure a level playing field between different recycling methods.

Third, reflecting the environmental cost in material price continues to be an area that needs policy support. As the material price determines the demand and energy recovery route being taken, it is critical that the environmental costs are internalized in material prices to level the playing field. Despite the EU ETS (Emission Trading Systems) covering the chemical sector, our interviewees reflect that the product producers' incentives often do not align with circular principles. Further monetary incentives are needed for the adoption of recycled materials e.g. through tax breaks for

[18]See European Commission, Proposal for a Regulation of the European Parliament and of the Council on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC, COM (2022), 677 Final.

[19]See European Commission. Proposal for a Regulation of the European Parliament and of the Council on circularity requirements for vehicle design and on management of end-of-life vehicles, amending Regulations (EU) 2018/858 and 2019/1020 and repealing Directives 2000/53/EC and 2005/64/EC, COM/2023/451 final.

[20]European Commission, Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (Text with EEA relevance).

recycled material or taxes on emissions in resource use. Market-based resource policies such as virgin material taxes that reflect material and energy efficiency are also options to move to the socially desired equilibrium. The price difference between new and used products also plays a role for recyclers and the low price for virgin plastic is a problem for reuse providers. Offering circular solutions must be profitable and attractive for their customers despite transaction or switching costs. Here, more supportive policies such as information provision could decrease the perceived switching costs.

Lastly, a policy package with a priority on reduction and reuse is needed. From the analysis of policy gaps thus far, it becomes obvious that there are much less policies that promote reuse compared to recycling. While there has been some progress in terms of repairability of products, other reuse policies such as deposit-return systems, reusable packaging, and repairability of more products are only slowly developing. Policy here could increase consumer acceptance. Looking to Germany, a law was introduced in 2023 that forces fast-food restaurants to offer reusable packaging.[21] While there seem to be some compliance problems according to our interviews, this law forces restaurants to re-evaluate and adjust their packaging options. Another policy that could help the uptake of reuse options is the plastic tax in the German city of Tübingen, which was introduced in 2022. As long as prices are sufficiently high so that consumers do not feel like they can pay for it to relieve their conscience without adjusting their behavior, this tax could increase demand for reusable options

5 Conclusion

Based on semi-structured interviews with 31 companies, this study contributes to existent literature with multi-dimensional perspectives of stakeholders across value chains of two distinct industries. In particular, it reveals a growing awareness of the CE reflected in the integration of CE principles into business strategies, with decision-making processes increasingly involving various functional departments. Compared to stakeholders in the plastics industry who explicitly phrase CE business strategies and are increasingly motivated by rising public awareness of global plastic pollution, CE is largely perceived as a way to achieve business climate neutrality goals by companies in the steel industry, who are primarily driven by customer demand in the downstream value chain.

[21] Restaurants that employ no more than five employees and are no larger than 80 square meters must provide reusable packaging such as reusable cups. Smaller restaurants must at least accept if consumers bring their own packaging (Umweltbundesamt, 2023).

Moreover, although the majority of interviewees agree on the crucial roles of product design for a successful industry-wide CE transition, opinions vary among stakeholder groups and industries. While recyclers and material-using producers focus more on product design (but not necessarily product regulations), material transparency along the value chain, and cost effectiveness of recycled materials, steel stakeholders and chemical companies emphasize the need for advancements in recycling technology. For reuse service providers, consumer acceptance and profitability of reused, repaired, refurbished, and remanufactured products are the top priorities for a successful transition.

Different opinions also exist in the identification of key challenges for a CE transition. While uncompetitive and volatile prices for recycled materials are a major challenge for both the plastics and steel industries, the lack of incentives for circular product design, slow and uncertain policy framework, and a policy bias toward recycling over reuse and reduction are more frequently highlighted in the plastics industry. In the steel industry, issues of scrap availability and quality, data reporting complexities, and uncertainty in technological development are more urgent.

In order to promote CE transition and address the challenges, more than 90% of interviewees believe mandatory regulations are necessary. Despite a consensus that producers should bear primary responsibility for the CE transition, preferences for specific regulations vary. Within the plastics industry, only 17% of material-using producers support product requirements, compared to 88% recyclers and 67% primary manufacturers. Plastic stakeholders also call for a clearer regulatory framework, aligning with their identification of its absence as a main challenge and their perception of the role of mandatory regulations in motivating cooperation across stakeholders in this industry. Furthermore, in contrast to other stakeholders, reuse service providers emphasize the regulations on information disclosure, consistent with their focus on consumer acceptance for circular products.

This study has several limitations that suggest the need for future research to deepen the understanding of stakeholder perspectives across industrial value chains. First, there is an urgent need for a shift in policy focus toward circular strategies beyond recycling that encourage value preservation at the product level and ultimately reduce transition costs. However, most companies interviewed still operate under linear business models, reflecting their incumbency and mature business structures. Future studies should include more diverse business models that utilize various CE strategies. Second, our sample has a geographical bias, predominantly comprising companies from northern and western EU countries (90%) with well-established technological infrastructure and legalized waste management systems. Future research should explore diverse contexts, as transitioning to a circular economy is crucial for addressing global environmental challenges.

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Appendices

A EU CE-relevant policies mentioned in interviews

		Production	**Recycling**	**Reuse**
Targeted	Both	Packaging and Packaging Waste Directive (94/62/EC), REACH Regulation (EC No 1907/2006), Ecodesign for Sustainable Products Regulation (EU 2024/1781), Internal market EU and eco design (EU 2021/690), EU climate neutrality law (EU 2021/1119)	Waste trade policy Regulation (EC 1418/2007, latest 2021/1840), Directive on landfill and waste (EU 2018/850), Directive on waste management (EU 2018/851), Industrial emissions (EU 2010/75)	Sale of goods, avoid planned obsolescence (EU 2019/770 and 2019/771)
	Plastics	Single use plastic Directive (2019/904)		
	Steel			3R Vehicles DIRECTIVE 2005/64/EC
Supportive	Both	Directive on CSR reporting (EU 2022/2464), Energy efficiency and CE principles (EU 2023/1791)	Just transition Fund	EU Taxonomy

B Roles of Interviewees in the Plastics and Steel Sectors

Stakeholder Group	Roles of Interviewees in the Plastics Sector	Roles of Interviewees in the Steel Sector
Primary Manufacturer	Global circular economy manager, Senior specialist on industry affairs and environmental policy, Sustainability policy and advocacy strategy director	Head of EU climate policy, Senior ESG manager, Business development director, Coordinator of transformative technology
Material-Using Producer	Head of corporate affairs, Managing director, Managing director of communication and sustainability, Senior manager recycling and sustainability, Project manager in sustainability and packaging, Head of global sustainability and circular economy, Sustainability manager	Programme manager sustainability
Recycler and Waste Manager	Managing director, Chief sustainability and external affairs officer, Purchase and sales manager, Group director sales division sorting and recycling, Manager strategy & business development, Department lead central customer service and sales, Project manager in sales and digitalization, Manager of strategy, digitalization and development	Business developer, Manager of marketing and communication, Sales engineer, Head of business development

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Table 8 – continued from previous page

Stakeholder Group	**Roles of Interviewees in the Plastics Sector**	**Roles of Interviewees in the Steel Sector**
Reuse Service Provider	Chief business development officer, Sustainability manager, Vice president of ESG, Head of sustainable solutions development, Business founder	Environmental officer