**MASTER THESIS**

# A Circular Business Model for Aluminium Suppliers: Drivers, Barriers and Enablers


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# Abstract

Our economic system has never moved beyond one fundamental characteristic established in industrialization: a linear resource consumption model. This linear model follows a 'take-make-disposal' pattern. Organizations extract raw materials, use labor and energy to produce and sell products to consumers. Consumers discard products when they no longer serve their purpose. The way our economy functions is by destroying the natural capital on which it depends.

The concept of a circular economy is an acknowledged solution for resource scarcity and waste production. The transition from a linear economy to a circular economy offers new opportunities. Therefore, new business models are required for organizational integration. The objective of this thesis was to offer insights into the drivers, barriers, and enablers experienced by a supplier in the Dutch building industry for adopting a circular business model for aluminium. Additionally, it sheds light on how the supplier can overcome these barriers in best-practice strategies.

First, a systematic literature review was conducted to select relevant literature. Second, an empirical study was conducted based on semi-structured interviews. The sample included 11 managerial and operational employees from the sub-supplier, supplier, and three construction companies to examine the factors from a supply chain perspective. These organizations have not yet integrated a circular business model, but include a vision to integrate sustainability in their organization. Consequently, the results from the literature review and empirical study have been compared on similarities and differences, and best-practice strategies were developed to overcome barriers and leverage enablers.

In this case, management commitment, employee involvement, awareness, and waste management were perceived as drivers. Market involvement, knowledge and competencies, intrinsic motivation, recycled aluminium quality, and its technological infrastructure hinder CBM development. Customer demand for recycled aluminium and product design indicated a dual perspective. Strategies for successfully overcoming these barriers and leverage enablers take into account: a process-wise business unit strategy, 2) stimulating awareness and knowledge to enable market involvement, 3) collaboration to integrate recycled aluminium and develop competencies, 4) education to enable customer demand, 5) product design for disassembly, and 6) management commitment and employee involvement to drive circularity.

This thesis has several limitations, owing to its broad nature. First, it was not possible to delve deeply into each individual factor. Second, the organizations from the sample are active in the Dutch and Belgian building industries, which is why the results for other companies and markets can be different. Hence, future research in different countries and industries, focusing on factorial, architectural, and end-client incorporation, would provide more substantial insights.


Keywords: circular economy, circular business model, drivers, barriers, enablers, strategies, metals, aluminium

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## List of abbreviations

| Concept | Abbreviation |
|---|---|
| Circular Economy | CE |
| Business Model | BM |
| Circular Business Model | CBM |
| Systematic Literature Review | SLR |
| Corporate Social Responsibility | CSR |
| Small-and Medium-sized Enterprise | SME |
| Construction and Demolition Waste | C&DW |

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# 1 Introduction

## 1.1 Problem statement

According to the United Nations (2021), buildings and construction constitute a significant share of global energy usage and energy-related CO2 emissions. In 2020, the estimated proportions were approximately 36% for energy usage and 37% for CO2 emissions. 11% of these emissions result from manufacturing building materials and products such as steel, cement, and glass. To achieve the Paris Agreement, the construction sector must be completely decarbonized. Simultaneously, the sector must meet a near-doubling global demand for energy services, and resource demand is rapidly increasing due to the industrialization of developing countries (European Commission, 2018; United Nations, 2021). The Dutch government has developed regulations and set objectives to realize a circular economy (CE) by 2050. While this may sound like a far-off vision, the first milestone is set for 2030, when primary resource usage must be reduced by 50% and all government tenders must be circular. This means that organizations must make a radical transition in a short timeframe from a traditional (linear) building and manufacturing model to a circular one (Mentink, 2014).

The division involved in this thesis is a Dutch supplier of aluminium products that is active in the building sector. This supplier modifies aluminium masonry profiles, sheet metal, sun blinds, balcony fences, and roof coverings, including service and maintenance, on behalf of construction companies (personal communication, February 2023). Primary mined aluminium from bauxite, which is currently applied, is known in the literature for consuming 2% of the world's energy for its production (Raabe et al., 2022). This is one of the factors that indicate that the division lags behind the integration of sustainability and circularity in its business model. How to integrate this into the division remains unclear and unfeasible. At the corporate level, the organization speaks about the feasibility of a circular business model (CBM) for aluminium to fill in this gap and perceives it as a possible solution for the delayed implementation of sustainability in this division. This contributes to an organizational vision in which creating economic value is balanced by ecological value. In addition, a CBM is perceived as having the potential to create a distinguished tender position, which can result in long-term economic benefits (personal communication, February 2023). Appendix A presents the company’s description.

This thesis can support organizations by retrieving insights into the drivers, barriers, and enablers influencing CBM integration and relevant best-practice strategies to overcome barriers and leverage enablers. This would enable them to make a substantiated and process-wise transition towards a CBM. This can contribute to an organizational vision in which creating economic value is balanced by ecological value. In addition, a CBM is perceived as having the potential to create a distinguished tender position, which can result in long-term economic benefits. This thesis investigates these factors from the perspectives of the sub-supplier, the supplier, and three different construction companies.

The thesis is structured as follows: subsection two covers the research questions, and subsection three involves a theoretical background, which attempts to create a basic understanding centered around the topic. In the second section, the methodology is discussed, including the research design, sample description, and description of the interview candidates. The third section describes the state-of-the-art perspective regarding drivers, barriers, and enablers of a CBM through a systematic literature review (SLR). The fourth section presents the results of semi-structured interviews. The final section discusses the findings, strategies, limitations, future research, and conclusions.

## 1.2 Research gap and research questions

Despite the acknowledged potential of CE, there remains a gap between awareness and actual behavior in organizations. Firms are aware of this concept, but most do not integrate it into their business ethics (Liu & Bai, 2014). This raises the question of why a CE is not widely applied in industry. One study showed that research still fails to provide a systematic view of the enablers and barriers to designing CBMs (Urbinati et al., 2021). In addition, there is still a lack of clarity about the theoretical conceptualization of the concept and its position in the economic and operations literature (Geissdoerfer et al., 2020). Previous research on value creation in CBMs remains relatively vague and lacks a system-level approach for presenting a comprehensive understanding of the interrelatedness and interdependencies of factors (Ünal et al., 2019). Once shifting towards the factors, several studies have identified drivers, barriers, and enablers that influence CBM adoption (Araujo Galvão et al., 2018; Bey et al., 2013; Guldmann & Huulgaard, 2020; Vermunt et al., 2019). More research on CBM adoption is necessary to explain these phenomena in more depth to support organizations effectively in implementing CBMs (Bocken et al., 2019). Several studies have indicated a scarcity of research concerning the CBM transition of incumbent organizations across sectors and the challenges experienced during implementation (De Pádua Pieroni et al., 2018; Franco, 2017).

This thesis responds to this gap by providing insights into the existing literature on drivers, barriers, and enablers faced by an incumbent firm. In addition, best-practice strategies to overcome barriers and leverage enablers have been added to the literature, which are only investigated in general and do not specifically consider internal processes, operational issues, or human perspectives (Chen, 2020). This thesis also differentiates itself by shedding light on the supply chain perspective by including the sub-supplier, the supplier, and three different construction companies.

The objective of this thesis is to engage companies in circular business development by investigating the drivers, barriers, and enablers they would face once they shift towards a CBM. Additionally, it would offer best-practice strategies to organizations to support them in overcoming barriers and leveraging enablers. Therefore, the research questions illustrated in table 1 were answered in this thesis. Appendix B presents a research planning.

*Table 1- Research questions*

| Research question | Data collection method | Outcome |
|---|---|---|
| What are the drivers, barriers, and enablers to a CBM for aluminium according to the state-of-the-art? | SLR | Provide a theoretical overview of drivers, barriers, and enablers |
| What are the drivers, barriers, and enablers to a CBM for aluminium in practice? | Semi-structured interviews | Provide an empirical overview of drivers, barriers, and enablers |
| What can we learn from this research by comparing the findings of the SLR with the results of the empirical study? | - | Provide an overview of the similarities and differences between the findings of the SLR and the empirical study |
| How can we solve barriers and leverage drivers and enablers? | - | Strategies on how to solve barriers and leverage enablers |

## 1.3 Theoretical background

This theoretical background provides theoretical insights about the basic concepts of CE, CBM, and its drivers, barriers and enablers. The objective is to offer a basic understanding about these concepts. Last, a theoretical model is defined based on the mentioned studies.

### 1.3.1 Circular economy

According to the Ellen MacArthur Foundation, the CE is a framework of systemic solutions to worldwide challenges such as climate change, waste, biodiversity loss, and pollution (The Ellen MacArthur Foundation, n.d.) The CE is a relatively new and inclusive paradigm that targets the minimization of waste and pollution, extends product life cycles, and enables a broad sharing of physical and natural assets. This concept strives for a competitive economy that creates sustainable and decent jobs while maintaining resource use within planetary boundaries (UNECE, 2023). Earth should be perceived as a desirable closed-loop system with limited assimilative capacity, where the economy and environment should coexist in equilibrium (Stahel, 2010).

Based on waste statistics, it can be stated that in 2020, 4.8 tons of waste was generated per EU inhabitant. Of this waste, 39.2% is recycled, while 31.3% is send to landfills (Eurostat, 2023). Our traditional economy takes a linear form, assuming that, at the end of the industrial system, there are unlimited resources, and the environment has an infinite capacity to absorb pollution and waste (Cooper, 1994). The linear economy is characterized by resource abundance, technological fixes, and modernization. However, to reduce the negative impact on the environment, it is important to take action beyond just understanding facts and processes. One such action is to stimulate a circular economy (Gutberlet, 2016).

“ *31.3% of European inhabitant’s waste in 2020 goes to the landfill’*”

From a historical perspective, sustainability has focused on the three Rs concepts of reduce, reuse, and recycle. Over time, this has evolved into six Rs (Sihvonen & Ritola, 2015) and even nine 9Rs: refuse, rethink, reduce, reuse, refurbish, remanufacture, repurpose, recycle, and recover. These 9Rs are integral to the concept of a circular economy (Kirchherr et al., 2017). Linear and circular waste management differ from one perspective. Linear waste management mainly focuses on minimizing collection and disposal costs (such as landfills versus recycling or incineration). In contrast, a circular economy aims to maximize the value at each stage of the product's life cycle (Stahel, 2018).

### 1.3.2 Circular business model

The literature offered a broad and varied understanding of a business model (BM) concepts. The concept is explained as a model of an organizational system (Baden-Fuller & Morgan, 2010). Another description is an abstract characteristic of an organizational unit (Osterwalder and Pigneur, 2010; Teece, 2010). Richardson (2011) offered a more actual and commonly used definition of a BM as an explanation of how a company does business and can be perceived as a blueprint of the underlying logic of a business. Their study divided the concepts into three basic components: (1) the value proposition, (2) the value creation and delivery system, and (3) the value capture system. Geissdorfer et al., (2018) added the interaction between these three described elements within an organizational unit. Since the organizational unit can be defined in several ways, it should be related to a firm's capabilities, resources, and strategies. The objective of a traditional linear business model is to create value for its actors in a take-use-dispose manner (Amit & Zott, 2010). The sustainability elements were not considered in this model. Figure 1 indicates the key elements of a BM.

When the concept of a sustainable business model was first conceived, the main objective was to put companies in a transformational stage to a more sustainable economic system and provide support for integrating sustainability considerations (Rashid et al., 2013). It should support organizations in achieving their sustainable ambitions (Stubbs & Cocklin, 2008; Wells & Seitz, 2005). Nowadays, a shift is occurring where a sustainable business model is increasingly seen as a source of competitive advantage (Nidomolu, 2009; Porter & Kramer, 2019). The definitions in the literature show similarities from the perspective of approaching a sustainable business model as a modification of the traditional business model. In this sustainable business model, certain characteristics and goals have been added that aim at sustainability or integrate sustainability into value proposition, value creation and delivery activities, and/or capture mechanisms (Geissdoerfer et al., 2018). A sustainable business model can be viewed as a middle-stage model between a traditional business model and a circular business model.

*" A sustainable business model can be seen as a middle-stage model between a traditional business model and circular business model "*

The objective of a circular business model is to achieve a harmonized balance between resource consumption and social development, which includes the environment and society as critical factors in social development (Stubbs & Cocklin, 2008). A CBM entails a broader understanding of stakeholders and business values. It allows to describe, analyze, manage and communicate (1) a company's sustainable value proposition to its customers, and all other stakeholders, (2) how it creates and delivers value and (3) how it captures economic value while maintaining or regenerating, naturally social and economic capital beyond organizational boundaries (Schaltegger et al., 2016). Figure 1 shows the key elements of a BM and CBM.

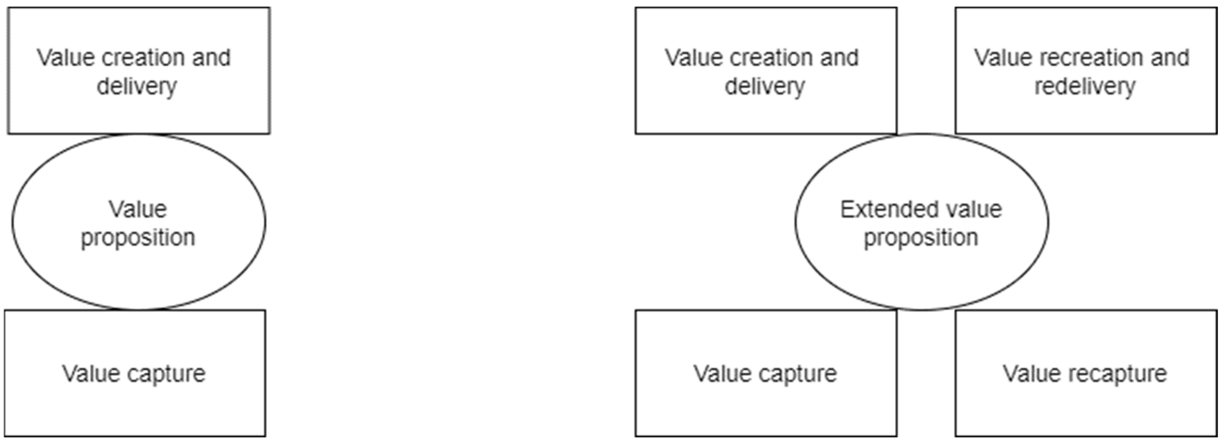
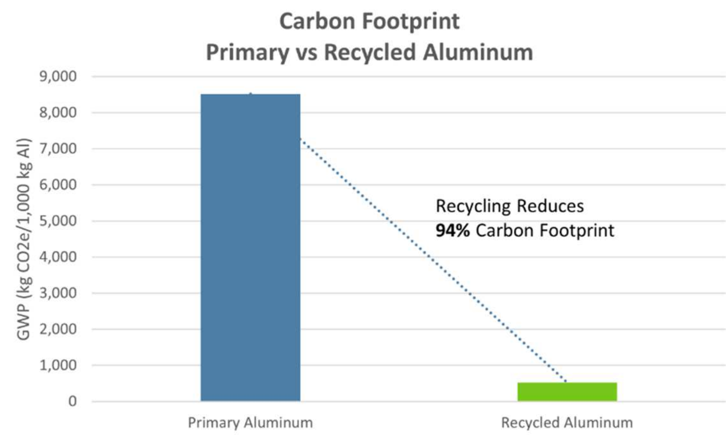



*Figure 1 - Key elements of a BM (left) (Richardson, 2011) and CBM (right) (Bocken. et al., 2016)*

The literature described a broad range of CBM understandings. Most of the definitions described by Geissdoerfer et al., (2020) included the elements of the value-creating framework of Richardson (2011) or the business model definition of Osterwalder and Pigneur (2010), in which a business model describes the rational law of how an organization creates, delivers, and captures value). Geissdoerfer et al., (2020) also translated the definitions into circular economy strategies. The transformation from a linear business model to a circular business model requires multiple holistic strategies, approaches, tools, and methods. A CBM is defined as how an organization creates, delivers, and captures value in a closed loop (Mentink, 2014). Transitioning towards a CBM requires the adoption of product design, supply chain design, enabling technologies, and infrastructure, which can be supported by circular strategies such as slowing, closing, and narrowing the resource loop (Bocken. et al., 2016).

A CBM can create various benefits for organizations. First, the extraction and primary input costs for resources are increasing as a result of continuous growth in resource demand (Trading Economics, 2023; World Economic Forum, 2014). The potential for higher efficiency in resource use, waste prevention, and waste management can help overcome the potential dangers of material and resource shortages (Johann Fellner et al., 2017). Second, climate change is another vital factor that can lead to an increasing number of natural disasters (climatic, meteorological, hydrological, and geophysical) that influence the demand, supply, trading prices, and energy needed for primary production (McKinsey & Company, 2020; Wzorek et al., 2017).

When light is shed on primary aluminium production, it globally consumes 2% of the world's energy, whereas recycled aluminium only requires approximately 5% of this consumed energy rate. This has the potential to develop more sustainable aluminium supply chains (Raabe et al., 2022). CBMs have the potential to decrease this uncertainty in the supply chain of primary materials and realize a tighter and more robust supply chain, with cooperation between organizations as the central point (Vermunt et al., 2019). In a CBM, organizations use fewer raw materials and an increasing rate of secondary materials (reused, remanufactured, recycled, etc.). This results in greater stability of the business model and a more stable situation for the company's long-run investments (Vermunt et al., 2019). In this case, stability is related to less dependency on cost fluctuations and the availability of primary mined resources. Figure 2 and 3 illustrate the differences in carbon footprint between primary aluminium and a recycled alternative, and the number of disruptive events in supply chains caused by climate change.



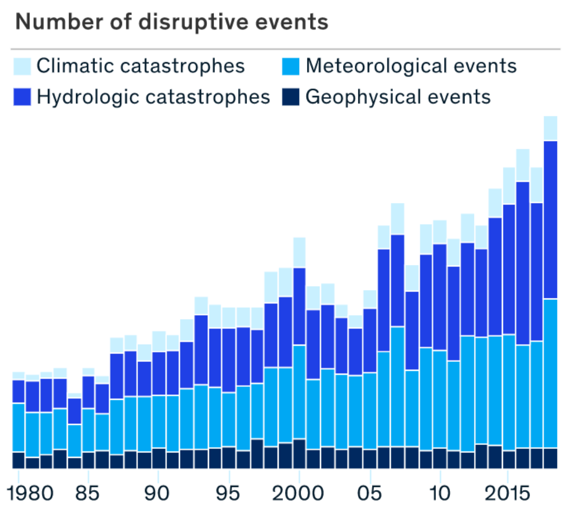




*Figure 2 & 3 – Carbon footprint of primary and recycled aluminium (Raabe et al., 2022) & Number of disruptive events in global supply chains (McKinsey & Company, 2020)*

### 1.3.3 Drivers, barriers and enablers for the aluminium industry

The following section describes the conceptualization of drivers, barriers and enablers. To make CBM implementation viable, it is vital to understand the drivers behind it (Govindan & Hasanagic, 2018). Stakeholders participate in circular economy ventures for various reasons, including seizing business opportunities, addressing environmental concerns, responding to stakeholder pressure, collaborating with others, improving business performance, and gaining access to limited resources (Abubakar, 2018; Gaur et al., 2019). Hina et al., (2022) categorized drivers as internal and external. Internal drivers are factors that force circular economy practices from the internal organization and can be classified as *organizational, resource availability and optimization, product design and process development, and financial drivers* (Hina et al., 2022). External drivers are factors that force circular economy practices from the external environment of the organization and can be classified as *policy and regulation, societal and environmental, supply chain, infrastructure, and stakeholder pressure* (Hina et al., 2022).

The circular transformation process can produce barriers that may delay or prevent the implementation of a circular business model. Scholars have identified different types of barriers, such as policy- or design-related barriers (Urbinati et al., 2021; van Keulen & Kirchherr, 2021). Generally, two types of barriers can be distinguished based on the most prevalent approaches in existing studies: internal and external (Bey et al., 2013; Chauhan et al., 2021). Internal barriers refer to the impediments that appear in the internal organization when attempting to implement a CBM (Vermunt et al., 2019). Hina et al., (2022), broadly categorized internal barriers into seven sub-categories: *a company's strategy and policies, financial barriers, technological barriers, lack of resources, collaboration, internal stakeholders and product design*. External barriers refer to the resistance, delay, or obstruction that arises in the implementation of a circular business model in the external environment of an organization (Vermunt et al., 2019). The literature has broadly categorized external barriers *as consumer, legislative and economic, supply chain, and cultural, social, and environmental* (Hina et al., 2022). Other barriers include *resource scarcity, the presence of regulations and laws, high speed of change in market requests, low returned product quality, low returned product quality, high investment cost, and low management risk appetite* (Urbinati et al., 2021). The main barrier is the *lack of awareness and willingness of clients* to participate in a circular economy (Kirchherr et al., 2018).

" *The main barrier is the lack of awareness and willingness to participate in a Circular Economy*"

Enablers can be identified as direct solutions for clearing existing barriers and creating favorable conditions for the CBM (Rizos et al., 2016). Urbinati et al., (2021) indicated the following enablers: availability of technical solutions for recycling practices, high price of input resources, high volatility of input resources' price, management environmental awareness, partner's availability for reverse supply chains, and geographical proximity of supply chain partners/customers (Urbinati et al., 2021).

The existing literature suggests various drivers, barriers, and enablers for adopting a CBM in organizations (Corral-Marfil et al., 2021; Hina et al., 2022; Kirchherr et al., 2018; Rizos et al., 2016; Stewart et al., 2018; Urbinati et al., 2021; van Keulen & Kirchherr, 2021; Vermunt et al., 2019). These factors can be translated into seven overlapping categories: *organizational strategy and policy, organizational behavior, financial, technological, product design, governmental policy, and customer demand*. The theoretical framework is illustrated in figure 4. Case specific barriers and enablers for the metallic industry are illustrated in appendix C and a comparison of all factors is illustrated in appendix D.

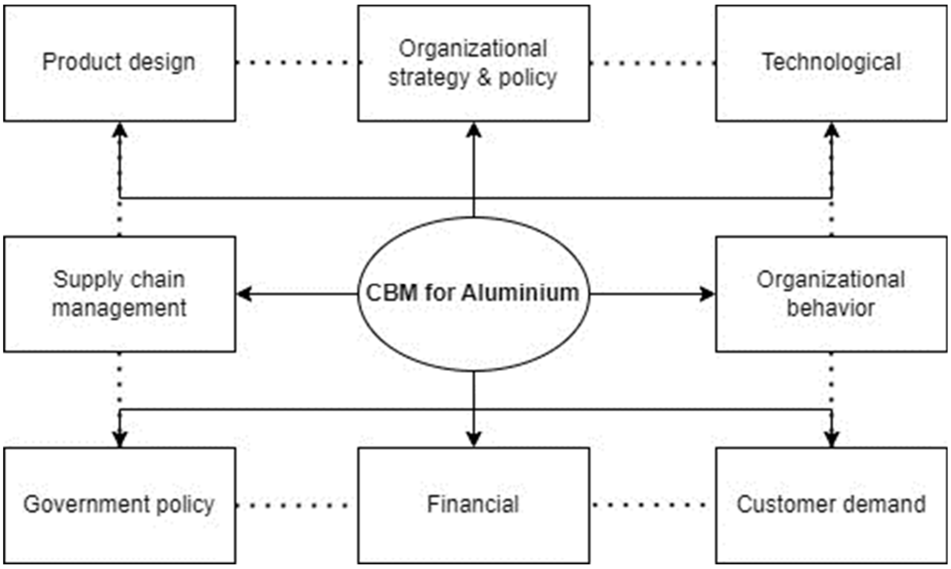



*Figure 4 – Theoretical framework*

# 2 Methodology

This first section outlines the research design for the SLR and the empirical study, detailing its procedures and building blocks. The second subsection delves into the sample selection. Specifically, it provides insights into the characteristics of the supply chain, companies involved, and candidates selected for the interviews. Finally, validity, reliability, and ethics will be discussed.

## 2.1 Research design

This thesis is designed to explore drivers, barriers and enablers to a CBM from the perspective of a sub-supplier, supplier and three construction companies. First, a SLR will provide an overview of the topic and drivers, barriers and enablers according to the state-of-the-art. This information formed the foundation for developing and verifying a theoretical model, including indicators. Then, interview guidelines were developed, interviews were conducted, and data were collected and analyzed. Finally, the identified drivers, barriers and enablers from the SLR and empirical study were compared in terms of their similarities and differences. This analysis attempted to also offered insights into why and how these factors influence CBM development. Thus, strategies have been formulated to overcome these barriers and leverage enablers for supplier. Figure 5 illustrates this process.

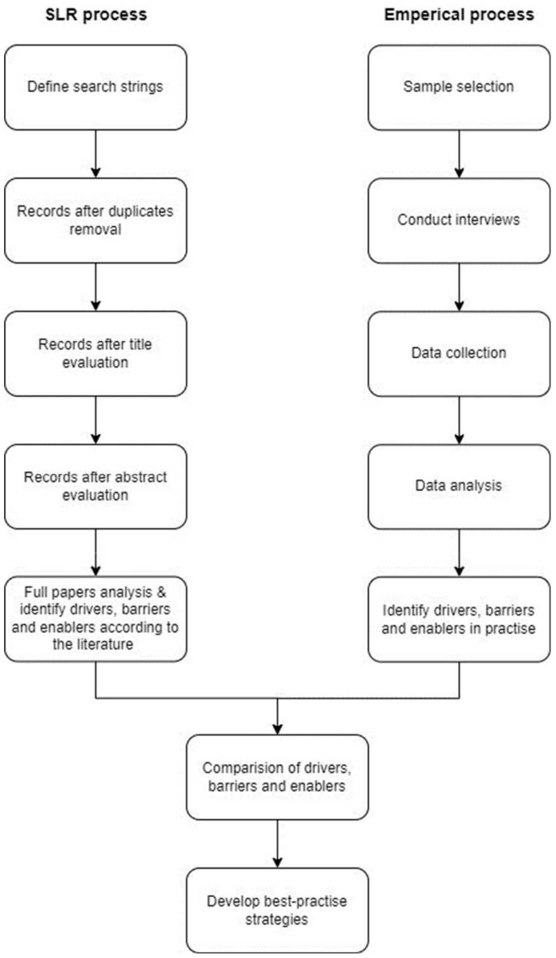



*Figure 5 – SLR and empirical study's process (Golev, 2015)*

The SLR is organized by developing search strings centred around the concepts of drivers, barriers, enablers, CBMs and aluminium. First, duplicates were removed owing to the use of two different online databases, which can generate similar articles. Records were then removed based on the relevance of the title and abstract. Finally, the remaining articles were categorized based on the theoretical model, and the drivers, barriers and enablers were identified. These steps were process-wise integrated using Microsoft Excel databases. This offers final insights into the drivers, barriers, enablers, and indicators for the theoretical model, according to the state-of-the-art.

The theoretical model was then translated into an empirical study. To develop the semi-structured interview questions, attention was paid to formulating questions as "open" as possible and structured (Hofmann & Jaeger-Erben, 2020). Overall, all interview questions were open-ended and formulated by own insights, because there are few comparable studies that have examined such a broad field of overarching and various factors. Therefore, these questions could not be retrieved from other articles. The interview guideline overarches different topics connected to the theoretical framework in the previous section. These topics include organizational strategy and policy, technological, organizational behavior, customer demand, financial, government policy, supply chain management, and product design. These factors were tested using two or three questions per factor. These questions are related to the indicators described in the previous section. The specific translation from factors to interview questions is illustrated in appendix E and the interview guideline is presented in appendix F. At all times, interview candidates were free to elaborate on the topics they perceived as important by combining practical examples to make answers more feasible (Geissdoerfer et al., 2018; Vermunt et al., 2019). The same standardized interview schedule is used for all interviews.

The sample selection has been organized through conversations with the CSR Manager, Director and Manager Aluminium from the supplier to identify and select appropriate interview candidates to be part of the study. Afterwards, interview candidates were contacted by email and phone calls. After agreeing to the appointments, interviews were conducted in person. Due to geographical distance, three interviews were conducted using Microsoft Teams. All the interviews were conducted. Subsequently, a transcription protocol for every interview was conducted based on the recordings.

This approach supported the identification of drivers, barriers, and enablers for CBM implementation in the supply chain and related the outcomes to those in the SLR (Rizos et al., 2016). In most studies, strategies to overcome these barriers have mostly been disregarded. Therefore, this thesis also focused on developing best-practice strategies for overcoming barriers and leveraging enablers based on the results. Additionally, this thesis also includes the uncovered human aspect, which is categorized as a factor in organizational behavior.

## 2.2 Sample analysis of selected organizations

The interview candidates and organizations were selected as part of the sample because they have an active role in the supply chain, from manufacturing and modifying sheets to integration in residual and non-residual building projects. The supplier's organization started by executing their sustainability initiatives and wanted to cover and include their aluminium department from a holistic perspective, but did not directly know how. The multiple-case perspective differentiates this study by including five organizations that are active in the construction industry. The range of investigated circular aspects is wide, from the organizations' strategic vision to technologies embracing more sustainable products, employee awareness, intrinsic motivation or customer behavior, and demand for recycled aluminium alternatives. To realize CBM change, organizations need to create new means not only for their value proposition, but also for value creation, delivery, and value capture.

Overall, the three organizations consider themselves to be in the initial phase of integrating circularity. Comparing their current positions in this long-term change process is difficult because of their varying core business activities, culture, and environmental aspects. The sub-supplier is classified as just started because its sustainability manager has begun a few months, but the organization has, in contrast, a mature business unit for aluminium recycling (sub-supplier). The supplier already integrates circular initiatives, but the aluminium division is falling behind. Construction companies mentioned that it was not enough to embrace circularity in their core businesses. Overall, all organizations described to be in a constant revision phase still had many goals to be achieved for integrating CBMs.

The sector covered in this sample is the business-to-business (B2B) market in the construction sector. To describe the supply chain, the sub-supplier manufactured alumimium sheets. The supplier modified the sheets, developed aluminium products, and integrated them into new or existing building projects for the construction company. In this case, the construction company was a customer. All organizations that participated in this study wanted to include sustainability or circularity in their business model, but integration in core business is limited. In the long run, organizations want to know how to adapt to their core business and the drivers, barriers, and enablers they face in this transition. Their goal is to reduce the negative impact on the planet and its people over the long term. The supplier stated that profit should be generated in an acceptable manner, but the focus should not be on profit maximization (Stubbs, 2016).

Interview candidates were selected based on their position in the company and knowledge of the topic through conversations with the Director, CSR Manager, and Manager Aluminium. Overall, organizations can be characterized as medium-sized (sub-supplier and supplier) and large-sized (construction companies A,B, and C) (CBS, 2023). The foundation years varied from 1937 (sub-supplier) and 1991 (supplier) to 1998, 1947, and 1911 (construction companies). Medium-sized companies are generally more flexible and responsive, and play a leading role in driving the circular economy (Cantore & Mazzanti, 2023). Table 2 provides information about the sample.

*Table 2 - Sample analysis*

| Company | Size | CBM phase | Foundation year | Interview candidate |
|---|---|---|---|---|
| Sub-supplier | Medium-size | Introductory | 1937 | Sustainability Manager |
| Sub-supplier | Medium-size | Introductory | 1937 | Recyling Manager |
| Sub-supplier | Medium-size | Introductory | 1937 | Account Manager |
| Supplier | Medium-size | Introductory | 1991 | Shareholder |
| Supplier | Medium-size | Introductory | 1991 | Director |
| Supplier | Medium-size | Introductory | 1991 | Department Manager Aluminium |
| Supplier | Medium-size | Introductory | 1991 | Coordinator Logistics Aluminium |
| Supplier | Medium-size | Introductory | 1991 | CSR Manager |
| Construction company A | Large-size | Introductory | 1998 | Sr. Supply Chain Manager |
| Construction company B | Large-size | Introductory | 1947 | Planner |
| Construction company C | Large-size | Introductory | 1911 | Purchaser |

## 2.3 Description of interview respondents

Overall, the interview respondents were selected based on their position in the organization, knowledge of CBMs, and sustainability (Hofmann & Jaeger-Erben, 2020). Eleven of the registered persons were male, and one was female. There was no preference for age or gender. Regarding the sample, three respondents were from Belgium and ten respondents were Dutch. The sub-supplier is located in Belgium, while the supplier and construction companies are located in the Netherlands. During this study, the interview respondents were asked about all the factors mentioned in the theoretical model and were given space to give one topic more input than the other. In this matter, certain factors were mentioned more frequently by respondents than others were. By applying this approach, valuable insights into drivers, barriers, and enablers to a CBM can be obtained. This would make the transition towards a CBM more transparent.

## 2.4 Reliability, validity and ethics

This study applied strategies to reduce the risk of validity issues. The researcher applied theory triangulation through a comparison of different theories and perspectives from different fields with the own developed theory. The theoretical model of this study was developed through a systematic literature analysis. This approach supported the researcher in obtaining a broad and comprehensive perspective of the phenomena (Robson, 2002).

Member checking is another approach for reducing threats from validity issues. Member checking refers to emerging findings with research participants to increase their validity (Robson, 2002). Practically, this approach can be applied by contacting participants to verify specific interpretations. Specifically, during the semi-structured interviews, the researcher constantly summarized the answers given by the participants to ensure that the answers were interpreted correctly. Once necessary, the researcher contacted the participant to briefly discuss uncertainties in interpretation issues (Robson, 2002). Peer debriefing is another important approach that is applied by discussing specific research phases with universities, company supervisors, and other students.

The interview participants were informed to comply with the ethical and legal requirements for this study. In this process, the participants were informed beforehand about all aspects of the research to enable them to make an informed decision to participate in the study (University of Twente, 2022). All interview participants were informed of their rights, study purpose, benefits, risks, and voluntary participation. An ethical form was sent to the interview participant approximately to 3-5 days before the interview, and the signed version was sent back before the actual interview. Before conducting the interview, the researcher described the importance of the form and asked the candidate whether there were still questions or uncertainties regarding the form to ensure that the process was sufficiently walked through. Ethical approval for this study was obtained from the University of Twente.

# 3 Systematic literature review

This section describes the SLR methodology, which is a scientific approach to evaluating existing information (Caldera et al., 2020). The first subsection contains information on the search strategy, including the applied search strings. The second subsection describes the search process using the information flowchart for selecting relevant articles. Further, it systematically describes the theoretical findings categorized in the substantiated factors of the theoretical model.

- *What are the drivers, barriers and enablers to a CBM for aluminium according to the state-of-the-art?*

## 3.1 Search strategy and selection

The SLR involved an examination of papers that addressed drivers, barriers, and enablers of a CBM for aluminium. These papers were sourced from two different online databases, Web of Science and Scopus. The use of these two databases was decided to ensure a more comprehensive coverage of articles, reduce bias, and enhance the overall quality of the systematic literature search. To enable the search process, the research question was divided into individual facets. These facets were then translated into search strings. The facets considered in this study encompassed drivers, barriers, enablers, circular business models, and aluminium. Notably, the construction industry was not included as a separate facet of this analysis. This decision was made to avoid limiting the search results to construction-related papers without considering other industries. This approach also accounts for concepts, such as supplier and geographical locations. Figure 6 illustrates the research question including the facets.

| |
|---|
| *"What are the **drivers**, **barriers** and **enablers** to a **circular business model** for **aluminium** at a supplier for the construction industry in the Netherlands?"* |

*Figure 6 – Translation of research question to individual facets*

Individual facets can also be adapted for use in different contexts by incorporating alternative spellings, such as synonyms. Consequently, the search strings included common terms used in the OR function. The first search string was specifically focused on and limited to circular practices for aluminium, while the second string broadens the scope to include metals in general. The decision to include two search strings was based on the limited results found in the aluminium search string. Therefore, both articles aimed to strengthen the body of the theoretical model. Table 3 & 4 illustrate these search strings. Appendix G illustrates more extensive tables describing the search strings.

*Table 3 - Search string 1: Aluminium*

| Database | Search string |
|---|---|
| **Scopus** | (TITLE-ABS-KEY(driver*) OR TITLE-ABS-KEY(challenge*) OR TITLE-ABS-KEY(barrier*) OR TITLE-ABS-KEY (facilitator*) OR TITLE-ABS-KEY(enabler*) ) AND (TITLE-ABS-KEY("circular business model") OR TITLE-ABS-KEY("circular economy business model") OR TITLE-ABS-KEY("circular economy") OR TITLE-ABS-KEY(circularity*) ) AND ( TITLE-ABS-KEY(aluminium*) OR TITLE-ABS-KEY(aluminum*) ) |
| **Web of Science** | (TS = (driver* OR challenge* OR barrier* OR facilitator* OR enabler* )) AND (TS = ( "circular business model" OR "circular economy business model" OR "circular economy" OR circularity* ) ) AND (TS= ( aluminium* OR aluminum* )) |

*Table 4 - Search string 2: Metal*

| Database | Search string |
|---|---|
| **Scopus** | (TITLE-ABS-KEY(driver*) OR TITLE-ABS-KEY(challenge*) OR TITLE-ABS-KEY(barrier*) OR TITLE-ABS-KEY (facilitator*) OR TITLE-ABS-KEY(enabler*) ) AND (TITLE-ABS-KEY("circular business model") OR TITLE-ABS-KEY("circular economy business model") OR TITLE-ABS-KEY("circular economy") OR TITLE-ABS-KEY(circularity*) ) AND ( TITLE-ABS-KEY(metal*)) |
| **Web of Science** | (TS = (driver* OR challenge* OR barrier* OR facilitator* OR enabler* )) AND ( TS = ( "circular business model" OR "circular economy business model" OR "circular economy" OR circularity* ) ) AND ( TS= (metal*)) |

## 3.2 Search process

The search process also included specific criteria for the selection of articles organized in an information flowchart (Prisma, 2021). This flowchart consists of four distinct phases.

1- Identification
2- Screening
3- Eligibility
4- Included

The first phase involved the identification of the results from Web of Science and Scopus, resulting in a total number of identified articles. Secondly, various articles were removed after carefully checking for duplicates. In the third phase (eligibility), the articles were chosen and assessed based on their titles. Abstracts of the selected articles were evaluated for relevance. In the final phase, full papers were reviewed for relevance. This systematic approach was applied to both search strings, yielding a final count of 23 articles (eight from the first search string and 15 from the second search string).

The 23 articles were analyzed entirely to identify which factor of the theoretical model was related to the described findings and which drivers, barriers, and enablers were found. Additionally, aspects such as the data collection method, limitations, conclusions, and the role of studies within the supply chain were addressed. The articles have also been summarized to better understand this case. This information was process-wisely addressed and documented in an Excel document.

In addition, two articles were added to the list because they delved into factors in greater depth. The first article, authored by von Kolpinski et al., (2022), explored the impact of internal company dynamics on circular business development. The second article, by Bhattacharya (2016), focused on the engagement of employees in the creation of a sustainable business. This resulted in a total of 25 articles. Figure 7 shows an information flow chart.

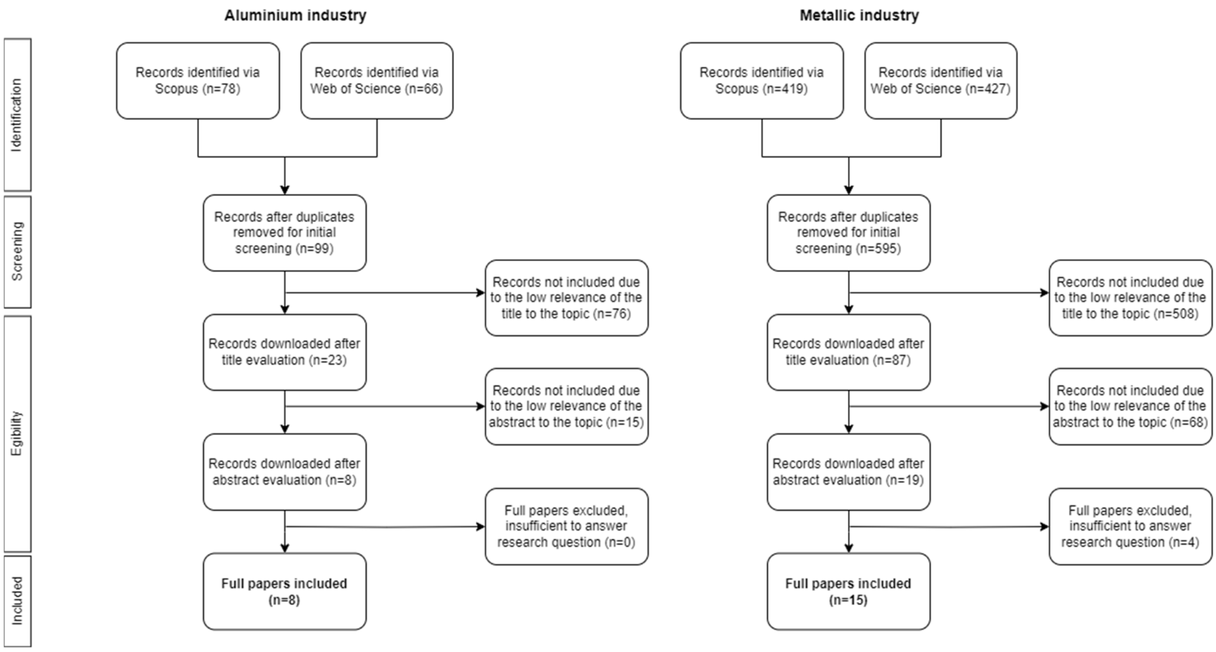



*Figure 7 - Information flowchart through the phases of a SLR (Prisma, 2021)*

### 3.2.1 Theoretical results

The 26 articles provide essential information that helps create an understanding of how the factors in the theoretical model are conceptualized and perceived in line with the latest research. The next section delves into the interpretation of these factors to examine their role as drivers, barriers, or enablers. Finally, a theoretical model is presented that incorporates this vital information into its indicators. Appendix H illustrates a list and summarization of the articles.

### Organizational strategy and policy

A company's strategy and policy directly affect CBM development by playing an enhancing or hindering role (Chiappetta Jabbour et al., 2020). The first company investigated by Chiappeta Jabbour et al., (2020) described a company's core business adoption towards sustainability trends to remain competitive as a key driver. Involving other organizational areas and companies in the supply chain to support this strategic circular transition is defined as a barrier. This is a challenge because of low customer awareness of the reverse logistics system and its sustainable benefits (Caldera et al., 2020; Chiappetta Jabbour et al., 2020; Orji, 2019). Low customer awareness negatively affects the development of organizations' environmental values, competencies, and resources to support CBM integration, which is defined as a barrier (Orji, 2019).

Another investigated company confirmed that limited knowledge and experience in CBM transition and the necessary competencies are barriers (Chiappetta Jabbour et al., 2020). This can be reduced by information sharing and individual and organizational transparency (Neves et al., 2019). Management commitment to sharing environmental values and concerns about the firm's potential impact stimulated awareness and, consequently, competencies to make this transition more feasible, in which a worker's training on sustainable performance is vital (Chiappetta Jabbour et al., 2020; Orji, 2019; Torres-Guevara et al., 2021). Torres-Guevara et al., (2021) described that employees with higher environmental awareness or green teams should have a primary role in informing the management of sustainability, which is defined as a driver. Both organizations relied on core business adaptation and, more specifically, product portfolio development as a key factor for embracing circularity.

Monitoring products has significant potential to unlock circular opportunities for organizations (Chiappetta Jabbour et al., 2020). An increasing number of sustainable suppliers have stimulated organizational change towards core business adaptation (Chiappinelli et al., 2021), but this is considered as skeptical (Fragapane et al., 2022). Organizations have a culture that does not contain saving resources or optimal usage (Caldera et al., 2020; Fragapane et al., 2022). From a cultural perspective, an organization should think and act holistically instead of acting as a silo to prevent a cultural mismatch in sustainable collaboration (Berlin et al., 2022).

The metallic industry is characterized by common waste streams of materials (Neves et al., 2019). Waste exchange in this industry is typically hindered by limited trust between organizations, uncertainty of benefits, and limited knowledge of other organizations. Existing cases mentioned that limited information sharing hinders waste exchange initiatives and collaboration processes (Berlin et al., 2022; Neves et al., 2019). Additionally, factors such as sharing expertise, consultancy, equipment, logistics, energy, and water infrastructure are potential CBM drivers.

### Technological

The integration of the latest technology and its access forms barriers for first-mover firms in CBM integration (Chiappetta Jabbour et al., 2020; Neves et al., 2019; Orji, 2019). The low maturity of $CO_2$ technologies and their risk bring challenges towards embracing circularity. These technologies are not commercially proven and can create longer operational shutdowns and increase operational costs (Oberthür et al., 2021). In particular, there is a lack of infrastructure for hydrogen, $CO_2$, and energy to be applied in the aluminium production process (Chiappinelli et al., 2021). Non-adapted reverse logistics infrastructure forms a barrier to CBM integration (Stewart et al., 2016). Setting up this collective infrastructure and EoL collection at a vertical level drives CBM integration (Hool et al., 2022). Additional, there is an absence of treatment facilities for waste recycling (Caldera et al., 2020).

These organizations also mentioned that introducing the use of recycled materials in the production process forms a hindering factor (Chiappetta Jabbour et al., 2020; Neves et al., 2019; Orji, 2019). Public support is needed for the integration of enhanced technologies and the stimulation of demand for recycled and clean materials (Chiappinelli et al., 2021). Currently, recycled products experience challenges in terms of quantity and quality owing to the fluctuating supply of waste and contaminated materials (Caldera et al., 2020). Contaminated materials require separation at the EoL, which reduces recycling efficiency (Soo et al., 2019).

Aluminium products in the building industry are typically characterized by a long product life, which has a significant effect on the feedstock of raw materials to meet the product market demand. This causes the product recovery system to become unstable owing to the uncertainty in scrap availability (Soo et al., 2019). Other factors hindering circularity for aluminium are location, the temporal availability and accessibility of recycled materials (Stewart et al., 2016; Winterstetter et al., 2021). Berlin et al., (2022) verified that long-term collaboration in the scrap market arises from the complexity of exchange due to variations in quality and quantity. Managers in the metal sector have reported that the collection and separation of metal scrap is exported to Asia, America, or other European countries (Abarca-Guerrero et al., 2022). The use of digital programs and platforms is considered to enable this transition (Neves et al., 2019).

### Organization behavior

Organizations that exchanged waste mentioned that they experienced limited trust and knowledge in the collaborative process between organizations. Stakeholder behavior does not include openness and willingness to establish this collaboration (Berlin et al., 2022; Neves et al., 2019). On the other hand, personal motivation and inner drive are both identified as key drivers in organizations that apply CBM (von Kolpinski et al., 2022). In the construction sector, company directors have limited awareness and knowledge related to managing construction and demolition waste (C&DW). This describes a culture that includes aspects of saving resources and/or their optimum use (Abarca-Guerrero et al., 2022; Caldera et al., 2020; Orji, 2019). By contrast, Fragapana et al., (2022) mentioned that an organizational culture shift should occur by focusing on solving problems and creating solutions from a production-centric and human perspective to a more environmentally-centric approach. The conservative nature of the construction sector keeps old habits and ways of thinking active and lacks holistic action, which hinders CBM integration (Fragapane et al., 2022). In addition, involving employees and business units to address environmental challenges gives employees a higher purpose in their work and drives sustainable change (Bhattacharya, 2016).

### Customer demand

Consumers generally lack consciousness regarding this reverse logistics system and on sustainability benefits (Chiappetta Jabbour et al., 2020). Organizations did not sufficiently involve the market and retail to properly integrate reverse logistics in their supply chain. An investigated organization described customer demand is one of the main drivers to integrate such a reverse logistics system (Chiappetta Jabbour et al., 2020). The demand for recycled products is depending on the social acceptance of recycled materials (Dominish et al., 2018).

Currently do markets for such recycled products not experience economies of scale, but due to growing markets this will change (Hool et al., 2022). The study described various success factors for improving circularity and one of these is an improved relationship between the product supplier and product user, which stimulates long-term contacts (Hool et al., 2022). In terms of consumer value, an organization generated a green branding image from integration a CBM. Where a closer relationship between organizations and customers exists, organizations become more dependent on customer behavior for recycling (Stewart et al., 2016). Once purely looking into customer demand did the study by Chiappinelli et al., (2021) mentioned that there is a lack of demand for recycled materials. The study stated that the effectiveness of the recycling system influences consumers awareness. Complex products, such as those in the building industry, are associated with a lower level of customer awareness (Soo et al., 2019).

## Financial

The recovery of anthropogenic resources is influenced by their economic viability as they are perceived to be more expensive (Hool et al., 2022; Torres-Guevara et al., 2021; Winterstetter et al., 2021). This implies that shifting from primary raw materials to recycled alternatives could result in increased costs. Transportation costs are reduced by organizations that share their resources (Torres-Guevara et al., 2021), and waste disposal costs have the potential to be reduced (Neves et al., 2019). Low waste disposal costs and funds for introducing circularity hinder CBM integration, which is influenced by governmental activities (Neves et al., 2019). This makes sending waste to landfills economically more attractive than recycling (Abarca-Guerrero et al., 2022). Organizations that exchanged waste experienced further benefits by saving resources, reducing inefficiencies, and creating jobs. In contrast, the competition between cheap and imported materials forms a significant barrier to replacing primary materials with waste alternatives (Dominish et al., 2018). Abarco-Guerrero (2022) explained that recycled products have low international prices, but few companies determined the price and bought these materials. The limited market for recycled products directly affects their prices for recycled products (Caldera et al., 2020). Additionally, the banking sector provides limited accessibility for green investment coverage to support C&DW management (Abarca-Guerrero et al., 2022).

Orji (2019) ranked providing insufficient budgetary allocation for investment in sustainable investment as a factor causing the highest impact on organizational change in sustainability. Investments and investigations into more sustainable aluminium alloys, treatments, and processes are accompanied by financial and time risks (Fragapane et al., 2022). Realizing the transition towards a CBM for aluminium requires business model investments and financial gains that impact the circular strategy (Stewart et al., 2016). These investments were characterized by long-cycles (10-30 years) and revealed high costs for fixed assets (Oberthür et al., 2021), but this varies per industry. Successful CBM integration has been realized in the beverage industry, which is characterized by a high turnover rate. This is in contrast with industries that use complex materials, such as the building industry, which has a slower turnover rate. The high economic value of aluminum should stimulate the turnover rate and increase the reliability of the collection system (Soo et al., 2019).

## Government policy

There is often an absence of regulations and supportive measures to create a level playing environment for recyclers (Horizon, 2016). This hinders the efficient collection and recovery of various waste streams. Another negative side effect of regulations is the administrative burden, which negatively impacts the marketability of recycled materials (Johansson et al., 2017). Governments can set requirements to make disposal alternatives more expensive than recycled products (Caldera et al., 2020; J. Fellner et al., 2015). In contrast, Neves et al., (2019) mentioned that existing policies and legislation for exchanging waste drive circular change. In contrast, the opposite effect has been observed in the aluminium beverage cans industry (Stewart et al., 2016).

Landfill tax and regulatory pressure were defined as drivers or barriers depending on the case. In contrast, the study described a lack of funds for promotion within regulatory frameworks (Neves et al., 2019). Governments have limited initiatives to implement the efficient usage of treatment places and their materials, which are defined as hindering factors (Abarca-Guerrero et al., 2022; Caldera et al., 2020). Legislation and policies should be clear, consistent, and bureaucratic to facilitate the waste exchange. The government also plays a role in stimulating the creation of infrastructure and supporting the accessibility of technological equipment. The enabling factors range from increasing the targeting of the design stage in policies and more sustainable design to more stringent legislative measures and fiscal policies (Caldera et al., 2020). Orji (2019) described government regulations and effective legislation as driving factors of organizational change for sustainability. Export taxes also influence the accessibility of materials and strong price swings. This results in higher product prices.

### Supply chain management

Berlin et al., (2022) described factors such as external knowledge, information sharing, and organizational support as important drivers of circular supply chain collaboration. A corporate culture mismatch between internal and external organizational cultures (old habits and ways of thinking), lack of alignment, and power imbalance are mentioned as barriers in this case (Berlin et al., 2022; Stewart et al., 2018). In the supply chain, organizations should act more holistically than silo thinking. Long-term collaboration is important because of the complexity and heterogeneity of exchange due to variations in quality and quantity (Berlin et al., 2022; Stewart et al., 2018). In addition to collaboration, there is a need to investigate new aluminium alloys, treatments, and processes to integrate sustainability. Enablers are the co-development of ideas for prototyping and testing. 3D visualization between project leaders, designers, and workshops. A major barrier was the reluctant industrial culture and industrial standards, which were mainly fixed (Fragapane et al., 2022). Parallel was the creation of awareness in value creation, which is vital for decision-making to integrate a more environmentally-centric approach (Fragapane et al., 2022). Geographical proximity is perceived as a driver or barrier depending on the case (Neves et al., 2019). Additionally, organizations experience challenges in information-sharing, lack of trust, and uncertainty in profitability. Another simplified challenge is the lack of openness and willingness of organizations to collaborate (Neves et al., 2019).

*"Single companies can not establish circular systems on their own"*

### Product design

Dominish et al., (2018) indicated that limited standardization in the design of current products results in incompatibility for reuse in the same application. A new design makes components incompatible or the technology becomes obsolete. Products are also degraded or corroded from previous usage and have different structural qualities (Caldera et al., 2020). Limitations in shareability and serviceability have resulted in the use of metals in lower-grade applications (Dominish et al., 2018). A study by Chiappinelli et al., (2021) indicated that the recycling of aluminium is limited due to the purity of scrap. This means that sectors use different aluminium alloys, which reduces the standardization and recycling efficiency (Soo et al., 2019).

## 3.3 Interpretation of theoretical results

This section presents a theoretical model that incorporates indicators. This model includes the same eight factors as presented in the theoretical background (section 1.3), but distinguishes itself by the defined indicators based on the literature. These indicators were chosen because they were the most mentioned in the articles. Appendix I lists the concepts mentioned for the indicator development. Throughout the SLR, it became evident that organizational strategy and policy can be substantiated by *market involvement, knowledge and competencies, sustainability strategy, and management involvement*. Technological factors can be substantiated by quality and composition of recycled aluminium, the *technical infrastructure for waste management and for recycled aluminium*. Organizational behavior includes *employee awareness, intrinsic motivation, and employee involvement* as measurable indicators. Customer demand is distinguished by *behavioral attitude and the demand for recycled aluminium*. Financial factors include *market and economic uncertainty, economic costs, and supportive measures*. Once shifting towards government policy, the factor contained *regulations and interventions* as the main indicators. Supply chain management is measured by *collaboration between companies, material sourcing, and recycling*. Finally, product design has one distinguishing indicator: *technical and functional design*. The dotted lines indicate that the underlying factors could affect each other. Figure 8 illustrates the theoretical model incorporated with the indicators.

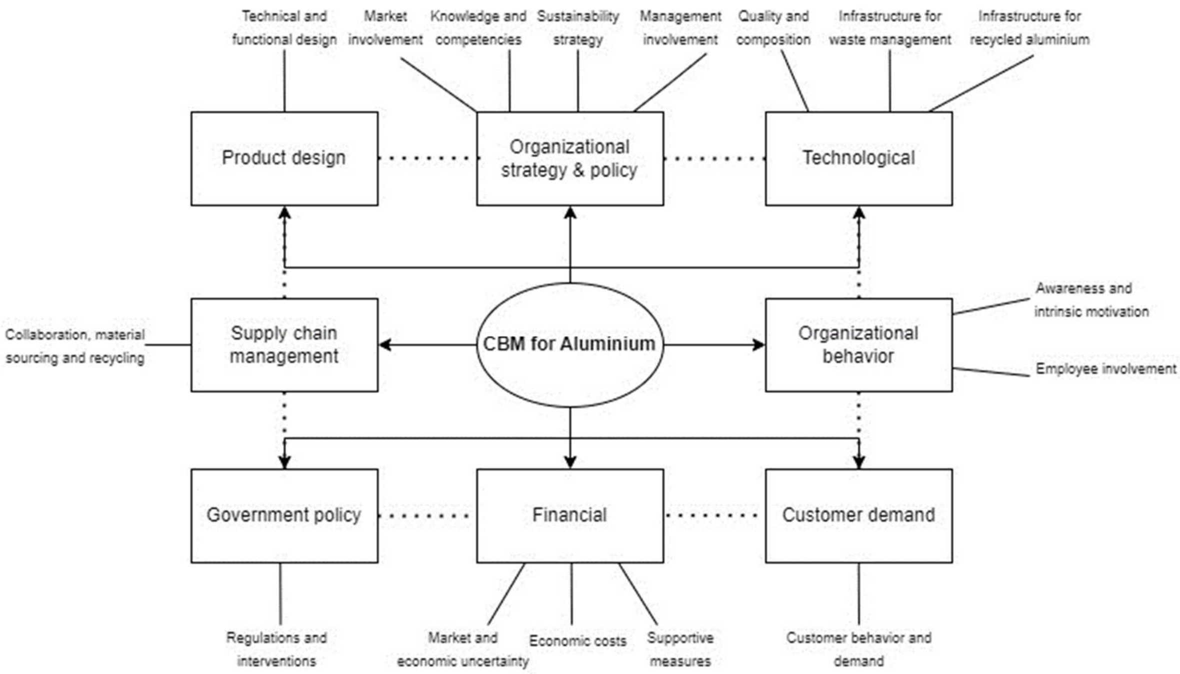



*Figure 8 - Theoretical framework incorporated by indicators*

This makes it possible to answer the first research question:

- *What are the drivers, barriers and enablers to a CBM for aluminium according to the state-of-the-art?*

Table 5 illustrates the drivers, barriers and enablers to a CBM for aluminium according to the state-of-the-art.

*Table 5 - Overview of drivers, barriers and enablers according to the state-of-the-art*

| **Factor** | **Indicator** | **Role** | **Article** |
|---|---|---|---|
| **Organizational strategy and policy** | Market involvement | Barrier | (Chiappetta Jabbour et al., 2020) |
| | Knowledge and competencies | Enabler or Barrier | (Chiappetta Jabbour et al., 2020; Neves et al., 2019; Orji, 2019; von Kolpinski et al., 2022) |
| | Sustainability strategy | Barrier | (Orji, 2019) |
| | Management commitment | Driver or Barrier | (Orji, 2019; Torres-Guevara et al., 2021; von Kolpinski et al., 2022) |
| **Technological** | Quality and composition | Barrier | (Abarca-Guerrero et al., 2022; Chiappetta Jabbour et al., 2020; Neves et al., 2019; Stewart et al., 2016) |
| | Waste management | Driver or Barrier | (Caldera et al., 2020; Chiappetta Jabbour et al., 2020; Neves et al., 2019; Stewart et al., 2016) |
| | Technological infrastructure | Barrier or Enabler | (Chiappetta Jabbour et al., 2020; Neves et al., 2019; Orji, 2019; Stewart et al., 2016) |
| **Organizational behavior** | Awareness | Barrier | (Abarca-Guerrero et al., 2022; Caldera et al., 2020; Chiappetta Jabbour et al., 2020; Orji, 2019) |
| | Intrinsic motivation | Driver | (von Kolpinski et al., 2022) |
| | Employee involvement | Barrier | (Bhattacharya, 2016; Caldera et al., 2020; Chiappetta Jabbour et al., 2020) |
| **Customer demand** | Customer behavior and demand | Driver or Barrier | (Abarca-Guerrero et al., 2022; Caldera et al., 2020; Chiappetta Jabbour et al., 2020; Dominish et al., 2018; Orji, 2019; Soo et al., 2019) |
| **Financial** | Market and economic uncertainty | Barrier | (Abarca-Guerrero et al., 2022; Caldera et al., 2020; Stewart et al., 2016) |
| | Economic costs | Barrier | (Abarca-Guerrero et al., 2022; Caldera et al., 2020; Stewart et al., 2016) |
| | Supportive measures | Driver or Barrier | (Orji, 2019) |
| **Government policy** | Regulations and interventions | Driver, Barrier or Enabler | (Abarca-Guerrero et al., 2022; Caldera et al., 2020; Neves et al., 2019; Orji, 2019; Stewart et al., 2016) |
| **Supply chain management** | Collaboration, material sourcing and recycling | Driver, Barrier or Enabler | (Berlin et al., 2022; Fragapane et al., 2022; Neves et al., 2019; Stewart et al., 2016) |
| **Product design** | Technical and functional design | Driver or Barrier | (Chiappetta Jabbour et al., 2020; Dominish et al., 2018; Soo et al., 2019) |

# 4 Results

This section presents the results of the interviews, focusing on how the respondents individually perceived the various factors. The organization of this presentation is based on questions related to the following aspects of CBMs:

1. Organizational strategy and policy
2. Technological
3. Organizational behavior
4. Customer demand
5. Product design

The extent to which the indicator is treated per company depends on the completeness of the data. Other factors (financial, supply chain management, and government policy) were described less extensively because of respondents' limited knowledge and scope of the study. A detailed breakdown of codes can be found in appendix J. The factors were ranked based on the number of codes attached in the previous section, and drivers, barriers, and enablers were identified. For a detailed breakdown of code numbers, please check appendix K. Product design is an exception in the elaboration, due to its potential to be internally modifiable with external impact.

## 4.1 Interpretation of the empirical study results

### 4.1.1 Organizational strategy and policy

The organizational strategy and policy factor contains four distinct indicators:1) market involvement, 2) knowledge and competencies, 3) sustainability strategy, and 4) management commitment. Each of the four indicators was analyzed individually to better define the factor. Market involvement, management commitment, and sustainability strategies were approached from the supplier's perspective. Knowledge and competencies were accessed from the entire supply chain. Figure 9 illustrates the organizational strategy and policy role.

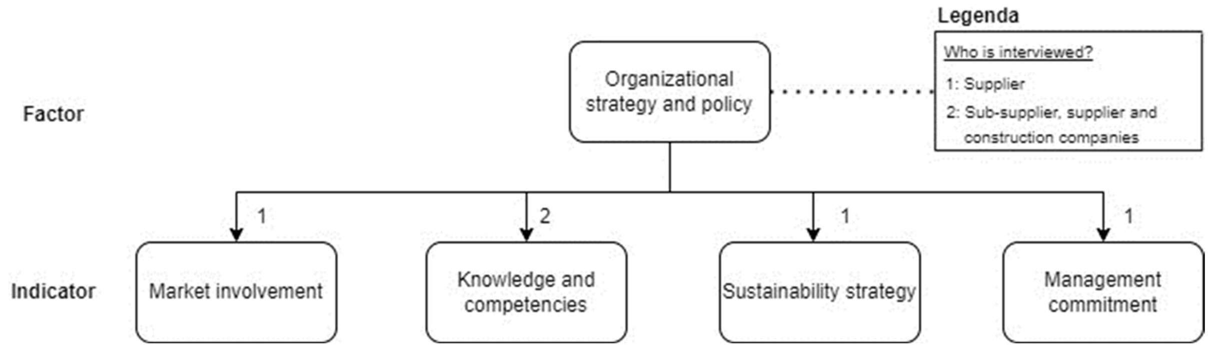



*Figure 9 - Organizational strategy and policy role*

## Market involvement

This indicator describes how the supplier involves other organizations within and outside its supply chain to integrate sustainability or circularity initiatives. Apparently, the supplier involves other organizations through initiatives. Initiatives that focus on and are limited to the involvement of suppliers and buyers. A respondent from the supplier stated that the main target of involvement is focused on core business activities to generate continued revenue and meet customer and market demands to maintain the financial viability of the current BM.

This means that involving other organizations in the integration of circularity is not considered an integrated element in the division's culture or current business model. This is confirmed by the pronunciation of one of the respondents, who believes that market involvement in sustainability does not result in improved employee performance or efficiency.

In addition to economic market participation, the organization is involved in a sustainability initiative with a waste treatment organization. This initiative consists of an agreement on collecting aluminium pre-consumed scrap, which is considered waste. Scrap is collected in containers by the supplier and retrieved and recycled by the waste treatment organization. This initiative can be considered skeptical in terms of sustainability because scrap is collected without the separation of alloys. This could result in alloy contamination and downcycling.

Additionally, there was an introductory meeting with an organization with business activities in sustainability and aluminium. This initiative was withheld because of the trust in long-term relationships with the current supplier. One respondent mentioned valuing the positive relationship with the sub-supplier and the benefits they gained through collaboration based on certainty and quality. No initiatives have been mentioned with anchor companies (companies who have already integrated a CBM for aluminium) or competitors to integrate sustainability or circularity.

When examining involvement with current long-term partners, it is mentioned that the supplier has involved the sub-supplier in integrating a waste collection system for preconsumed scrap. This system includes the separation of aluminium alloys to enable upcycling. However, this initiative has not been implemented yet. Shifting the focus to the procurement side of the supplier, it was noticed that there is limited information available on the sustainability of currently applied aluminium.

"*The main target of involvement is focused on core business activities to generate continued revenue, meet customer and market demand to maintain the financial viability of the current business model*"

### Sub-conclusion

Overall, there is unexplored potential to involve the market in integrating sustainable or circular initiatives. Involvement mainly focuses on core business activities to generate revenue to ensure the viability of the current business model, and the business model and organizational culture do not include sustainability or circularity as key elements. The main causes are the limited knowledge of the sustainability of applied aluminium, potential recycling opportunities, and CBM benefits. Therefore, market involvement can be identified as a *barrier*, because it impedes a company's ability to effectively integrate a CBM due to limited market support.

### Knowledge and competencies

This indicator assesses how respondents in the supply chain estimate their level of knowledge of sustainability and circularity. Respondents were asked to rate their knowledge of whether the supplier had integrated a CBM. It has been suggested that a CBM would involve an aluminium alloy with scrap percentages ranging from 30% to 95%. In the entire sample, respondents possessed a basic understanding of sustainability and circularity. Additionally, respondents expressed a sense of urgency, awareness, and necessity for organizations to adopt sustainable practices and minimize their environmental impact. They described the importance of implementing sustainable change for future generations.

Respondents from the sub-supplier stated that it is unknown what knowledge and competencies are needed to integrate an aluminium alloy with a high percentage of scrap. They described a limited understanding of the quality of such alloys and the composition of the scrap materials used. The approach mentioned to gathering this information is to learn through practical experience, commonly known as "learning by doing." Additionally, as the scrap percentage of aluminium alloys increases, there is a greater need for knowledge to accurately assess the requirements of the organization.

" *It is quite unknown which knowledge and competencies we need for a CBM* "

Respondents from the supplier expressed that there was no need to develop new knowledge or competencies specifically for the integration of the mentioned aluminium alloy. They mentioned that the feasibility of the integration relies on the quality of the alloy itself, which is considered unknown. Additionally, respondents mentioned having limited knowledge of the sustainability of aluminium, its environmental impact, and waste streams. This observation was applicable to the entire sample.

### Sub-conclusion

Overall, respondents from the entire sample described that they do not directly know what knowledge and competencies are needed for the integration of a CBM. This makes its impact relatively vague and unclear. Therefore, knowledge and capacities are identified as a barrier that impede the company's ability to effectively integrate a CBM because of limited insights into the required knowledge and competencies.

" *The need for knowledge and competencies in the organization depends on the quality of recycled aluminium* "

### Sustainability strategy

This indicator explains how respondents experience the influence of the overarching sustainability strategy on the integration of sustainable or circular initiatives for aluminium, and is focused on the supplier.

Respondents described that they primarily associated their sustainable development initiatives with the CSR manager's overarching initiatives, sustainability strategies, and self-initiated activities. These self-initiated activities include integrating an air-cutting aluminium modification machinery, adopting more efficient material usage in the modifier machinery, an air-filtering system, and reducing packing material.

However, respondents mentioned a limited defined vision, mission, or roadmap for aligning their aluminium core business with the sustainability trend. There is an absence of a specific vision or roadmap that results in ambiguities in the necessary steps that the supplier must take to enhance sustainability or circularity in its business model. Respondents described experiencing unexplored potential in the integration process.

" *There is no clear road to follow* "

### Sub-conclusion

The corporate overarching sustainability strategy was defined as an *enabler* for CBM integration. However, respondent mentioned an absence of specific vision or a roadmap, which result in ambiguities on the necessity steps the supplier has to take to enhance sustainability or circularity in its BM. Therefore, it enables the transition, but lacks specification.

### Management commitment

This indicator explains how respondents were committed to sustainability and circularity. This indicator covers the perspective of the supplier's managerial employees (2). A notable observation is that both managerial respondents mentioned the urgency and need for the organization to embrace sustainable business practices. Additionally, the organization allocates a budget for investments to facilitate this integration, which also covers circularity. One requirement for these investments is that they be economically viable in the long term. Two other respondents, who held a position that granted them decision-making authority, mentioned sharing this vision and commitment.

### Sub-conclusion

The collective alignment among the four suppliers underscores the shared understanding and commitment to incorporating sustainability initiatives into the business model and organization. Therefore, management commitment was identified as a *enabler*, because it enables the organization to move forward and integrate circular initiatives.

### 4.1.2 Technological

The technological factor contains three distinct indicators. These indicators are: 1) quality and composition of recycled aluminium, 2) technological infrastructure for waste management, and 3) technological infrastructure for recycled alumniium. To gain a closer understanding of this factor, the three indicators were analyzed individually. Quality and composition are approached from the perspective of the sub-supplier. Waste management and technological infrastructure are accessed from the entire supply chain. Figure 10 illustrates the technological tole.

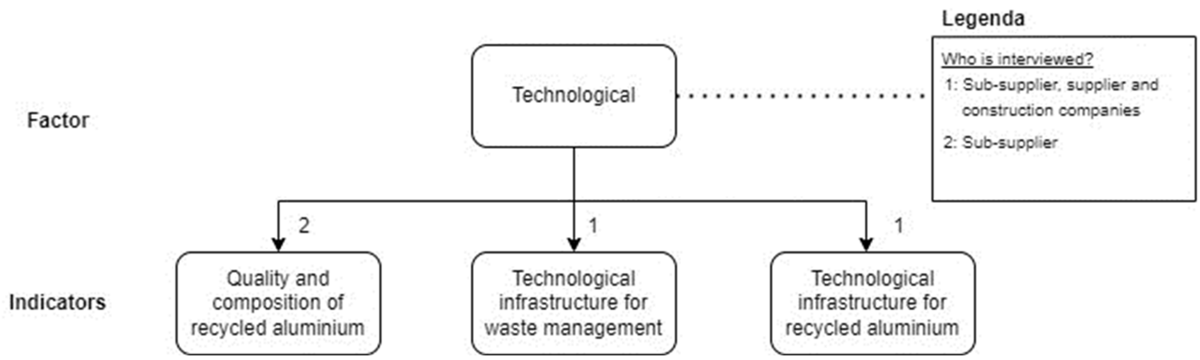



*Figure 10 - Technological role*

### Quality and composition of recycled aluminium

Respondents from the sub-supplier mentioned that factories offer diverse options for more "sustainable" aluminium alloys. These alloys have compositions that include 30%, 70%, or 95% pre- and post-consumption scrap. These were sourced from different factories in Europe with varying locations from Norway to Turkey. In contrast to alloys with higher percentages of pre- and post-consumed scrap, factories offer alloys that are produced with lower $CO_2$ emissions. The manufacturing process for this alloy emits 4 kg of $CO_2$ per kg of aluminium. One respondent mentioned that this emission level is considered low compared to the European average of 12 kg and the Asian average of 20 kg per kilogram. Respondents from the sub-supplier highlighted quality issues related to the integration of recycled aluminium. These issues vary from uncertainties in the coating, the need for a different pre-treatment, to uncertainties in the lifespan.

" *Aluminium alloys consisting of 70-95% scrap do have quality issues and uncertainties regarding pre-treatment, coating and corrosion resistance* "

One respondent stated that the coating tests confirmed lower quality outcomes. Additionally, the tests revealed that recycled aluminium faces challenges in terms of its corrosion resistance. Apart from corrosion resistance, quality differences may arise owing to the hardness of the material. This could result in additional changes during the supplier-modification process. However, it is important to note that this assumption was made. Moreover, another respondent described potential differences in ductility and malleability that should be considered.

The alloy whose composition consists of 30% scrap and the alloy produced using less $CO_2$ emissions do not experience any quality issues compared with the primary mined alternative. However, respondents mentioned that uncertainties increase when focusing on alloys containing 70-95% scrap.

" *We can reduce our carbon emission for aluminium by carefully investigating and comparing alloys* "

### Sub-conclusion

Overall, there are opportunities to integrate recycled alminium alloys. These recycled alloys have various opportunities, ranging from to 30-95% scrap in their composition, which are perceived to be higher than the current applied alloy. In addition, this alloy has uncertainties in terms of quality (corrosion resistance, strength, shape, ductility, and malleability). These uncertainties have a major effect on market acceptance; therefore, this indicator was identified as a *barrier*.

## Technological infrastructure for waste management

This indicator focuses on the aluminium waste management system of sub-suppliers, suppliers, and construction companies. Respondents from the supplier stated that their recycling initiative for pre-consumed waste did not involve the separation of aluminium alloys. This resulted in alloy contamination and downcycling. The presence of impurities or elements in alloys can affect desired characteristics, such as strength, corrosion resistance, and coating quality, and may limit the options for reuse in certain applications. It is likely that separating alloys during the recycling process prevents alloy contamination and ensures higher-quality recycled aluminium for broader applications.

The sub-supplier offers a waste collection system that meets the requirements for effectively separating alloys during recycling, ensuring the retrieval of high-quality aluminium. Preconsumed scrap is retrieved from aerospace, automotive, packaging, and machinery industries. The scrap is smelted into aluminium blocks and sent back directly to the factory for use in manufacturing new sheets.

As part of the sub-supplier strategy and business model, they want to increase the number of partners and quantity of collected waste. Challenges to increasing this number include scrap contamination and transportation costs when available quantities are low. Notably, the organization holds exclusive legal rights in Europe to include a maximum of 30% of contaminated materials in their smelting process. This makes the threshold for collecting aluminium waste more accessible.

Construction companies from the sample mentioned organizing initiatives to separate waste at project locations and focus on reducing $CO_2$. Waste separation in project locations is limited, and has a negative impact on recycling possibilities. The extent of waste separation depends on the type of the contractor involved. Another factor is that architects and end-clients often demand a wide variety of building materials. This causes waste separation during the demolition process. Initiatives to adapt a company's core business to sustainability remain vague.

## Sub-conclusion

Overall, the role of this indicator varies among sub-supplier, suppliers, and construction companies. The sub-suppliers' pre-consumed waste management system, perceived as a driver, is one of its core business activities. The supplier has an integrated waste management system for aluminium, which is discussed in terms of sustainability. Owing to its integration, this indicator was identified as a driver. From the perspective of construction companies, waste separation in project locations is limited due to collaboration issues with contactors and a wide variety in demand for building materials from end clients and architects. Therefore, this indicator was identified as a *barrier*.

## Technological infrastructure for recycled aluminium

Respondents from the sub-supplier mentioned that the smelting industry uses technologies that are considered unsustainable. Aluminium smelters primarily rely on fossil fuels for their energy supply. The transportation of pre- and post-consumed scrap between waste suppliers, smelting locations, and factories is facilitated by vehicles powered by fossil fuel. Factories must collect scrap from various locations and industries to ensure that they meet specific quality standards for smelting recycled aluminium. Moreover, this exchange does not offer the advantages of geographical proximity. Pre-consumed waste streams are considered more consistent and reliable than post-consumed waste streams for aluminium because of the following:

1. *Consistency of source*: pre-consumed aluminium scrap originating from industrial processes is more controlled and well-documented, which makes it more consistent in terms of quality and composition and leads to less contamination)
2. *Lower level of contamination*: pre-consumed aluminium scrap originating from industry processes tends to have lower contamination levels than post-consumed scrap. Post-consumed scrap may contain different contaminants, such as coating, adhesive substances or other materials that can make complicate the recycling process
3. *Consistent quality of alloys*: pre-consumed scrap is more often manufactured from consistent alloys, which is vital for the desired material properties in the recycling process. Post-consumed scrap can contain a wider range of alloys, which makes recycling more complicated and intensive
4. *Market reliability*: Long-term agreements are generated for selling pre-consumed scrap, which creates a stable waste stream. Post-consumption scrap depends more on customer behavior and market economic factors
5. *Other causes*: sorting pre-consumed scrap is easier, because it is manufactured in controlled environments. This results in higher recycling efficiencies and lower energy consumption. Post-consumption scrap often requires more intensive cleaning and separation during recycling processes

Besides, the lack of demand impedes the transition to recycled aluminium and prevents the realization of economies of scale and necessary support for technological infrastructure. This lack of demand is influenced by the perceived potential for lower quality and higher costs of recycled aluminium. A closer look at the supplier's role shows that modification machinery relies on compressed air. Although this machinery is electrified, it does not use the self-generated energy. Additionally, transport movements between the supplier and construction company are not electrified because of limited alternatives with comparable functions and high investment costs. However, driving movements were minimized.

## Sub-conclusion

Applied technologies for manufacturing recycled aluminium and driving movements between supply chain partners rely on fossil fuel for their energy supply. The inconsistent nature of pre-consumed scrap waste streams make the technological infrastructure for recycled aluminium inconsistent, which is opposite for the pre-consumed scrap waste stream. Besides, the lack of demand impedes the transition to recycled aluminium, which is fueled by quality and costs considerations. This results in a higher cost of recycled aluminium alloys. Therefore, the infrastructure was identified as a *barrier*.

### 4.1.3 Organizational behavior

The organizational behavior factor contains two distinctive indicators. These indicators are 1) awareness and intrinsic motivation, and 2) employee engagement. To gain a closer understanding of this factor, the two indicators were analyzed individually. This analysis considered the presence of respondents at the individual level from sub-suppliers, suppliers, and construction companies. Figure 11 illustrates the organizational behavior role.

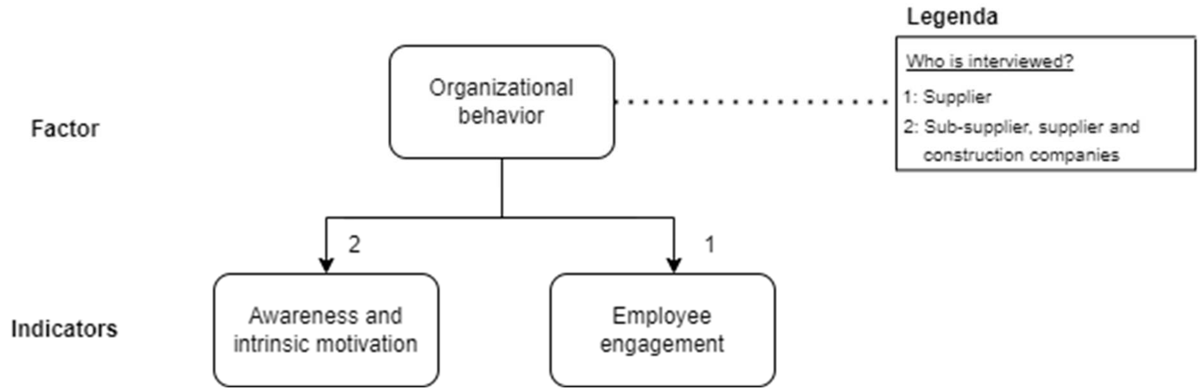



*Figure 11 - Organizational behavior role*

#### Awareness and intrinsic motivation

Individuals' awareness and intrinsic motivation are closely related. Therefore, both indicators are considered when describing organizational behavior. In this case, one's awareness of sustainability can influence their intrinsic motivation to participate in sustainability initiatives. These initiatives were considered personally meaningful. When addressing individual awareness, all respondents in the sample became aware of the urgency and necessity for sustainable change at both the company and societal levels. Additionally, they mentioned the need to reduce the negative environmental impact of economic activities.

However, these numbers change when shifting the focus to intrinsic motivation. Of the three respondents from the sub-supplier, only one was observed as being intrinsically motivated to develop a more sustainable business or integrate circularity into their organization. The remaining two respondents ranked economic growth as their primary organizational goal. Three of the five supplier respondents described their intrinsic motivation. From the perspective of the construction companies, one of the three respondents expressed intrinsic motivation. Overall, this indicates that a total of five out of eleven respondents are intrinsically motivated. Figure 12 illustrates the level of awareness and intrinsic motivation present in the sample.

*" I feel very responsible to leave a better world for my children and grandchildren "*

Respondents from the sample described and justified their behavior by highlighting the larger environmental impact of others. They express that their behavior is negligible compared to individuals or even countries, which they perceive as "bigger polluters." Additionally, two of the five supplier respondents do not believe that sustainable actions directly contribute to increased efficiency or improvements in employee performance. Figure 12 shows the levels of awareness and intrinsic motivation.

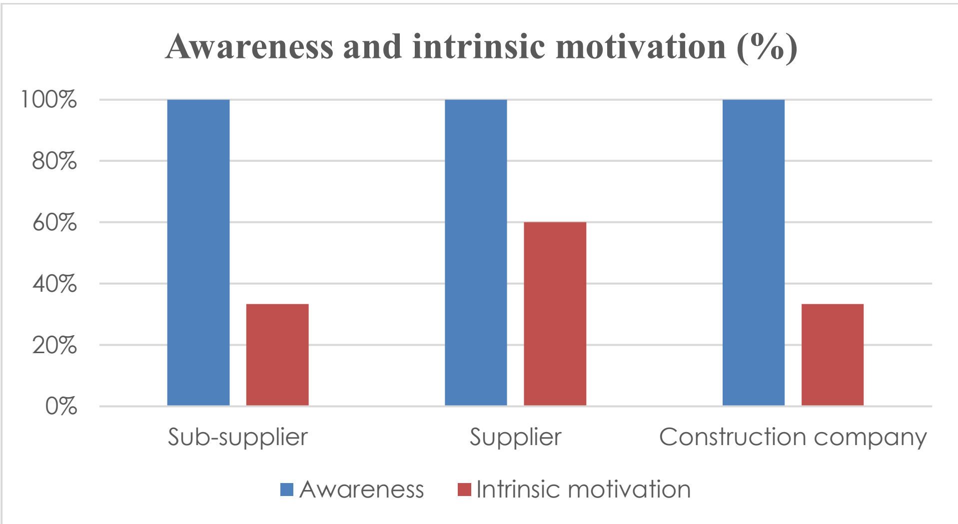



*Figure 12 – Respondent's awareness and intrinsic motivation*

### Sub-conclusion

All respondents mentioned a sense of awareness, urgency, and necessity for sustainable change at the company and societal levels. Therefore, awareness was identified as a *driver*. The intrinsic motivation level of respondents from the sub-supplier and construction company was significantly lower and, therefore, was identified as a *barrier*. In contrast to the supplier, where intrinsic motivation was identified as a *driver*.

### Employee involvement

This indicator examines how individuals perceive their divisions' involvement in sustainability initiatives. Respondents expressed a sense of engagement with sustainability initiatives, such as visits to the pre-consumed scrap smeltery, the supplier's construction location, and initiatives from the CSR Manager. Both two respondents from the supplier described feeling a collective presence of feeling enthusiasm or motivation about sustainability integration. The respondents mentioned that sustainability initiatives created overarching involvement in the organization.

### Sub-conclusion

Respondents mentioned feeling involved in sustainability initiatives organized by the CSR Manager, the visit to the pre-consumed crap smeltery and the suppliers' construction location. Therefore, this indicator was identified as a *driver*.

## 4.1.4 Customer demand

The customer demand factor contains one distinct indicator. This indicator is customer behavior and demand. Specifically, this refers to behavioral change and demand from the customer's perspective for circular materials such as recycled aluminium. This analysis considers the perspectives of the sub-supplier, supplier, and construction companies. Figure 13 illustrates the role of customer demand in CBM development.

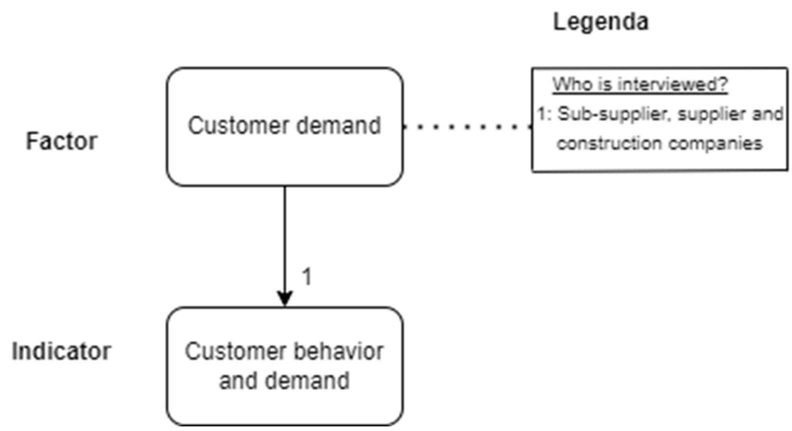



*Figure 13 - Customer demand role*

### Customer behavior and demand

One respondent from the sub-supplier mentioned experiencing a shift in customer behavior towards recycled aluminium. This shift indicates that customers show greater interest in opportunities. However, this change has not yet translated into a shift in the final demand for products such as recycled aluminium. Customers are willing to integrate recycled aluminium, but there is a lack of action owing to higher costs. This results in limited consideration of environmental factors in comparison to costs and quality. Consequently, there is a low demand for recycled aluminium owing to cost-driven decision making and customer concerns about quality. Exceptions are intrinsically motivated organizations and governments that have shown increasing interest in the application of recycled aluminium.

*" Customers show curiosity, but this is not yet changing demand "*

When addressing the waste recycling system, respondents mentioned that they experienced limited customer awareness. The respondent noted that the extent of collaboration to integrate this recycling system into organizations depends on the sustainable values held by each firm, which could be a result of a level of awareness.

*" Customers should holistically analyze the environmental, cost and quality impact of recycled aluminium in an equal matter "*

A supplier's respondent believed that incorporating recycled aluminium can strengthen the market proposition of the organization. This could potentially open new markets and meet the increasing demand for government tenders focused on developing sustainable buildings. Larger construction companies are witnessing an increasing demand for sustainable and circular materials. Another respondent confirmed this trend by stating that there is a growing overall demand for more sustainable products. However, it is noted that two respondents from the supplier experienced limited demand for more sustainable aluminium. They mentioned their worries on losing market share due to the integration of recycled aluminium.

*" The integration of recycled aluminium should bring economical advantages "*

Construction companies are the customers of the supply chain. Therefore, their role is strongly associated with determining and selecting tender products. This means that their input into customer demand is valuable. From this perspective, end clients are unwilling to pay more for sustainable and circular buildings. Costs and willingness are the primary drivers during the tender phase, resulting in sustainable alternatives being overlooked because of their higher prices compared to conventional options. This presents a challenge for government tenders, who should target more circular materials and reduce the usage of products with a negative environmental impact. The cost-driven nature of tenders makes it difficult to promote circularity.

This results in unfair competition between sustainable materials and materials that have negative environmental impacts. One respondent mentioned that they did not explicitly request sustainable materials from suppliers in tenders. In addition to costs, the respondents emphasized that the quality and cost of recycled aluminium should be comparable to that of primary-mined aluminium. In addition to these challenges, the respondents expressed opportunities to integrate recycled aluminium. One respondent expressed openness to embracing recycled aluminium if the price increase was not excessive.

*" We would embrace recycled aluminium if the price increase is not excessive"*

Government tenders prioritize sustainability requirements. However, in the healthcare sector, tenders are characterized as having minimal room for sustainability due to limited budgets and primarily focusing on patient-oriented aspects driven by cost considerations. In addition to the healthcare sector, housing associations faced growing demand. Private individuals also expressed interest in limited sustainability demands.

*" We expect a growing demand for more sustainable materials "*

### Sub-conclusion

Customer behavior was identified as a driver of the entire sample. The cost-drivenness of tenders and the quality of recycled aluminium pose difficulties for customers. In contrast, it was mentioned that customers would embrace recycled alumnium if the price increase was not excessive and if quality was not an issue. However, this indicator was not clearly identifiable. Respondents have arguments that make it categorizable as a *driver* or *barrier*.

### 4.1.5 Product design

The product design factor contains one distinct indicator. This indicator is the technical and functional design. Specifically, it refers to the degree to which an aluminium product can be disassembled from its construction and under which conditions. This analysis considers the supplier's perspective. Figure 14 illustrates the product design role.

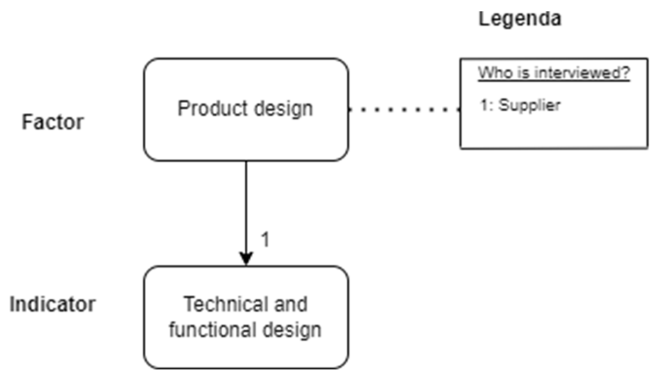



*Figure 14 - Product design*

#### Technical and functional design

A respondent from the supplier stated that aluminium caps were easy to disassemble from the building. They do not decay, and have long lifespans. Aluminium facades can be easily unscrewed from the construction, whereas components glued to aluminium plates are more complex to disassemble. Apart from the detachment method, aluminium does not require maintenance during its lifetime. One respondent mentioned that using glue to secure aluminum in the ceiling posed risks due to the expansion of aluminium. Even when the glue supplier provides guarantees. The use of screws to secure aluminium could be safer and more sustainable. Mentioned is that architects and end-clients influence the decision-making process regarding the choice between glue and screws.

The respondents explained that products developed by suppliers with aesthetic value face fewer restrictive government requirements in their application, but their importance is emphasized in product design. Additionally, it was mentioned that there is limited knowledge on what happens with aluminium products when the building is disassembled at the end of life.

“ *Using screws to confirm aluminium in buildings could be safer and more sustainable* ”

#### Sub-conclusion

Aluminium components are easy to dissemble during construction, have a long lifetime, and do not require maintenance. This makes the indicator identifiable as a *driver*.

### 4.1.6 Drivers, barriers and enablers in practice

The previous section contained information on the specific role of indicators along with substantiated information. This sub-section will present a total overview of the identified drivers, barriers and enablers according to the empirical study. This makes it possible to answer the second research question:

- *What are the drivers, barriers, and enablers to a CBM for aluminium in practice?*

Table 6 illustrates an overview of drivers, barriers and enablers according the empirical study.

*Table 6 - Overview of drivers, barriers and enablers according to the empirical study*

| Factor | Indicator | Role | Note* |
|---|---|---|---|
| **Organizational strategy and policy** | Market involvement | Barrier | |
| | Knowledge and competencies | Barrier | |
| | Sustainability strategy | Enabler | |
| | Management commitment | Enabler | |
| **Technological** | Quality and composition of recycled aluminium | Barrier | |
| | Technological infrastructure for waste management | Driver | Sub-supplier= Driver and for Construction companies= Barrier |
| | Technological infrastructure for recycled aluminium | Barrier | |
| **Organizational behavior** | Awareness | Driver | |
| | Intrinsic motivation | Driver | Sub-supplier = Barrier and for Construction companies = Barrier |
| | Employee involvement | Driver | |
| **Customer demand** | Customer behavior and demand | Driver or Barrier | |
| **Financial** | Market and economic uncertainty | Driver or Barrier | |
| | Economic costs | Barrier | |
| | Supportive measures | Driver* | Sub-supplier= Driver and for Construction companies= Barrier |
| **Supply chain management** | Collaboration, material sourcing and recycling | Barrier | |
| **Government policy** | Regulations and interventions | Barrier | |
| **Product design** | Technical and functional design | Driver | |

**The role for the sub-supplier or construction companies varies from the suppliers role*

# 5 Discussion and conclusion

## 5.1 Key findings

This section aims to discuss why the supplier did not yet ingrate a CBM. This is organized by delving into the factors and comparing the empirical findings with those in the literature. It is essential to note that there is not a single factor driving this decision, but rather a complex interplay of various factors that collectively create enough uncertainty for organizations to simply not integrate a CBM. This section sheds a light on the five factors, which are mentioned more in depth: *organizational strategy and policy, technology, organizational behavior, customer demand*, and *product design*. This does not mean that these factors are considered as more important or having a larger effect on CBM integration, but is mainly due to the study scope. The explanation of the financial, supply chain management and government policy part is illustrated in appendix L. Last, an overview of all drivers, barriers and enablers according to the state-of-the art and empirical study is illustrated in appendix M.

### Organizational strategy and policy

### Market involvement

Supplier respondents perceived market involvement as uncertain and unclear. Respondents expressed limited clarity on how to involve the market in circularity and the potential benefits for the organization. Current involvement mainly occurs around core business activities between buyers and suppliers, which primarily aim to sustain and maintain the financial viability of the current business model and exclude circular activities. The reasons for this one-sided market involvement are the limited awareness of its benefits, limited knowledge of the environmental impact of aluminum applied by the organization, recycling potential, and advantages of CBMs in general. Collaborations with anchor companies were not mentioned as being present.

Comparatively, the literature sheds light on limited market involvement due to low customer and customer awareness of reverse logistics systems, sustainable benefits, and the introduction of recycled materials in production processes (Caldera et al., 2020; Chiappetta Jabbour et al., 2020; Orji, 2019). The empirical findings are consistent with the state-of-the-art. Limited knowledge of the currently applied aluminium's sustainability clarifies why sustainable changes have not yet been realized. The state-of-the-art described the integration of sustainable core business activities and integrating collaboration with anchor companies as drivers (Chiappetta Jabbour et al., 2020; Neves et al., 2019). Core business adoption has not been realized in this sample yet and anchor companies were not mentioned to be present in the organizations.

This means that underlying dimensions of one-sided market involvement are centred around the behavioral aspect of the individual. Behavioral aspects are observed to be substantiated by common assumptions formed in the organizational culture, driven by leadership and resistance to change.

## Knowledge and competencies

A significant barrier identified by respondents was the limited presence of needed knowledge and competencies required for CBM integration. This uncertainty is created by a lack of understanding of the impact of CBM integration on organizational knowledge and competencies, which is particularly related to the application of recycled aluminium. It is described that higher percentages of scrap (60%-95%) in the composition of recycled aluminium alloys result in quality uncertainties. Therefore, knowledge and competencies are needed. Lower percentages (0%-30%) of scrap are described to have similar characteristics because of the higher percentages of primary mined aluminium. The supplier is characterized as actively integrating sustainability into its culture, but respondents' input gave the impression that, unconsciously, there is limited knowledge and competencies in the organization to fully support the realization of the transition. In the whole sample, respondents only referred to technology-based skills as important without considering other skills and knowledge-based skills, or soft skills.

The literature emphasized the importance of skills- and knowledge-based competencies and soft skills aimed at system thinking to be more important than tech-based skills. These competencies are related to hiring, education, consultancy, skills to be a precondition in management, open network collaboration, strategy development and focus, and marketing. Besides, the inner drive makes the CBM work out, and it shows the importance of human behavioral aspects in this field (von Kolpinski et al., 2022). Soft skills are related to the commitment of individuals to work in the organization, flexibility and engagement (to quickly adapt to new situations), and being able to inspire others from their vision. Furthermore, it includes the alignment of the individual with the organization and team composition.

The findings suggested that the required knowledge and competencies are contingent on changes in core business activities, which reflect a learning-by-doing approach. This makes it for the larger part consistent with the state-of-the-art (von Kolpinski et al., 2022). In contrast, this perspective only focused on tech-based skills related to changes in technological processes in aluminium modification, but respondents did not describe the importance of the presence of soft skills (behavioural traits, mission alignment, team competencies) or skills- and knowledge-based competencies (hiring, education, consultancy, open network collaboration or strategy adaption) (Chiappetta Jabbour et al., 2020; Neves et al., 2019; Orji, 2019; von Kolpinski et al., 2022). The literature also highlighted the importance of an increased inner drive by employees. This inner drive makes it possible to learn from each other to develop the necessary knowledge and competencies (von Kolpinski et al., 2022). When the organization collectively has the knowledge and competencies, it can be transformed into an enabler.

This means that the development of knowledge and competencies is only mentioned from a single perspective. The organization is process-wisely integrating the other two pillars, but these are not yet fully explored. The prevailing culture within the organization may influence this perspective, driven by certain leadership values and limited awareness on its importance.

## Sustainability strategy

The corporate sustainability strategy facilitated the integration of sustainability initiatives across the suppliers' organizations, and its application can vary per division. However, respondents indicated that the strategy needs further specification to align the core business with CBMs. Specifically, this would include a more specified defined vision, mission, that shows process-wise steps in the short and long term, and in which direction. This relates to employees and organizations' knowledge and competencies in CBMs. The supplier mentioned having a long-term relationship with the sub-supplier, which is characterized by trust and quality. These values are perceived as fundamental for organizations to integrate CBM development. Additionally, green teams were not mentioned to be present.

In contrast, the literature underscored that organizations rely significantly on adopting their core business to embrace CBM development (Chiappetta Jabbour et al., 2020). This adoption should be proactively translated into organizational plans and strategies, which is perceived as a barrier (Orji, 2019). Another driver of core business adoption is the availability of sustainable suppliers (Chiappetta Jabbour et al., 2020). Besides, is the successful application of green teams to receive certification and inform management defined as a driver (Torres-Guevara et al., 2021). In the empirical study, the supplier mentioned that core business activities have not yet been transformed into CBM development, and proactive plans for incorporation are not specified enough to explore maximum facilitation. The corporate strategy is in an early stage of development and therefore not yet translated to business unit strategies. This strategy enables the transition, but lacks specification. Besides, leadership in the business units is perceived as possible barrier hindering the translation.

The literature suggested that the availability of sustainable suppliers is a driver for companies, whereas the supplier mentioned a long-term relationship with the current supplier based on trust and quality. Green teams are also defined as driving forces but are not present in the organization of the supplier (Torres-Guevara et al., 2021).

### Management commitment

Managerial respondents and decision-makers from the supplier mentioned their commitment to embrace a CBM and allocate budgetary resources for necessary investments. Their commitment is fueled by certain factors:

1) the presence of a certain level of awareness, driven to positively impact the environment and society
2) concerns about climate change
3) customer demand for sustainable products
4) regulatory pressure
5) potential to hire younger generation employees

The literature provided a dual perspective on the effects of management commitment on CBM development. When management shares environmental values and concerns about firms' potential environmental impacts, it is found to have a positive effect on the organization's environmental awareness (Torres-Guevara et al., 2021). It stimulates the development of the awareness and competencies required for CBM integration (Orji, 2019; Torres-Guevara et al., 2021; von Kolpinski et al., 2022). From another perspective, it is worth mentioning that management commitment is also identified as having an opposite effect on CBM development (Orji, 2019). In the supplier it is perceived as an enabler, because it's a foundation force to integrate circularity. This makes its effect different with that from the state-of-the-art.

### Technology

### Quality and composition of recycled aluminium

Respondents mentioned that the supplier modified an aluminium alloy containing between 2% and 12% aluminium scrap. Leaning closer to 2% than to 12%. The remaining percentage consisted of primary mined aluminum. The quality and composition of recycled aluminium alloys present a significant barrier to CBM development. Recycled alloys with higher scrap percentage (70-95%) often encounter quality challenges related to pretreatment requirements, material hardness, corrosion resistance, strength, shape, and coating quality. However, specific knowledge regarding these quality issues remains limited. The respondents mentioned that the higher the scrap percentage, the greater the uncertainty regarding quality and the higher the costs. These issues depend on the chosen recycled alloy.

The literature stated that the introduction of recycled materials in the production process is often a significant challenge that depends on public demand (Chiappetta Jabbour et al., 2020; Orji, 2019). Another reason for not yet integrating recycled materials is due to a lack of the amount of materials needed to carry it forward and higher costs (Chiappetta Jabbour et al., 2020). Recycled materials often lack quality and standardization because there is no continuous supply of clean materials (Caldera et al., 2020; Stewart et al., 2016; Winterstetter et al., 2021). The quality issues and higher costs of recycled aluminium are consistent with the state-of-the-art. The availability of recycled aluminium is not an issue. This results in a wait-and-see attitude, which is characterized by reluctance to change. The supplier is afraid of not being able to deliver the expected quality to customers, which is described to result in losing market share.

### Technological infrastructure for waste management

The sub-supplier had a mature infrastructure for collecting and smelting pre-consumed aluminium scrap. This scrap is collected from various industries, smelted, and sent back to factories, where it is processed in recycled mined alloys. This pre-consumed scrap infrastructure is characterized as one of its core business activities and a driving force for circularity. This organization is one of the few in Europe that have legal rights to have a relatively high percentage of contamination in their collected scrap. This lowers the scrap collection threshold. Applied smelting technologies are powered by fossil fuels because sustainable energy sources have an inconsistent energy supply. Currently, the supplier does not use this waste management system because it sells its scrap to waste treatment companies for recycling.

The literature mentioned that recycling technologies are often immature and not commercially proven, which can lead to extended operational shutdowns and increased operational costs (Oberthür et al., 2021). Neves et al., (2019) and Stewart et al., (2016) described that existing cases of waste exchange and the infrastructure are a driving force. This is confirmed in the empirical study results, which described the presence of a mature and commercially proven waste recycling system. What stands out here is that the infrastructure was mature, commercially proven, and available, but the supplier was simply not aware of this opportunity. In addition, the maturity and commercial proneness of the infrastructure are not an issue, but the technologies that are powered by fossil fuels. The respondents did not mention an increase in operational shutdowns or shutdowns.

### Technological infrastructure for recycled aluminum

The lack of demand impedes the transition to recycled aluminium and prevents the realization of economies of scale and necessary support for technological infrastructure. This lack of demand is influenced by the perceived potential for lower quality and higher costs of recycled aluminium. In addition, factories have experienced varying inputs of pre- and post-consumed aluminium scrap from different industries and geographical locations. Pre-consumed waste streams are considered more consistent and reliable than post-consumed waste streams for aluminium because of the following:

1. *Consistency of source*
2. *Lower level of contamination*
3. *Consistent quality of alloys*
4. *Market reliability*

Additionally, sorting, higher efficiencies in recycling, lower energy consumption and cleaning and separation activities influence these considerations. These combined factors result in higher operational and economic costs for recycled aluminium. The waste management system for selling and collecting pre-consumed scrap can be characterized as mature and efficient; however, this does not account for the factorial infrastructure of manufacturing recycled aluminum. Therefore, this indicator was defined as a barrier to CBM development. This means that organizations must shift and develop support for such infrastructure for recycled aluminium to generate a more sustainable metal industry.

The literature described that the infrastructure for recycled metals is subject to a fluctuating supply of waste materials and issues related to contaminated materials (Caldera et al., 2020). This affects the economies of scale, production costs, and price of recycled materials. Additionally, recycled materials frequently encounter issues related to alloy contamination. This results in EoL separation (Caldera et al., 2020). In contrast, it is also perceived as an enabling force (Soo et al., 2019; Stewart et al., 2016). The empirical study results are partly consistent with the state-of-the-art, which makes it identifiable as a *barrier*.

### Organization behavior

#### Awareness and intrinsic motivation

In the empirical study, respondents were questioned about their perspectives on sustainability in order to determine their levels of awareness and intrinsic motivation. It became evident that while respondents generally acknowledged the urgency of sustainable organizational and societal change, the picture changed when considering intrinsic motivation. From the sub-suppliers and construction companies, only one out of the three displayed an intrinsic motivation to integrate circularity in their organization. By contrast, among the supplier respondents, three out of five demonstrated intrinsic motivation. This implies that a certain level of awareness does not imply that a respondent is intrinsically motivated to drive sustainable change. On a corporate level, there is support for CBM development, but on a division level, it seems not to be so obvious. Respondents from construction companies shared their concerns that their organization was not sufficiently rapid to integrate the necessary sustainable changes. Internal dynamics at various layers seem to impede organizations' sustainable transitions. In particular, varying and opposing opinions on this topic had a hindering effect. Therefore, awareness is defined as a *driver,* whereas intrinsic motivation is defined as a *driver* for the supplier and a *barrier* for the sub-supplier and construction companies.

Within the supply chain, organizations attempt to integrate circular changes, but the conservative nature of the construction sector often acts as a barrier to change. Throughout the entire supply chain, organizations appear to move their responsibility for not implementing circularity to their supply chain partners.

The literature mentioned a limited level of awareness forms a barrier to organizational change towards sustainability (Abarca-Guerrero et al., 2022; Caldera et al., 2020; Chiappetta Jabbour et al., 2020; Orji, 2019). Awareness affects the development of organizations' environmental competencies on sustainability, which is also identified as a barrier (Chiappetta Jabbour et al., 2020; Orji, 2019). This effect is the opposite in the empirical study results, where respondents have a certain level of awareness. The inner drive positively affects CBM integration for the supplier and is consistent with the literature (von Kolpinski et al., 2022), whereas the effect seems less dominant in sub-suppliers and construction companies.

### Employee involvement

Respondents from the supplier mentioned that sustainable involvement comes mainly from top-down and bottom-up perspectives. These activities focus on waste management and the efficient use of materials. Department managers have a free role in interpreting and organizing these initiatives. Supplier respondents expressed a sense of involvement in sustainability initiatives. Specifically, they mentioned feeling a collective presence in the organization, which is characterized by enthusiasm and motivation. This attitude is developed through the role of the CSR Manager in the organization and research activities, which could give the organization insights into circularity. Additionally, respondents from the supplier experienced a limited defined vision, mission, knowledge, and competencies, which influenced their role in integrating circularity. Therefore, this indicator is defined as a *driver* of CBM development.

The literature stated that employee involvement goes much further than simply involving employees in sustainability. Bhattacharya (2016) mentioned that organizations and employees have reciprocal obligations and mutual commitments that define their relationships. Successful integration of sustainability into business requires management to reconcile the gap between personal and corporate values in formal, psychological, and social dimensions. This means involving employees and business units to address environmental challenges (Bhattacharya, 2016). Caldera et al., (2020) and Chiappetta Jabbour et al., (2020) described a lack of involvement and incentives as a barrier. The supplier's organization had initiatives to involve employees top-down and bottom-up and attempts to motivate and inspire them to work on this topic, which is percieved as motivating by the respondents. This is not consistent with the state-of-the-art.

### Customer demand

### Customer behavior and demand

Among the sub-supplier respondents, there was a noteworthy observation of a shift in customer behavior towards recycled aluminium. Customers are increasingly expressing interest in integrating recycling aluminium. However, this trend does not translate immediately into demand. While customers showed willingness to incorporate recycled materials, they were reluctant to act, stemming from the perceived higher costs for these recycled materials. It was mentioned that the costs of recycled aluminium alloys are higher than those of primary-mined aluminium alloys, and concerns about quality have also been raised.

The demand for circular materials is increasing from the perspective of construction companies. However, respondents mentioned that this demand faced stagnation due to economic considerations, quality issues, and the limited willingness of end clients to pay a premium price, which is associated with circular materials. Overall, it was mentioned that circular materials often require a backseat because of their relatively higher costs compared to conventional options. The competitive and cost-driven nature of construction tenders poses significant challenges to the integration of CBMs within the construction sector. In contrast, respondents expressed opportunities to integrate recycled aluminium. One construction firm mentioned embracing recycled aluminium if the price increase was not excessive. Therefore, this indicator is defined as both a *driver* and *barrier* for CBM development.

These findings are consistent with the state-of-the-art, which described that customer behavior and demand can be a driver or barrier in integrating recycled materials (Chiappetta Jabbour et al., 2020; Dominish et al., 2018; Soo et al., 2019). Markets for recycled products do not experience economies of scale (Hool et al., 2022). However, this trend is expected to change as these markets continue to grow. A key success factor is the stronger relationship between product suppliers and users (Hool et al., 2022).

### Product design

#### Technical and functional design

Respondents from the supplier mentioned that aluminium caps are relatively easy to detach from buildings and their subsystems. Aluminium facades can be unscrewed, whereas components adhered to alumnium plates use adhesive substances, posing a more complex disassembly challenge. The choice of the attachment method often depends on architectural and end-client requirements, which are driven by aesthetic considerations. These components are characterized as having exceptional durability and a long lifespan. Additionally, respondents mentioned that aluminum's tendency to expand under certain conditions may introduce further safety risks. Finally, the respondents mentioned that they had limited knowledge of the EoL view of these products. Therefore, this indicator is defined as a *driver* for CBM development.

Product design for disassembly plays a vital role in the disassembly process. In the case of aluminium products in construction, the objective is to ensure that they can be disassembled more easily from their individual subsystems and within the building context (Hool et al., 2022), which makes it identifiable as driver (Chiappetta Jabbour et al., 2020; Dominish et al., 2018; Soo et al., 2019), but once not adapted it hindered CBM development (Dominish et al., 2018). The driving force was empirically confirmed by the use of screws for easy detachment. This means that the organization need to think differently and consider the EoL stage already in the design stage. This mindset would enable the organization to contribute to a more mature waste stream for recycled aluminium.

## 5.2 Limitations

In this study, there was a relative chance of prolonged involvement due to a collegial relationship with employees of the organization. This may reduce the threat from reactivity and respondent bias, but increase the threat from researcher bias. During the semi-structured interviews, the researcher used an audit trail. This refers to monitoring and keeping records of all interview-related data, including audio recordings and coding books (Robson, 2002). It is worth acknowledging that interviews are the main method used in this thesis. Interviews require skillful requirements from the researcher but are also limited to the researcher's view. This method is a limitation by the fact that no objectively verifiable conclusions can be drawn from the data (Choy, 2014).

The theoretical model developed in this study is supported by twenty-three scientific articles. These articles formed the foundation for the development of defined factors and indicators. However, it is important to acknowledge the limitations of the search strategy. The applied search string encompassed articles that primarily focused on drivers, barriers, and enablers related to aluminium and metals. Consequently, there is a potential for variation in the role the factors play when applied to different types of metals.

Moreover, the broad nature of the theoretical model has its limitations. Given the factors in the search strategy and time restrictions, it was not possible to delve deeply into each factor or fully illuminate each facet. Another aspect to consider is the geographical- and industry-specific focus of this study. Country-specific variables can influence a factor's role and its perception. In addition, industry characteristics can vary and influence the perceptions of factors.

The findings of this empirical study are supported by data from 11 interviews. It is worth noting that conducting additional interviews has the potential to provide further insights into drivers, barriers, and enablers within this domain. Specifically, an increase in the number of interviews with higher-ranking participants in construction companies can yield more comprehensive and substantiated findings. This would, in turn, reduce the risk of selection or sampling bias (Bhandari, 2023; Institute for Work & Health, 2014). It is also worth acknowledging the limitations associated with the selected samples. While this study included respondents from the sub-supplier, supplier, and three construction companies, it did not include other key stakeholders in the supply chain. These include factories, architects, end clients, and other relevant parties. These limitations underscore the need for caution when generalizing our findings to a broader context

.

## 5.3 Future research

Previous research on value creation in CBMs remains relatively vague and lacks a system-level approach to presenting a comprehensive understanding of the interrelatedness and interdependencies of factors (Ünal et al., 2019). Therefore, future research on system-level approaches can help create a more comprehensive understanding of CBMs and their influencing factors. Future research can incorporate the perspectives of factories, architects, end clients, or other stakeholders involved in the supply chain. These insights can provide more substantiated insights into overall supply chain dynamics.

It is worth noting that this study delved deeper into certain factors (organizational strategy and policy, technology, organizational behavior, and customer demand) than others (financial, government policy, supply chain management, and product design). A more comprehensive and in-depth investigation of these factors would enhance our understanding of their specific influences. Replicating this study would be beneficial for its reliability, validity, robustness, and generalizability. In particular, it has a broad scope.

Improvements in data triangulation are also possible by using different data collection instruments. This was not included in the research design or future research recommendations. Moreover, for members, there are certain limitations due to the research time span. Complete interview data were not verified after completion. Besides member checking, there could be more focus on negative case analysis in future research recommendations.

Finally, a quantitative research design was applied to test the effects of various indicators. For instance, it could examine how market involvement affects organizational behavior, the effect of the quality and composition of recycled materials on the required knowledge and competencies within the organization, and the influence of employee involvement in circular initiatives on their behavior. There are only a few examples of potential quantitative research designs, and more can be identified to further enrich our understanding.

## 5.4 Strategies to overcome barriers and leverage enablers

This section presents best-practice strategies to overcome the barriers that hinder the integration of a CBM for the supplier. These strategies do not provide a comprehensive guide or roadmap for addressing every threat or barrier, but explain practical mechanisms that can prove to be valuable when the organization seeks to develop a CBM. The primary objective of this section is to enhance an understanding of how to overcome barriers to CBM development. These strategies specifically address the challenges which occur in the supply chain from the suppliers' perspective as they integrate circular business development. The strategies are substantiated by data received in this studty.

### Process-wise business unit strategy for CBM integration

Respondents from the supplier mentioned the need for clearer specifications in their business unit strategy to effectively adopt their core business towards circularity. Specifically, this means establishing a long-term mission and vision that outlines the strategic direction for the organization, including practical short- and long-term steps. The creation and development of these strategic aspects can be translated into a roadmap that encompasses all the identified barriers outlined in this study. These barriers are related to various areas, including the integration of recycled aluminium into the core business, increase in supply chain collaboration, further development of product design to stimulate design for disassembly, market involvement, building knowledge and competencies, involving employees, and careful attention to customer behavior/demand. These key pillars can serve as a systematic approach or framework for integrating circular principles throughout the organization. The development of such a roadmap has the potential to maximize facilitation of the organizations sustainability strategy to effectively address and overcome all the organizational barriers identified in this study.

### Awareness and knowledge to enable market involvement

The above findings highlighted that the supplier's market involvement is dominantly one-sided and centered around core business activities that do not include circularity. This is primarily due to limited awareness regarding the benefits, limited knowledge concerning the environmental impact of aluminium applied, recycling potential, and the advantages of adopting a CBM. These causes are primarily related to the awareness and knowledge of individuals within the organization. To address these issues effectively, enhancing an individual's awareness and knowledge is vital for fostering their knowledge and commitment. This development can be achieved through various techniques, such as education initiatives and through leadership, hiring new employees, or even consulting experts (von Kolpinski et al., 2022). However, it is essential that this training focuses on explaining the long-term advantages of circular market involvement, knowledge about the environmental impact of aluminium usage, its recycling potential, and the benefits associated with integrating a CBM. Including these factors would yield the most effective alignment with the organization's needs. Besides, it is vital to access the outcomes of these training efforts to ensure its effectiveness and expectations. Involving supply chain partners into this initiative can broaden the scope of awareness and knowledge development. Armed with this knowledge, employees can create a better understanding of their decisions, align them with CBM integration, and change their attitudes towards the market. In essence, would a higher degree of market involvement concerns learning and collaboration with anchor companies, sub-supplier, and construction firms in the aluminum industry. This collaborative approach is fundamental in transitioning towards a CBM, fostering a more sustainable and process-wise transformation.

### Supply chain collaboration as enabler for integrating recycled alumnium and developing competencies

Currently, the supplier applies an aluminium alloy containing between 2% and 12% recycled content. The integration of recycled aluminium has the potential to significantly reduce carbon emissions. The Aluminium Foundation provides compelling data, indicating that the carbon footprint of recycled aluminium is 94% lower than that of primary mined aluminium (The Aluminium Association, 2021). However, recycled alloys with higher scrap percentages (ranging from 70 to 95%) often encounter quality-related issues. These issues are related to pretreatment requirements, material hardness, corrosion resistance, strength, shape, and coating quality.

These issues pose substantial barriers for integrating circular business development across the entire supply chain. Addressing these issues effectively would establish a solid foundation for progress. This effort can be made by engaging multiple firms, both within and outside the supply chain, which share a common interest in resolving these challenges. In addition, collaborative efforts to test these recycled aluminium alloys can lead to cost and time savings. This collaborative approach involved conducting tests and prototyping on a small-scale pilot test. Leveraging the facilitating effect of supply chain management can systematically address and resolve quality and composition barriers, and make these aspects more feasible. This would enable the organization to process-wise integrate alloys with a higher percentage of scrap. In addition, the integration of recycled aluminium can offer valuable insights into the tech-based competencies required and necessary modifications in the production process.

### Education to enable customer behavior and demand for recycled aluminium

This study examined a dual perspective on customer behavior and demand for recycled materials. To transition into a driving force, a strategic approach that includes both customer and industry challenges is needed. This begins with educing customers about the advantages of recycled aluminium, highlighting its environmental benefits, and upcoming governmental regulations. Additionally, it is important to address possible misconceptions regarding increasing costs and quality issues to provide a transparent and reliable perspective.

### Product design as enabler for long-term circularity

Respondents pointed out that aluminium products can be conveniently disassembled through unscrewing, whereas components adhered to aluminium plates using an adhesive substance present a more complex disassembly challenge. Decisions regarding detachment are frequently influenced by architectural and end-client demands, which are primarily driven by aesthetic or cost considerations. The organization should include circularity in deciding the method of detachment. Specifically, this would include a vision that facilitates easier detachment of product-building subsystems. This entails adopting a comprehensive perspective when considering the EoL phases of products.

### Management commitment and employee involvement drives long-term circularity

In this study, a significant majority of the supplier's respondents mentioned the driving role of management commitment behind circularity development. Both managerial respondents and decision makers expressed their strong dedication and willingness to allocate resources to develop a more sustainable business. This commitment serves as a foundational pillar for embedding CBM aspects within the organization, as described in the previous sections.

Employee involvement was another influential factor in this empirical study. The development of circular business principles in the entire organization can be supported by engaging a diverse range of employees. Creating a culture in which employees are actively engaged in contributing, entrusted with responsibilities, and included in the transition process.

## 5.5 Conclusion

The central research question guiding this study was as follows:

- *What are the drivers, barriers and enablers to a CBM for aluminium?*

Management commitment and employee involvement emerged as key drivers in this study to drive the CBM transition. The supplier organization has actively embedded sustainability within its organizational culture. Still, there is unconsciously, limited knowledge and competencies within the organization to fully facilitate the CBM transition. Tech-based skills related to process changes and daily job routines are perceived to be important, overlooking other skills and knowledge related to soft skills, which are the foundation for behavior change (von Kolpinski et al., 2022).

While respondents appeared to be aware of the necessity and urgency of sustainable business development, intrinsic motivation appeared to be present to a lesser extent. The organization's corporate sustainability strategy facilitates the transition, but a business unit strategy including specific steps to move the core business towards a CBM is missing. The core business primarily relies on products sourced from primary-mined bauxite, which is known for its negative environmental impact (The Aluminium Association, 2021). This also reflects customers' attitudes towards recycled aluminium. Although there is a positive shift in their perceptions, this has yet to translate into increased demand. The reluctance to embrace this change is rooted in the perceived higher costs and quality concerns associated with recycled aluminium. The organization's market involvement is one-sided, does not include circular activities, and is primarily focused on sustaining the financial viability of the existing business model. Additionally, assembly methods present challenges for disassembly, such as the use of adhesive substances rather than screws, which hinder circularity. Finally, the waste management of pre-consumed scrap involved selling it to a waste treatment company, without considering alloy separation and downcycling.

The organization can overcome these barriers by leveraging its internal and external strengths and initiatives. First, the corporate sustainability strategy, coupled with management commitment and employee involvement, are found to be foundational pillars to facilitate the CBM transition. Second, a process-wise business unit strategy for core business adaption should drive organizational support for CBM integration and enable feasibility in the necessary steps. These strategy steps should include a vision and mission, potentially mapped out as a roadmap. To incorporate circularity in the business model, the leadership style should also include this aspect to stimulate sustainable behavior. This can stimulate awareness and include sustainability in daily routines and decision-making. Third, market involvement should be transformed from a barrier to a driver. This transformation should begin by addressing the root causes of the one-sided market involvement, which are 1) limited employee awareness of the benefits of circular market involvement, 2) limited knowledge of the environmental impact of applied aluminium, and 3) limited knowledge of the advantages of a CBM in general. Fourth, supply chain collaboration should enable the integration of recycled aluminium. This would increase knowledge of its quality and costs, and increase trust in both recycled aluminium and CBMs. Fourth, educating customers about the advantages of recycled aluminium can reshape their role as a driving force. Finally, product design should consistently incorporate a disassembly design to identify potential improvements for scrap recycling.

- *What can we learn from this research by comparing the findings of the SLR with the results of the empirical study?*

A comparison of the findings from the empirical study with those from the literature revealed similarities and differences. This study underscores that organizations aspiring to transition to a CBM will face numerous challenges that vary from both internal dynamics and external factors. Understanding these challenges is not the main lesson, but how and why they influence matters more. Creating an understanding of the mechanisms that create drivers or barriers is vital, as it would enable researchers and organizations to effectively solve barriers and maximize the use of drivers in order to develop a CBM. Finally, it is important to note that this thesis does not provide an all-in-one solution to overcome every possible barrier to CBM development. Instead, this thesis aims to provide a comprehensive overview of the current factors influencing CBM development by investigating various aspects such as strategy, behavior, technology, and policy. It is vital to understand that the organizations included in this study have not yet fully integrated a CBM into their organization. This means that not all respondents have direct experiences in CBM integration but were approached to explain their perspective on the matter.

These findings are particularly relevant and focus on established companies seeking insights into the challenges that they may encounter when transitioning to a CBM. However, the applicability of these insights may vary for younger or smaller organizations. Different samples or industries may yield similar results, but perceptions of drivers, barriers, and enablers may differ. Therefore, the strategies proposed to overcome these barriers may not be universally applicable to every case. Instead, they offer valuable insights into larger incumbents active in the building industry for CBM implementation. In conclusion, a deeper understanding of these factors and their underlying mechanisms is essential for effectively overcoming barriers, leveraging enablers, and confidently navigating the CBM transformation path.

This study presents findings from 11 semi-structured interviews conducted with respondents from a sub-supplier, supplier, and three construction companies in the building industry. Building upon these findings, we have developed best-practice strategies to support the supplier to overcome these barriers and leverage enablers. These strategies hold particular significance, as they are specifically developed to address barriers in the supply chain through a combination of internal and external strengths and initiatives.

# References

Abarca-Guerrero, L., Lobo-Ugalde, S., Méndez-Carpio, N., Rodríguez-Leandro, R., & Rudin-Vega, V. (2022). Zero Waste Systems: Barriers and Measures to Recycling of Construction and Demolition Waste. *Sustainability (Switzerland)*, *14*(22), 1–16. https://doi.org/10.3390/su142215265

Abuabara, L., Paucar-Caceres, A., & Burrowes-Cromwell, T. (2019). Consumers' values and behaviour in the Brazilian coffee-in-capsules market: promoting circular economy. *International Journal of Production Research*, *57*(23), 7269–7288. https://doi.org/10.1080/00207543.2019.1629664

Abubakar. (2018). *An investigation into drivers, barriers and policy implications of circular economy using a mixed-mode research approach*. *March*. https://etheses.whiterose.ac.uk/20947/

Amit, R., & Zott, C. (2010). Business Model Innovation: Creating value in times of change. *Long Range Planning*, *3*(2–3), 216–226. http://linkinghub.elsevier.com/retrieve/pii/S0024630109000533

Araujo Galvão, G. D., De Nadae, J., Clemente, D. H., Chinen, G., & De Carvalho, M. M. (2018). Circular Economy: Overview of Barriers. *Procedia CIRP*, *73*, 79–85. https://doi.org/10.1016/j.procir.2018.04.011

Baden-Fuller, C., & Morgan, M. S. (2010). Business models as models. *Long Range Planning*, *43*(2–3), 156–171. https://doi.org/10.1016/j.lrp.2010.02.005

Berlin, D., Feldmann, A., & Nuur, C. (2022). Supply network collaborations in a circular economy: A case study of Swedish steel recycling. *Resources, Conservation and Recycling*, *179*(December 2021), 106112. https://doi.org/10.1016/j.resconrec.2021.106112

Bertassini, A. C., Ometto, A. R., Severengiz, S., & Gerolamo, M. C. (2021). Circular economy and sustainability: The role of organizational behaviour in the transition journey. *Business Strategy and the Environment*, *30*(7), 3160–3193. https://doi.org/10.1002/bse.2796

Bey, N., Hauschild, M. Z., & McAloone, T. C. (2013). Drivers and barriers for implementation of environmental strategies in manufacturing companies. *CIRP Annals - Manufacturing Technology*, *62*(1), 43–46. https://doi.org/10.1016/j.cirp.2013.03.001

Bhandari, P. (2023). *Sampling Bias and How to Avoid It | Types & Examples*. https://www.scribbr.com/research-bias/sampling-bias/

Bhattacharya, P. P. (2016). *Engaging Employees to Create a Sustainable Business*. https://ssir.org/articles/entry/engaging_employees_to_create_a_sustainable_business#

Bocken., Pauw, Bakker, & Grinten, van der. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N., Strupeit, L., Whalen, K., & Nußholz, J. (2019). A review and evaluation of circular business model innovation tools. *Sustainability (Switzerland)*, *11*(8), 1–25. https://doi.org/10.3390/su11082210

Caldera, S., Ryley, T., & Zatyko, N. (2020). Enablers and barriers for creating a marketplace for construction and demolition waste: A systematic literature review. *Sustainability*

*(Switzerland)*, *12*(23), 1–19. https://doi.org/10.3390/su12239931

Cantore, N., & Mazzanti, M. (2023). *Small and medium-sized enterprises can drive the circular economy*. https://iap.unido.org/articles/small-and-medium-sized-enterprises-can-drive-circular-economy

Chauhan, C., Singh, A., & Luthra, S. (2021). Barriers to industry 4.0 adoption and its performance implications: An empirical investigation of emerging economy. *Journal of Cleaner Production*, *285*, 124809. https://doi.org/10.1016/j.jclepro.2020.124809

Chen, C. W. (2020). Improving circular economy business models: Opportunities for Business and Innovation A new framework for businesses to create a truly circular economy. *Johnson Matthey Technology Review*, *64*(1), 48–58. https://doi.org/10.1595/205651320x15710564137538

Chertow, M. R. (2000). Industrial symbiosis: Literature and taxonomy. *Annual Review of Energy and the Environment*, *25*(November 2000), 313–337. https://doi.org/10.1146/annurev.energy.25.1.313

Chiappetta Jabbour, C. J., De Camargo Fiorini, P., Wong, C. W. Y., Jugend, D., Lopes De Sousa Jabbour, A. B., Roman Pais Seles, B. M., Paula Pinheiro, M. A., & Ribeiro da Silva, H. M. (2020). First-mover firms in the transition towards the sharing economy in metallic natural resource-intensive industries: Implications for the circular economy and emerging industry 4.0 technologies. *Resources Policy*, *66*(July 2019), 101596. https://doi.org/10.1016/j.resourpol.2020.101596

Chiappinelli, O., Gerres, T., Neuhoff, K., Lettow, F., de Coninck, H., Felsmann, B., Joltreau, E., Khandekar, G., Linares, P., Richstein, J., Śniegocki, A., Stede, J., Wyns, T., Zandt, C., & Zetterberg, L. (2021). A green COVID-19 recovery of the EU basic materials sector: identifying potentials, barriers and policy solutions. *Climate Policy*, *21*(10), 1328–1346. https://doi.org/10.1080/14693062.2021.1922340

Choy, L. T. (2014). The Strengths and Weaknesses of Research Methodology: Comparison and Complimentary between Qualitative and Quantitative Approaches. *IOSR Journal of Humanities and Social Science*. https://doi.org/10.9790/0837-194399104

Cooper, T. (1994). Beyond The longer life option The longer life option. *The New Economics Foundation*, *November*, 1–212.

Copper Alliance. (2022). *Facilitating a greener, more renewable, energy efficient and connected world*. https://copperalliance.org/

Corral-Marfil, J. A., Arimany-Serrat, N., Hitchen, E. L., & Viladecans-Riera, C. (2021). Recycling technology innovation as a source of competitive advantage: The sustainable and circular business model of a bicentennial company. *Sustainability (Switzerland)*, *13*(14). https://doi.org/10.3390/su13147723

de Boer, B. F., Rietveld, E., Rodrigues, J. F. D., & Tukker, A. (2021). Global environmental and socio-economic impacts of a transition to a circular economy in metal and electrical products: A Dutch case study. *Journal of Industrial Ecology*, *25*(5), 1264–1271. https://doi.org/10.1111/jiec.13133

De Pádua Pieroni, M., Pigosso, D. C. A., & McAloone, T. C. (2018). Sustainable Qualifying Criteria for Designing Circular Business Models. *Procedia CIRP*, *69*(May), 799–804. https://doi.org/10.1016/j.procir.2017.11.014

Dominish, E., Retamal, M., Sharpe, S., Lane, R., Rhamdhani, M. A., Corder, G., Giurco, D.,

& Florin, N. (2018). “Slowing” and “narrowing” the flow of metals for consumer goods: Evaluating opportunities and barriers. *Sustainability (Switzerland)*, *10*(4). https://doi.org/10.3390/su10041096

European Commission. (2018). *Developments and Forecasts of Aggravating Resource Scarcity*. https://knowledge4policy.ec.europa.eu/foresight/topic/aggravating-resource-scarcity/more-developments-relevant-aggravating-resource-scarcity_en#water

Eurostat. (2023). *Waste statistics*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics

Fellner, J., Lederer, J., Purgar, A., Winterstetter, A., Rechberger, H., Winter, F., & Laner, D. (2015). Evaluation of resource recovery from waste incineration residues - The case of zinc. *Waste Management*, *37*, 95–103. https://doi.org/10.1016/j.wasman.2014.10.010

Fellner, Johann, Lederer, J., Scharff, C., & Laner, D. (2017). Present Potentials and Limitations of a Circular Economy with Respect to Primary Raw Material Demand. *Journal of Industrial Ecology*, *21*(3), 494–496. https://doi.org/10.1111/jiec.12582

Fragapane, G., Schulte, K. O., Eleftheriadis, R., Reke, E., & Ringen, G. (2022). A cross-disciplinary, cross-organizational approach to sustainable design and product innovation in the aluminum industry. *Procedia CIRP*, *107*, 59–64. https://doi.org/10.1016/j.procir.2022.04.010

Franco, M. A. (2017). Circular economy at the micro level: A dynamic view of incumbents’ struggles and challenges in the textile industry. *Journal of Cleaner Production*, *168*, 833–845. https://doi.org/https://doi.org/10.1016/j.jclepro.2017.09.056

Gaur, J., Mani, V., Banerjee, P., Amini, M., & Gupta, R. (2019). Towards building circular economy: A cross-cultural study of consumers’ purchase intentions for reconstructed products. *Management Decision*, *57*(4), 886–903. https://doi.org/10.1108/MD-07-2018-0728

Geissdoerfer, M., Pieroni, M. P. P., Pigosso, D. C. A., & Soufani, K. (2020). Circular business models: A review. *Journal of Cleaner Production*, *277*, 123741. https://doi.org/10.1016/j.jclepro.2020.123741

Geissdoerfer, M., Vladimirova, D., & Evans, S. (2018). Sustainable business model innovation: A review. *Journal of Cleaner Production*, *198*, 401–416. https://doi.org/10.1016/j.jclepro.2018.06.240

Golev, A. (2015). Barriers to Industrial Symbiosis: Insights from the Use of a Maturity Grid. *Journal of Industrial Ecology*. https://doi.org/https://doi.org/10.1111/jiec.12159

Govindan, K., & Hasanagic, M. (2018). A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective. *International Journal of Production Research*, *56*(1–2), 278–311. https://doi.org/10.1080/00207543.2017.1402141

Guldmann, E., & Huulgaard, R. D. (2019). Barriers to circular business model innovation: A multiple-case study. *Journal of Cleaner Production*, *243*, 118160. https://doi.org/10.1016/j.jclepro.2019.118160

Guldmann, E., & Huulgaard, R. D. (2020). Barriers to circular business model innovation: A multiple-case study. *Journal of Cleaner Production*, *243*, 118160. https://doi.org/10.1016/j.jclepro.2019.118160

Gutberlet, J. (2016). Ways Out of the Waste Dilemma : Transforming Communities in the

Global South. *RCC Perspectives: Transformations in Environment and Society*, *A Future w*(3), 55–68.

Hina, M., Chauhan, C., Kaur, P., Kraus, S., & Dhir, A. (2022). Drivers and barriers of circular economy business models: Where we are now, and where we are heading. *Journal of Cleaner Production*, *333*(July 2021), 130049. https://doi.org/10.1016/j.jclepro.2021.130049

Hofmann, F., & Jaeger-Erben, M. (2020). Organizational transition management of circular business model innovations. *Business Strategy and the Environment*, *29*(6), 2770–2788. https://doi.org/10.1002/bse.2542

Hool, A., Schrijvers, D., van Nielen, S., Clifton, A., Ganzeboom, S., Hagelueken, C., Harada, Y., Kim, H., Y. Ku, A., Meese-Marktscheffel, J., & Nemoto, T. (2022). How companies improve critical raw material circularity: 5 use cases: Findings from the International Round Table on Materials Criticality. *Mineral Economics*, *35*(2), 325–335. https://doi.org/10.1007/s13563-022-00315-5

Horizon. (2016). *D1 Synthesis of the state-of-the-art: Key barriers and opportunities for Materials Passports and Reversible Building Design in the current system*. http://www.bamb2020.eu/wp-content/uploads/2016/03/D1_Synthesis-report-on-State-of-the-art_20161129_FINAL.pdf

Institute for Work & Health. (2014). *Selection bias*. https://www.iwh.on.ca/what-researchers-mean-by/selection-bias#:~:text=Selection bias is a kind,and cross-sectional studies).

International Aluminum Institute. (2009). *Global Aluminium Recycling: A Cornerstone of Sustainable Development; International Aluminium Institute*. https://international-aluminium.org/resource/global-aluminium-recycling-a-cornerstone-of-sustainable-development/

Johansson, N., Krook, J., & Frändegård, P. (2017). A new dawn for buried garbage? An investigation of the marketability of previously disposed shredder waste. *Waste Management*, *60*, 417–427. https://doi.org/10.1016/j.wasman.2016.05.015

Kaur et al. (2022). *Bamboo for value-added products* (pp. 5437–5463). https://doi.org/10.15376/biores.17.3.Kaur Keywords:

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union (EU). *Ecological Economics*, *150*(December 2017), 264–272. https://doi.org/10.1016/j.ecolecon.2018.04.028

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*(April), 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Korinek, J. (2019). Trade restrictions on minerals and metals. *Mineral Economics*, *32*(2), 171–185. https://doi.org/10.1007/s13563-018-0161-z

Liu, Y., & Bai, Y. (2014). An exploration of firms' awareness and behavior of developing circular economy: An empirical research in China. *Resources, Conservation and Recycling*, *87*, 145–152. https://doi.org/10.1016/j.resconrec.2014.04.002

McKinsey & Company. (2020). *Supply chain risk management is back*. https://www.mckinsey.com/capabilities/operations/our-insights/supply-chain-risk-management-is-back

Mentink, B. (2014). Circular Business Model Innovation: A process framework and a tool for business model innovation in a circular economy. *Delft University of Technology*, 168.

Neves, A., Godina, R., Azevedo, S. G., Pimentel, C., & Matias, J. C. O. (2019). The Potential of Industrial Symbiosis: Case Analysis and Main Drivers and Barriers to Its Implementation. *Sustainability (Switzerland)*, *11*(24), 1–68. https://doi.org/10.3390/su11247095

Nickless, E., & Yakovleva, N. (2022). Resourcing Future Generations Requires a New Approach to Material Stewardship. *Resources*, *11*(8), 1–17. https://doi.org/10.3390/resources11080078

Nidomolu, R. (2009). Why Sustainability Is Now the Key Driver of Innovation. *Harvard Business Review*, 12. https://www.billsynnotandassociates.com.au/images/stories/documents/sustainability_the_key_driver_of_innovation.pdf

Oberthür, S., Khandekar, G., & Wyns, T. (2021). Global governance for the decarbonization of energy-intensive industries: Great potential underexploited. *Earth System Governance*, *8*, 100072. https://doi.org/10.1016/j.esg.2020.100072

Orji, I. J. (2019). Examining barriers to organizational change for sustainability and drivers of sustainable performance in the metal manufacturing industry. *Resources, Conservation and Recycling*, *140*(August 2018), 102–114. https://doi.org/10.1016/j.resconrec.2018.08.005

Osterwalder and Pigneur. (2010). *Business Model Generation*. Wiley & Sons, Hoboken, 2010.

Porter, M. E., & Kramer, M. R. (2019). Creating Shared Value. In *Managing Sustainable Business* (pp. 323–346). Springer Netherlands. https://doi.org/10.1007/978-94-024-1144-7_16

Prisma. (2021). *Welcome to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) website!* https://prisma-statement.org/

Raabe, D., Ponge, D., Uggowitzer, P. J., Roscher, M., Paolantonio, M., Liu, C., Antrekowitsch, H., Kozeschnik, E., Seidmann, D., Gault, B., Geuser, D., Deschamps, A., Hutchinson, C., Liu, C., Li, Z., Prangnell, P., Robson, J., Shanthraj, P., Vakili, S., … Pogatscher, S. (2022). *Progress in Materials Science Making sustainable aluminum by recycling scrap : The science of " dirty " alloys*. *128*(April). https://doi.org/10.1016/j.pmatsci.2022.100947

Rashid, A., Asif, F. M. A., Krajnik, P., & Nicolescu, C. M. (2013). Resource conservative manufacturing: An essential change in business and technology paradigm for sustainable manufacturing. *Journal of Cleaner Production*, *57*, 166–177. https://doi.org/10.1016/j.jclepro.2013.06.012

Richardson, J. E. (2011). The Business Model: An Integrative Framework for Strategy Execution. *SSRN Electronic Journal*, 1–27. https://doi.org/10.2139/ssrn.932998

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. *Sustainability (Switzerland)*, *8*(11). https://doi.org/10.3390/su8111212

Robson, C. (2002). Real World Research: A Resource for Social Scientists and Practitioner-Researchers. *Oxford: Blackwell Publishers Ltd*, *2nd edition*.

Schaltegger, S., Hansen, E. G., & Lüdeke-Freund, F. (2016). Business Models for Sustainability: Origins, Present Research, and Future Avenues. *Organization and Environment*, *29*(1), 3–10. https://doi.org/10.1177/1086026615599806

Sihvonen, S., & Ritola, T. (2015). Conceptualizing ReX for aggregating end-of-life strategies in product development. *Procedia CIRP*, *29*, 639–644. https://doi.org/10.1016/j.procir.2015.01.026

Soo, V. K., Compston, P., & Doolan, M. (2019). Life cycle modelling of end-of-life products: Challenges and opportunities towards a circular economy. *Procedia CIRP*, *80*, 607–612. https://doi.org/10.1016/j.procir.2019.01.092

Stahel. (2010). *The Performance Economy*.

Stahel. (2018). *Circular economy*. *March 2016*. https://doi.org/10.1038/531435a

Stewart, R., Bey, N., & Boks, C. (2016). Exploration of the Barriers to Implementing Different Types of Sustainability Approaches. *Procedia CIRP*, *48*, 22–27. https://doi.org/10.1016/j.procir.2016.04.063

Stewart, R., Niero, M., Murdock, K., & Olsen, S. I. (2018). Exploring the Implementation of a Circular Economy Strategy: The Case of a Closed-loop Supply of Aluminum Beverage Cans. *Procedia CIRP*, *69*(May), 810–815. https://doi.org/10.1016/j.procir.2017.11.006

Stubbs, W. (2016). *Sustainable Entrepreneurship and B Corps*. https://doi.org/https://doi.org/10.1002/bse.1920

Stubbs, W., & Cocklin, C. (2008). Conceptualizing a "Sustainability Business Model." *Organization & Environment*, *21*(2), 103–127. https://doi.org/10.1177/1086026608318042

Tague, N. (2005). *The Quality Toolbox, Second Edition*. https://asq.org/quality-press/display-item?item=H1224&utm_source=pareto&utm_medium=webpage&utm_campaign=pareto&utm_id=LAQ

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning*, *43*(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

The Aluminium Association. (2021). *Aluminum Carbon Footprint Cut in Half Over 30 Years*. https://www.aluminum.org/aluminum-carbon-footprint-cut-half-over-30-years

The Ellen MacArthur Foundation. (n.d.). *What is a circular economy?* https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

Torres-Guevara, L. E., Prieto-Sandoval, V., & Mejia-Villa, A. (2021). Success drivers for implementing circular economy: A case study from the building sector in colombia. *Sustainability (Switzerland)*, *13*(3), 1–17. https://doi.org/10.3390/su13031350

Trading Economics. (2023). *Aluminium*. https://tradingeconomics.com/commodity/aluminum

Tura, N., Hanski, J., Ahola, T., Ståhle, M., Piiparinen, S., & Valkokari, P. (2019). Unlocking circular business: A framework of barriers and drivers. *Journal of Cleaner Production*, *212*, 90–98. https://doi.org/10.1016/j.jclepro.2018.11.202

Ünal, E., Urbinati, A., Chiaroni, D., & Manzini, R. (2019). Value Creation in Circular Business Models: The case of a US small medium enterprise in the building sector. *Resources, Conservation and Recycling*, *146*(December 2018), 291–307. https://doi.org/10.1016/j.resconrec.2018.12.034

UNECE. (2023). *Circular Economy*. https://unece.org/trade/CircularEconomy
United Nations. (2021). *2021 Global Status Report for Buildings and Construction*. https://www.unep.org/resources/report/2021-global-status-report-buildings-and-construction
University of Twente. (2022). *Informed Research Participation Procedure*. https://www.utwente.nl/en/bms/research/ethics-domainHSS/informed-consent-procedure/
Urbinati, A., Franzò, S., & Chiaroni, D. (2021). Enablers and Barriers for Circular Business Models: an empirical analysis in the Italian automotive industry. *Sustainable Production and Consumption*, *27*, 551–566. https://doi.org/10.1016/j.spc.2021.01.022
van Keulen, M., & Kirchherr, J. (2021). The implementation of the Circular Economy: Barriers and enablers in the coffee value chain. *Journal of Cleaner Production*, *281*, 125033. https://doi.org/10.1016/j.jclepro.2020.125033
Vermunt, D. A., Negro, S. O., Verweij, P. A., Kuppens, D. V., & Hekkert, M. P. (2019). Exploring barriers to implementing different circular business models. *Journal of Cleaner Production*, *222*, 891–902. https://doi.org/10.1016/j.jclepro.2019.03.052
von Kolpinski, C., Yazan, D. M., & Fraccascia, L. (2022). The impact of internal company dynamics on sustainable circular business development: Insights from circular startups. *Business Strategy and the Environment*, *February*, 1–20. https://doi.org/10.1002/bse.3228
Wells, P., & Seitz, M. (2005). Business models and closed-loop supply chains: A typology. *Supply Chain Management*, *10*(4), 249–251. https://doi.org/10.1108/13598540510612712
Winterstetter, A., Heuss-Assbichler, S., Stegemann, J., Kral, U., Wäger, P., Osmani, M., & Rechberger, H. (2021). The role of anthropogenic resource classification in supporting the transition to a circular economy. *Journal of Cleaner Production*, *297*. https://doi.org/10.1016/j.jclepro.2021.126753
World Economic Forum. (2014). *Towards the Circular Economy : Accelerating the scale-up across global supply chains*. *January*, 1–64.
Wzorek, A., Ivashchuk, O., & Wzorek, Ł. (2017). Analysis of the factors influencing the price of aluminum on the world market. *Mechanik*, *90*(7), 565–567. https://doi.org/10.17814/mechanik.2017.7.74
Zeng, X. (2023). Win-Win: Anthropogenic circularity for metal criticality and carbon neutrality. *Frontiers of Environmental Science and Engineering*, *17*(2), 1–12. https://doi.org/10.1007/s11783-023-1623-2

# Appendix

## A - Company description

The supplier has grown from a small family business involved in trading iron to a versatile organization with over 500 employees. The organization is active in the construction sector, focusing on building, industry, security and sustainability. A key objective of suplier is to address social issues through entrepreneurial action. For instance, the company provides employment opportunities for individuals with physical or mental disabilities (personal communication, February 2023).

The organization consists of several business units. One of the main units, aluminium, is the central point for this study. This business unit assembles aluminium products from its warehouse for various industries, with a focus on the construction industry as the primary contractor. This business unit works on new construction and renovation projects on behalf of construction companies, housing associations, architects and private individuals. Currently, its global aluminium business model globally consists of a total system for a masonry profile, a specialist position in aluminium modification, aluminium sheet metal, aluminium sun blinds, aluminium balcony fences, aluminium coverings for roofs and service and maintenance for all products within the business model (personal communication, 14 February 2023). According to the Division Leader of Aluminium, the unit supplies 95% of its products and services to the residual and non-residual construction sectors, where 94% of its core business is wall coverings, water hammers, and façade elements, such as flower frames, façade bands, and façade cladding (personal communication, February 2023).

Other business units of the supplier include Beveiligingstechniek, Industrietechniek, Toegangstechniek, Industriedeuren, Bouw en Industrie and Duurzaam. The organization is characterized by several core value drivers, including craftsmanship, entrepreneurship, collaboration, reliability, mutual respect and customer drive (personal communication, February 2023).

## B - Research planning

| Month | Process | Data collection method | Outcome |
|---|---|---|---|
| **November/ December / January** | Research proposal | - | Research proposal |
| **February/ March** | Systematic literature review | Systematic literature review | Overview of the drivers, barriers and enablers according to the literature |
| **April** | Prepare interview content | Scan outcome systematic literature review | Define interview factors out of article sheets and select candidates |
| **April** | Prepare interview content | Define questions | Interview schedule |
| **May** | Interviews with supplier employees | Semi-structured interviews | Interview outcome |
| **May** | Interviews with<br>- Sub-supplier<br>- Supplier<br>- Construction companies | Semi-structured interviews | Interview outcome |
| **March/ April/May** | Transcribe and code interviews | Coding | First and second-order codes connected to interview outcome |
| **June/July** | Developing a theoretical framework and practical advice | - | Theoretical framework/ Strategies |
| **September** | Finalizing report | - | Final report |
| **September** | Reserve | - | Reserve |
| **October** | Deadline report | - | Final report |

## C - Barriers and enablers for the metallic industry

La Farga is a bicentennial Catalan company that manufactures semi-finished copper products using secondary copper as its primary input, instead of mined copper. Copper is highly recyclable and can be reused repeatedly without any loss in quality or performance, which is comparable to the characteristics of aluminium (Copper Alliance, 2022; Corral-Marfil et al., 2021). Various reasons why the organization has made recycling's core business is closely related to the enablers described in the study by Tura et al., (2019).

However, despite La Farga's position, the organization has not stopped its production using mined copper. Instead, the company established a subsidiary to manufacture the copper wires. Since then, the sales income from products manufactured using mined copper has grown proportionally more than the sales of products manufactured using scrap copper (Corral-Marfil et al., 2021). Despite a company's strategic focus on recycling, its development and growth may be impeded by various barriers. This study describes cultural barriers as more important, contrary to popular belief, while technological barriers are less important. The market and regulatory barriers are of intermediate importance. The main barrier is the lack of awareness and willingness among clients to participate in the circular economy, especially among purchasing and production departments, which does not account for sustainability departments (Kirchherr et al., 2018).

" *The main barrier is the lack of awareness and willingness to participate in a Circular Economy*"

Stewart et al., (2018) investigated the business implementation of a beverage producer's circular strategy, which involves creating a closed-loop supply of aluminium beverage cans. This study describes that the regulation of waste trading is less of an issue because of the presence of waste criteria in the EU, and challenges related to complex materials are low. However, more significant challenges include resource quality, quantity, consumer behavior, and dispersed products (Stewart et al., 2018).

These challenges require separate waste streams for the beverage cans used. The high upfront investment and realization of financial gains demand teaming up with other beverage brands. Infrastructure and reverse logistics are strengths and challenges. The biggest challenge in developing a change in the existing ecosystem is the powerful actors with investment interests in the current business systems. Another challenge is disinterest in non-core business activities, which may prevent retailers from engaging in this network (Stewart et al., 2018).

## D - Comparison of drivers, barriers and enablers from literature review

According to Araujo Galvão et al., (2018), the most frequent and major barriers to the implementation of a circular economy are technological, policy and regulatory, financial and economic, managerial, customer, and social barriers and performance indicators. Bey et al., (2013) describe that there is a lack of information on environmental impact and a lack of expert knowledge and allocated resources. Guldmann & Huulgaard, (2019) reveal 31 external and internal barriers. External barriers range from governmental and technological, while internal barriers are related to a lack of management support, knowledge, resource and incentive structures and organizational adaptability, complexity in organizational design and unclear business cases (Guldmann & Huulgaard, 2019). In this case, barriers to circular business model innovation have been found at all socio-technical levels. Most barriers are encountered by companies at the organizational level, followed by the value chain, employee level and finally, market and institutional level (Guldmann & Huulgaard, 2019).

Araujo Galvão et al., (2018), Guldmann & Huulgaard (2019), Urbinati et al., (2021) and Hina et al., (2022) describe global comparable barrier categories, where technical, policy and regulation, consumer, financial, environmental and economic barrier categories dominate as micro or external barrier category. At an organizational level, social barriers, are categorized as impactful to the implementation of the circular business model (Guldmann & Huulgaard, 2019; Hina et al., 2022). Urbinati et al., (2021) and Hina et al., (2022) describe that further organizational barriers are a company's strategy, collaboration, internal stakeholders, product design, a low management risk appetite, shirt-middle term management incentive scheme, high organizational inertia, and high complexity of the organizational hierarchy.When comparing the barriers in the case of Corral-Marfil et al., (2021) with the previously described barriers, it can be noticed that global barrier categories are matched and ranked on impact. The main barrier is the lack of awareness and willingness of clients to take part in the circular economy, followed by cultural barriers with high impact. Market and regulation barriers have an intermediate impact, and finally, technological barriers are less important. In the case of aluminium, Stewart et al., (2018) describe that the presence of regulation is less important and the main challenges are: resource quality and quantity, infrastructure, investments and consumer behaviour, and dispersed products. In addition to external factors the following internal factors will be considered: organizational behavior, technology, financial, product design and the company's strategy and policy. This section aims to provide an overview of the comprehensive dynamic field and interrelated factors that influence circular business model implementation.

Tura et al., (2019) and Hina et al., (2022) outline various categories of drivers to a circular business model, including environmental, social, financial, technological and informational, supply chain and organizational. Organizational drivers are related to the potential to differentiate and strengthen the company brand, and increase understanding of sustainability demands, including circularity in the company's strategy and goals, the development of skills and capabilities, leadership, innovational research and organizational infrastructure. Enablers to a circular business model are divided into technical, economic, organizational, supply chain/customer, political and environmental categories (Urbinati et al., 2021). Specific enablers identified in previous studies include the company's environmental culture and awareness, financial attractiveness and personal knowledge (Rizos et al., 2016; Urbinati et al., 2021). Corral-Marfil et al., (2021) identify environmental, economic, social, technological, supply chain and management reverse network and organizational enablers. Other enablers are focused to differentiate and strengthen the company's brand and increase the understanding of demands of sustainability and the integration of circularity into the strategy and goals of the company.

Although the categories and specific factors identified by these studies are general and case-specific, they are useful in understanding the factors an organization may face and how these factors interrelate when shifting to a circular business model from a supply chain perspective (Tura et al., 2019).

The study by Bertassini et al., (2021) presents a closed-loop model describing hard and soft skills for a circular economy oriented culture. This model indicates that mindsets are rooted in values. Values are translated into daily behavior and behavior is executed by the combination of right capabilities (theoretical knowledge and abilities). Capabilities can form competences when they are repeatedly applied and when they are supported by the attitude (combination of value, mindsets and behaviors). In this case, awareness could be interpreted as subpart of an individual's mindset that shapes behavior and finally capabilities and competences. So awareness, behavior, capabilities and competence could be created from mindset perspective, but also via sustainable initiatives through capabilities and competences.

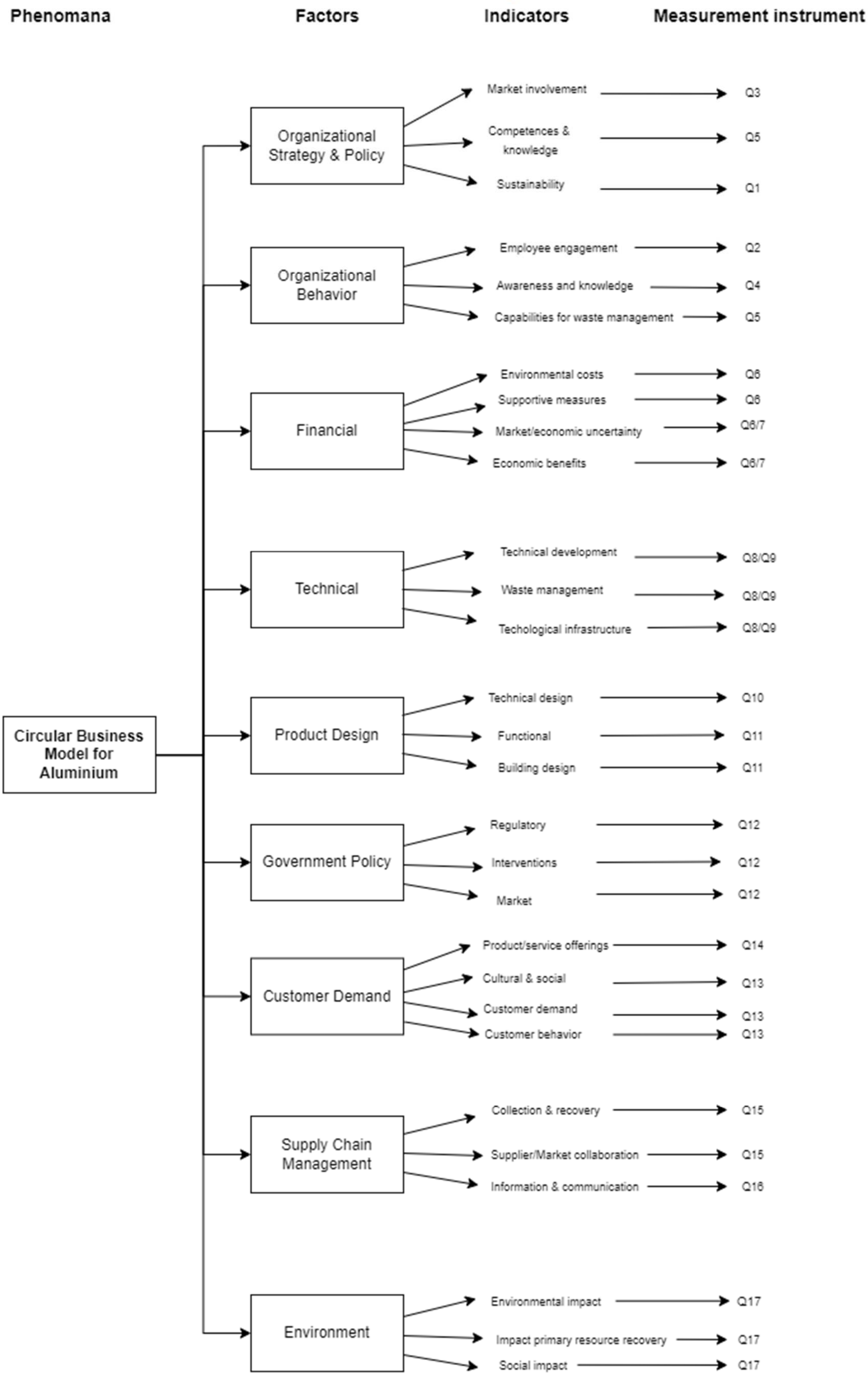
Once focusing on the aluminium production process, is thermal energy commonly supplied by thermal energy, which can be replaced by electrical energy due to the low temperature of the Bayer process (180 degrees Celsius). Alumina is processed via electrolysis, making aluminium production process relative intensive in Gj/t. Optimization of this process could reduce energy demand by 15%, which have been implemented on an industrial scale in the Norwegian plant Hydro. Carbon anode consumption is the main source of emissions (Chiappinelli et al., 2021). Even when using decarbonized electrical energy, emissions of a about 304 $CO_2$ per ton aluminium remains. Carbon-free anodes are currently not implemented on industrial-scale due to market readiness. Recycling of aluminium is limited by availability and purity of scrap, which form quantity and quality barriers. Predicted is that the availability of post-consumed scrap will grow (Chiappinelli et al., 2021).

Export taxes do also have influence the accessibility of the supply of materials and strong swings of prices. Consequently will this result in higher end-product prices. This may lower the threshold to export waste materials abroad (Korinek, 2019). Once keeping the focus on the role of the international governance several institutions can be mentioned. The Paris Agreement (PA) has a global decarbonizations vision but lacks sectorial specifications. Also does the PA not specially focus on energy intensive industries such as aluminum, iron, steel and cement (Oberthür et al., 2021). The G20 attempted to phase out subsidies and enhance regulation ton anti-dumping and cut over-capacity, but this does not come close to limiting international emissions. The World Trade Organization (WTO) has significantly supported countries that would like to stick to their import and exclude unfair import. The UNFCCC/PA, CSI and ICCA contribute to increase transparency and accountability. Financial support is gained through the UNFCCC/PA, World Bank and UNIDO. Technical development is supported by the UNFCCC.UNEP, UNIDO and PA. Additionally, did the ICAE contribute to technological collaboration programs.

From supplier perspective does the organization has one long-term and quality-oriented supplier who is responsible for delivering aluminum sheets. In the last three years did the supplier approximately deliver a weight of 270 tons of aluminium to the supplier (personal communication, May 2022). According to this information it was vital to include interview candidates who were closely in this collaboration process. Therefore three candidates were selected from this supplier: Account Manager Aluminium (to gain an overview from purchase perspective), Sustainability Manager (to gain from global perspective) and Account Manager Recycling (to gain overview from recycling perspective).

Once selected candidates from supplier, it was important to take the role of the specific individual into consideration. Basically, two candidates were selected who were directly involved in the aluminium department: Manager Aluminium and Logistic Coordinatior Aluminium. These two candidates were directly active in operational field. Besides operational perspective, are three candidates selected who are having a strategical role in the organization: Shareholder, Director and Corporate Social Responsibility Manager. These candidates directly have effect on strategical decisions on sustainability and circularity transitions in the organization.

## E - Translation of theoretical model to interview questions



## F - Interview guideline

| Time | Content |
|---|---|
| 1 minutes | **Index**<br>• Introduction<br>• Background<br>• Experience & knowledge<br>• Part 1<br>• Part 2<br>• Conclusion<br><br>**Other relevant information**<br>• Duration: 30-45 minuten<br>• Type questions: Open questions<br>• Reporting: Interview will be recorded<br>• Anonimaty: Guaranteed<br>• Confidentially: Guaranteed<br>• Questions? |
| 2 minutes | **Introduction**<br>1.1. Start by introducing myself and purpose of the interview<br>1.2. Explain the purpose of the research, goals and overview |
| 5 minutes | **Background**<br>1.3. Ask the participant to provide some background information about themselves (name, occupation, educational background, function)<br>1.4. Ask the participant how they came to be interested in the topic being researched |

| | |
|---|---|
| 30-40 minutes | **Block 1 – Organizational strategy and policy, organizational behavior and financial factors**<br>Q1 What is your perspective on the translation within your division of the sustainability/circularity strategy of the company?<br><br>Q1 Wat is je visie op de praktische vertaling van de duurzaamheid/circulariteitsstrategie naar de aluminiumdivisie?<br><br>Q2 Could you explain the initiatives of your organizational division in sustainable/circular incentives of the organization?<br><br>Q2 Kun je de toelichten hoe de aluminiumdivisie betrokken wordt bij duurzaamheid/circulariteitsinitiatieven van de organisatie?<br><br>Q3 How does the organizational division involve other company's in the supply chain in sustainable/circular initiatives? (Note: suppliers and customers e.g.)<br><br>Q3 Hoe betrekt de aluminiumdivisie andere bedrijven in de keten bij duurzame en circulaire initiatieven? |

Q4 Could your explain your view on sustainability and circularity?

Q4 Kun je jouw visie op duurzaamheid en circulariteit toelichten?

Q5 If we make the transition to a circular business model, how would you rate you knowledge/capabilities/competneices on this topic?

Q5 Als het bedrijf de overstap maakt naar een duurzaam/circulair bedrijfsmodel, hoe zou je dan je kennis/capaciteiten/competenties over dit onderwerp inschatten?

Q6 What is your view on the financial side of a transitioning to a sustainable/circular business model?

Q6 Wat is jouw visie op de financiële kant van een transitie naar een duurzaam/circulair bedrijfsmodel?

Q7 What supportive financial measures does the organization takes to become more sustainable/circular? (Note: budgetary allocation)

Q7 Van welke financiële middelen maakt de organisatie intern en extern gebruik van om duurzamer en circulair te worden? (Opmerking: budgettaire toewijzing)

**Block 2 – Technological, product design and governmental factors**
Q8 Could you explain what technologies the organization can adopt to improve sustainability/circularity (in the supply chain)? (Note: physical, software, programs, platforms)

Q8 Kun je uitleggen welke technologieën de aluminiumdivisie toepast/kan toepassen om duurzaamheid/circulariteit (in de toeleveringsketen) te verbeteren? (Opmerking: fysieke machines, software, programma's en platforms, technologie voor groene energie)

Q9 What are the requirements for reusing aluminium waste and scrap for our primary production process?

Q9 Aan welke eisen dient aluminiumafval en -schroot te voldoen om het te kunnen gebruiken in het aluminiumbewerkingsproces?

(Opmerking: deelbaarheid is de mogelijkheid van een product om te worden gedeeld of hergebruikt door meerdere gebruikers van toepassingen. In de bouw betekent hoge deelbaarheid dat het is ontworpen om gemakkelijk te worden gedemonteerd of opnieuw te worden gebruikt voor gebruik in andere gebouwen. Onderhoudsgemak verwijst naar hoe een product kan worden onderhouden, gerepareerd of vervangen)

Komende twee vragen focussen op het productontwerp:
De eerste op het ontwerp van het product zelf.

| | |
|---|---|
| | Q10What could be changes in the design of the product that could improve our aluminium product are optimized for recoverability and reusability?<br><br>Q10 Wat zouden veranderingen in het productontwerp kunnen zijn die de terugwinbaarheid en het hergebruik kunnen stimuleren? (betreft het ontwerp van het product)<br><br>De tweede vraag focust op de eindbestemming waarin het product is gemonteerd<br><br>Q11 What is your view on the serviceability and shareability of our aluminium product?<br><br>Q11 Welke veranderingen kunnen op het product toegepast worden om de levensduur te verlengen en hergebruik te stimuleren in de toepassing?<br><br>(Note: Regulations: Increasement of landfill tax, Extended Producer Responsibility (EPS) requires that producers take responsibility for collection and recycling of products. Incentives: Funding opportunities and tax incentives.<br><br>(Opmerking: Regelgeving: verhoging van belasting op afval storten, product verantwoordelijkheid (ESP) vereist dat producenten verantwoordelijkheid nemen voor de inzameling en recycling van producten. Initiatieven: financieringsmogelijkheden en belastingvoordelen.<br><br>Q12 How do you experience that the current government policy is affecting the attractiveness to integrate a circular business model?<br><br>Q12 Hoe ervaar je dat de huidige wet-en-regelgeving de transitie naar circulariteit beïnvloedt?<br><br>**Block 3 – Customer demand and supply chain management**<br>Q13 Could you describe any changing patterns in customer behavior and demand occurring in the last years? Do you experience a specific type of customer creating demand?<br><br>Q13 Kun je veranderingen in klantgedrag en klantvraag van de afgelopen jaren beschrijven? Ervaar je een specifieke groep klanten die vraag creëert?<br><br>Q14 What specific factors do you think are influences customer demand for a circular product? (Note: environmental, costs or quality)<br><br>Q14 Welke specifieke factoren zijn volgens jou van invloed op de vraag van klanten naar een circulair product? (Let op: milieu, kosten of kwaliteit)<br><br>Q15 How do you see customer demand for circularity evolving over the next few years? |

| | |
|---|---|
| | Q15 Hoe ziet u de vraag van klanten naar circulariteit de komende jaren evolueren?<br><br>Q16 What are company initiatives to collaborate with suppliers and customers on sustainable/circularity?<br><br>Q16 Wat zijn bedrijfsinitiatieven om met leveranciers en klanten samen te werken op het gebeid van duurzaamheid en circulariteit?<br><br>Q17 How is information communicated to suppliers and customers on sustainability/circular initiatives?<br><br>Q17 Hoe wordt informatie gecommuniceerd naar leveranciers en klanten over duurzaamheids- en/of circulariteitsinitiatieven?<br><br>Q18 What are initiatives the company can integrate to reduce negative environmental impact?<br><br>Q18 Welke initiatieven organiseert (kan) het bedrijf (organiseren) om negatieve impact op het milieu te verminderen? |
| 2 minutes | **Conclusion**<br>Thank you for the participation and input<br>Ask if there is anything else they would like to add<br>Remind them of the purpose of the research and how their input will be used |

Source interview schedule: (Sanne van den Barselaar, 2009)

## G - Extensive tables for SLR

*Table: Search string 1 for Scopus*

| Individual facet | Search term in string |
|---|---|
| **Drivers** | (TITLE-ABS-KEY(driver*) |
| **Barriers** | OR TITLE-ABS-KEY(challenge*) OR TITLE-ABS-KEY(barrier*) |
| **Enabler** | OR TITLE-ABS-KEY (facilitator*) OR TITLE-ABS-KEY(enabler*) ) |
| **Circular business model** | AND (TITLE-ABS-KEY("circular business model") OR TITLE-ABS-KEY("circular economy business model") OR TITLE-ABS-KEY("circular economy") OR TITLE-ABS-KEY(circularity*) ) |
| **Aluminium** | AND ( TITLE-ABS-KEY(aluminium*) OR TITLE-ABS-KEY(aluminum*) ) |
| **Final string** | (TITLE-ABS-KEY(driver*) OR TITLE-ABS-KEY(challenge*) OR TITLE-ABS-KEY(barrier*) OR TITLE-ABS-KEY (facilitator*) OR TITLE-ABS-KEY(enabler*) ) AND (TITLE-ABS-KEY("circular business model") OR TITLE-ABS-KEY("circular economy business model") OR TITLE-ABS-KEY("circular economy") OR TITLE-ABS-KEY(circularity*) ) AND ( TITLE-ABS-KEY(aluminium*) OR TITLE-ABS-KEY(aluminum*) ) |
| **Final number of articles** | **78** |

*Table: Search string 1 for Web of Science*

| Individual facet | Search term in string |
|---|---|
| **Drivers** | (TS = (driver* |
| **Barriers** | OR challenge* OR barrier* |
| **Enabler** | OR facilitator* OR enabler* )) |
| **Circular business model** | AND ( TS = ( "circular business model" OR "circular economy business model" OR "circular economy" OR circularity* ) ) |
| **Aluminium** | AND (TS= ( aluminium* OR aluminum* )) |
| **Final string** | (TS = (driver* OR challenge* OR barrier* OR facilitator* OR enabler* )) AND (TS = ( "circular business model" OR "circular economy business model" OR "circular economy" OR circularity* ) ) AND (TS= ( aluminium* OR aluminum* )) |
| **Final number of articles** | **66** |

*Table: Search string 2 for Scopus*

| Individual facet | Search term in string |
|---|---|
| **Drivers** | (TITLE-ABS-KEY(driver*) |
| **Barriers** | OR TITLE-ABS-KEY(challenge*) OR TITLE-ABS-KEY(barrier*) |
| **Enabler** | OR TITLE-ABS-KEY (facilitator*) OR TITLE-ABS-KEY(enabler*) ) |
| **Circular business model** | AND (TITLE-ABS-KEY("circular business model") OR TITLE-ABS-KEY("circular economy business model") OR TITLE-ABS-KEY("circular economy") OR TITLE-ABS-KEY(circularity*) ) |
| **Aluminium** | AND ( TS= (metal*)) |
| **Final string** | (TITLE-ABS-KEY(driver*) OR TITLE-ABS-KEY(challenge*) OR TITLE-ABS-KEY(barrier*) OR TITLE-ABS-KEY (facilitator*) OR TITLE-ABS-KEY(enabler*) ) AND (TITLE-ABS-KEY("circular business model") OR TITLE-ABS-KEY("circular economy business model") OR TITLE-ABS-KEY("circular economy") OR TITLE-ABS-KEY(circularity*) ) AND ( TITLE-ABS-KEY(metal*)) |
| **Final number of articles** | **419** |

*Table: Search string 3 for Web of Science*

| Individual facet | Search term in string |
|---|---|
| **Drivers** | (TS = (driver* |
| **Barriers** | OR challenge* OR barrier* |
| **Enabler** | OR facilitator* OR enabler* )) |
| **Circular business model** | AND ( TS = ( "circular business model" OR "circular economy business model" OR "circular economy" OR circularity* ) ) |
| **Aluminium** | AND ( TS= (metal*)) |

| | |
|---|---|
| **Final string** | (TS = (driver* OR challenge* OR barrier* OR facilitator* OR enabler* )) AND ( TS = ( "circular business model" OR "circular economy business model" OR "circular economy" OR circularity* ) ) AND ( TS= (metal*)) |
| **Final number of articles** | **427** |

## H - List and summarization of articles

*Table: Final remaining articles*

| Article number | Author(s) | Article title |
|---|---|---|
| **1** | Jabbour, CJC; Fiorini, PD; Wong, CWY; Jugend, D; Jabbour, ABLD; Seles, BMRP; Pinheiro, MAP; da Silva, HMR | First-mover firms in the transition towards the sharing economy in metallic natural resource-intensive industries: Implications for the circular economy and emerging industry 4.0 technologies |
| **2** | Winterstetter, A; Heuss-Assbichler, S; Stegemann, J; Kral, U; Wager, P; Osmani, M; Rechberger, H | The role of anthropogenic resource classification in supporting the transition to a circular economy |
| **3** | de Boer, BF; Rietveld, E; Rodrigues, JFD; Tukker, A | Global environmental and socio-economic impacts of a transition to a circular economy in metal and electrical products: A Dutch case study |
| **4** | Torres-Guevara, LE; Prieto-Sandoval, V; Mejia-Villa, A | Success Drivers for Implementing Circular Economy: A Case Study from the Building Sector in Colombia |
| **5** | Nickless, E; Yakovleva, N | Resourcing Future Generations Requires a New Approach to Material Stewardship |
| **6** | Dominish, E; Retamal, M; Sharpe, S; Lane, R; Rhamdhani, MA; Corder, G; Giurco, D; Florin, N | Slowing and Narrowing the Flow of Metals for Consumer Goods: Evaluating Opportunities and Barriers |
| **7** | Kaur, PJ; Yadav, P; Gupta, M; Khandegar, V; Jain, A | Bamboo as a Source for Value Added Products: Paving Way to Global Circular Economy |
| **8** | Neves, A; Godina, R; Azevedo, SG; Pimentel, C; Matias, JCO | The Potential of Industrial Symbiosis: Case Analysis and Main Drivers and Barriers to Its Implementation |
| **9** | Abarca-Guerrero, L; Lobo-Ugalde, S; Mendez-Carpio, N; Rodriguez-Leandro, R; Rudin-Vega, V | Zero Waste Systems: Barriers and Measures to Recycling of Construction and Demolition Waste |
| **10** | Caldera, S; Ryley, T; Zatyko, N | Enablers and Barriers for Creating a Marketplace for Construction and Demolition Waste: A Systematic Literature Review |
| **11** | Orji, IJ | Examining barriers to organizational change for sustainability and drivers of sustainable performance in the metal manufacturing industry |
| **12** | Korinek, J | Trade restrictions on minerals and metals |
| **13** | Hool, A; Schrijvers, D; van Nielen, S; Clifton, A; Ganzeboom, S; Hagelueken, C; Harada, Y; Kim, H; Ku, AY; Meese-Marktscheffel, J; Nemoto, T | How companies improve critical raw material circularity: 5 use cases Findings from the International Round Table on Materials Criticality |
| **14** | Wu F., Liu X., Qu G., | Supply network collaborations in a circular economy: A case study of Swedish steel recycling |
| **15** | Etxabide A., Young B., Bremer P.J., Kilmartin P.A., | A cross-disciplinary, cross-organizational approach to sustainable design and product innovation in the aluminum industry |
| **16** | Stewart, R; Niero, M; Murdock, K; Olsen, SI | Exploring the implementation of a circular economy strategy: the case of a closed-loop supply of aluminum beverage cans |

| | | |
|---|---|---|
| **17** | Abuabara, L; Paucar-Caceres, A; Burrowes-Cromwell, T | Consumers' values and behaviour in the Brazilian coffee-in-capsules market: promoting circular economy |
| **18** | Zeng, XL | Win-Win: Anthropogenic circularity for metal criticality and carbon neutrality |
| **19** | Oberthur, S; Khandekar, G; Wyns, T | Global governance for the decarbonization of energy-intensive industries: Great potential underexploited |
| **20** | Chiappinelli, O; Gerres, T; Neuhoff, K; Lettow, F; de Coninck, H; Felsmann, B; Joltreau, E; Khandekar, G; Linares, P; Richstein, J; Sniegocki, A; Stede, J; Wyns, T; Zandt, C; Zetterberg, L | A green COVID-19 recovery of the EU basic materials sector: identifying potentials, barriers and policy solutions |
| **21** | Soo V.K., Compston P., Doolan M., | Life cycle modelling of end-of-life products: Challenges and opportunities towards a circular economy |

**A1 (Org. strategy, customer demand, technological, supply chain)**

According to literature various and variating factors determining the success of a firms transition towards a CBM. The study of Chiappetta Jabbour et al., (2020) investigated "first-mover" cases of Brazilian companies in the metallic industry. The main driver and opportunity for the first investigated firm, is the necessity of adapting the company's core business to new trends of sustainability to remain competitive in the market. Besides competitiveness, is exploring services with final customers, private companies and public illumination driving identified as another driving factor, but also identified as barrier (Chiappetta Jabbour et al., 2020). Integration of the latest technology and introducing the use of recycled material in the production process are other technological focused barriers.

From supply chain perspective, organizations need to involve market and retail properly to implement reverse logistics. Due to a lack of consumer consciousness regarding this reverse logistics system and on sustainable benefits this can be challenging. From organizational perspective, there is still a lack of employee engagement and awareness on new business types in order to integrate sustainability or even circularity. Developing new competences and resources to support the business for integrating a CBM is identified as another barrier. Besides the developing perspective, seems involving all organizational areas to be another hindering factor (Chiappetta Jabbour et al., 2020).

The second investigated company experiences other driving and hindering factors. The main driver for a product service system (PSS) is the market and customers needs and complying with European standards (Chiappetta Jabbour et al., 2020). The company experiences barriers in the form of a lack of experiences and knowledge on the transition to a sustainable or circular business model. In summary, it stands out that for firm A customer demand is identified as barrier and for firm B it has a driving effect. In both cases do the firms rely on the modification of their product portfolio and product development as key factors. Monitoring products has significant potential to unlock circular practices (Chiappetta Jabbour et al., 2020).

**A2 (technological, financial, government policy)**

From European perspective has the study of Winterstetter et al., (2021) investigated how resource classification could contribute to promote anthropogenic resource recovery. The scope was to investigate waste from old landfills, buildings or waste streams. Challenges related to resource potential are the quantity of waste, location, temporal availability, accessibility and quality are identified challenges. Once focusing on the resource recovery are feasibility, infrastructure, legal framework, economic viability and social and environmental impact identified as hindering factors. From utilization perspective, do regulatory factors, health & safety concerns, supply security, quality and markets, public acceptance and comparability with natural resources form barriers (Winterstetter et al., 2021). A motivation is to gain insights into an inventory of available and accessible anthropogenic resources at regional and national level. Further can resource classification play a role in assessing resource potential, resource potential and utilization potential (Winterstetter et al., 2021).

**A3 (Global impact CE vs LE on societal factors)**

The environmental and social economical footprint caused by Dutch demand having an significantly higher global impact on countries outside Europe, followed by countries within Europe and having the least impact on the Netherlands (de Boer et al., 2021). The study by de Boer et al., (2021) investigated through the use of input-output modelling the potential impact of the transition towards a circular economy. Once observing this impact on countries outside Europe, factors such as global warming, material use, water consumption and land use can be significantly reduced once shifting towards a circular economical system. Employment and value added of products could be negatively impacted in this shift. Comparable effect can be identified on countries within Europe. Once analyzing the impact on the Netherlands, there will be an increase in global warming potential, and material use. What could be interpreted as logical due to more production and consumption of national products within geographical boundaries. What can be noticed, is that even in a circular economy scenario, their will be a decrease in national water consumption and land use. Employment and value added is significant positively impacted (de Boer et al., 2021).

**A4 (Org. behavior, financial, org. strategy, government policy, supply chain, technological)**

Management commitment on sharing environmental values and authentic concern about the firm's potential impact has a key driving effect on implementing a circular economy in the building sector (Torres-Guevara et al., 2021). A financial barrier is the economic viability for reusing waste as it could be more expensive, but resource scarcity could drive this reuse process from environmental perspective.

Focusing on organizational strategy and policy do various barrier effect CBM integration. Grean teams to solve environmental issues and strengthen sustainability strategy and achieve certification are identified as drivers (Torres-Guevara et al., 2021). Another driver is that the identification of valuable materials increases firm's interest in circular economy and increase economic, environmental and social impact. Where making use of valuable waste materials, and informing the management on sustainability are defined as enablers (Torres-Guevara et al., 2021). The study of Torres-Guevara et al., (2021) indicate that a fertile ecosystem is a driver for circular practices which is lead by regional and sectorial government policy and regulations that may influence and motivate consumers and suppliers environmental practices by supporting eliminating political barriers.

From supply chain management perspective is open communication with various circular economy intermediaries reduce the knowledge gap having a driving effect. Besides communication, does interaction through open innovation and sharing resources and closing geographical proximity drive the transition. This can result in collective benefits, such as a reduction in transport costs. Also there is a high availability of sustainable suppliers (Torres-Guevara et al., 2021). Factors that form a hindering effect are the lack of reuse markets and supply chains, longer deconstruction times (especially in the building sector) and the complexity of recertification (Torres-Guevara et al., 2021). From technical perspective, aluminium in the building and transport sector has a high recovery rate of approximately 85-95 on global scale (International Aluminum Institute, 2009). Metals like steel, aluminium and copper have a high significance to ensure building security (Torres-Guevara et al., 2021).

**A5 (Motivation for responsible mineral production, connection to supplier?)**

Nickless & Yakovleva, (2022) concludes that adopting the principles of a circular economy by minimizing waste, improving the design for recovery and recycling alone will not be sufficient to meet future generations demand for metals. Primary mining will be needed for the foreseeable future. Responsible and low-carbon mining and a role for material stewardship is suggested. From global perspective, there are two top-level priorities political drivers that support economic development in the mineral industry. These drivers are the international climate change policy defined by the United Nations Framework Convention on Climate Change and the United Nations Sustainable Development Agenda 2030 including the SDGs. Besides political drivers, are market related trends occurring. From resource demand perspective, there is an increase in the overall resource demand and the use of a wide range of metals and minerals. From resource supply perspective, there is a decrease in ore grades and increasing competition with other land users. Primary mining has various technological issues: mining is going deeper, ore grades are declining, discovery rates are falling and the cos of exploration is increasing. Human rights, child labor, gender equality, indigenous peoples, environmental conduct and artisanal mining are factors from responsibility perspective occurring in primary metal mining. What enablers material stewardship is maximizing the value of metals to society, focus on supply collaboration, and communication with stakeholders (Nickless & Yakovleva, 2022).

**A6 (Financial, technological, customer demand)**

The application of material efficiency strategies to improve sustainability of metals experiences various opportunities and barriers. Material, social and economic barriers are identified and opportunities to expand the use of these strategies (Dominish et al., 2018). Several material barriers limit component reuse. There is a lack of standardization for design, technology becomes obsolete or design makes components incompatible. Degradation and corrosion from previous use and the required structural qualities may differ. Also their may be limits in shareability and serviceability. This can result in application in lower-grade applications. Cheap, imported, new products are signification economic barriers just as a business protecting its market share and a shifting profits in the supply chain. From social perspective, does the demand for second-hand components depends on their social acceptability (Dominish et al., 2018).

**A7 (Bamboo)**

Biodegradability is one the factor with circular potential. Replacing non-biodegradable materials with renewable materials is here an example of. Bamboo has a higher density than steel, concrete and timber. Furthermore has bamboo potential to replace construction materials. Energy to produce bamboo is comparable to the production of wood and waste bamboo has potential for use in another application(Kaur et al., 2022). Its industrial-scale application depends on various constraints. It's biodegradability makes it eco-friendly, but susceptible to microbial and insect attacks. Chemical preservation has negative effect on human health and environment and there is a lack of government policy (Kaur et al., 2022).

**A8 (IS: supply chain, government policy, org. behavior, org. strategy, financial, technological)**

Industrial Symbiosis (IS), a process-oriented solution that involves the waste output of one organization turning into feedstock for a process in another organization contains various driving, hindering and enabling factors (Chertow, 2000). The diversity of industries that has potential for this solution and geographical proximity is identified as driver (Neves et al., 2019). Geographical proximity is a factor that is discussable and its function could vary depending on case specific situations. Existing policy and legislation are continually referred to as a driver for IS. Especially in the manufacturing industry it has greatest potential due to the more common waste streams of organic, plastic, and metallic materials (Neves et al., 2019).

Factors that hinder the exchange of this waste incentive are a lack of trust, uncertainty on benefits, a lack of knowledge on the concept, and a lack of information sharing. Driving factors for the waste exchange solutions are the need to reduce raw materials and waste disposal costs. Landfill tax and regulatory pressure is described as both driver or barrier (Neves et al., 2019). The sharing of expertise, consultancy, equipment, logistics and transport, energy, and water infrastructure has been identified as having potential. Economical, environmental and social benefits can be obtained through the saving of resources, cost savings, reducing inefficiencies and job creation. Important is to gain an understanding of the numbers and types of waste or by-products that are available (Neves et al., 2019). Enablers for interaction on IS are digital programs and platforms. Of the studied companies did they at least obtain one of the three benefits: environmental, social or economic. The reduction of carbon emission was most frequently addressed. Followed by the savings in the usage of resources such as energy, water, raw material and fossil fuels. Also did the significantly reduce the quantity of waste send to landfill. Barriers are low taxes on landfill disposal, a lack of policies that encourage IS collaboration and a lack of funds for the promotion of the practice with regulatory frameworks.

In the collaboration process a lack of knowledge on the other organization occurs, a lack of trust, resistance to provide information, uncertainty of profitability, implementing measures to reduce waste also has an hindering effect. Other barriers from stakeholders perspective are a lack of openness, willingness to initiate collaboration. Technology demands high costs, and there is a lack in available technology of equipment (Neves et al., 2019).

The study describes various strategies to overcome these barriers. First of all there is a role for the government to provide the necessary legislation and policies that are clear, consistent and less bureaucratic. This legislation and policies should also facilitate the waste exchange. Besides regulation and policy, could the government stimulate the creation of an infrastructure and support in the acquisition of technological equipment for the relationships. From organizational perspective is transparency in information sharing a vital factor influencing the collaboration. This could result in awareness. The usage of digital platforms and programs can support to overcome a lack of trust and stimulate interaction (Neves et al., 2019).

**A9 Zero Waste Systems: Barriers and Measure to Recycling of Construction and Demolition Waste (supply chain, tech, financial, org. behavior, government policy)**

26% of construction and demolition waste (C&DW) in the Netherlands is located at different landfill sites. Construction companies dispose waste without separation, expect for metals due to their value. Managers in the metal sector report the collection and separation for metal scrap such as copper, bronze, aluminium and other metals to be exported to mainly Asia and other European and American countries or recycle theme in their own country (Abarca-Guerrero et al., 2022). Access to credits and modern transformation technologies are vital barriers to be more effective in recycling waste. From governmental perspective there a limited incentives to implement the efficient use of materials and treatment places (Abarca-Guerrero et al., 2022).

A reason for the low recycling rates in the C&DW is consideration of the end-of-life (EoL) in building design. Metals are an exception due to the price on the international market. Additionally there is an absence of infrastructure and equipment for the separation of waste. Another barriers to that sending waste to landfills is economically more attractive than producing new recycled products. In construction company's, director have a lack of awareness and knowledge related to managing C&DW and specific laws are missing (Abarca-Guerrero et al., 2022).

Strategies to overcome most of the barriers are mostly focused on creating awareness, encouraging partnerships and realize technological and financial possibilities (Abarca-Guerrero et al., 2022).

**A10 Enablers and Barriers for Creating a Marketplace for Construction and Demolition Waste: A Systematic Literature Review (government, supply chain, org. behavior, org. strategy, financial and tech)**

Regarding the creation of an marketplace for waste sharing certain barriers and enablers for construction and demolition occur. Metals have the highest recovery rate among waste generation. Cost minimization is a vital factor that could have an enabling effect on the creation of a market for C&DW (Caldera et al., 2020).

Enabling factors from government perspective are increasing targeting of design stages in polices and extension of sustainable design appraisal systems, increasing the stringency of legislative measures, fiscal policies, corroboration of policy requirements, taxing primary materials, recyclable materials that are landfilled and subsidizing the C&DW recycling business (Caldera et al., 2020). From technological perspective, do reliable technology and the continuous supply of contamination-free material, organized transport and effective communication and the engagement of stakeholders. From market perspective, does an increase in client awareness, the presence of a market for recycled materials from demolition, standardization of the quality of recycled materials and the creation of ongoing demand for recycled materials form enabling factors (Caldera et al., 2020).

Governance also forms a hindering a factor. More specifically, there is lacking enforcement law for C&DW generators, immature strategy policies for effective waste recycling and management. Also there is limited coordination between waste provider and user. From technological perspective there is an improper infrastructure for disposal of landfills and an absence of treatment facilities, Contamination with hazard materials such as asbestos, is also hindering the recyclability. From organization perspective, there is a lack of motives, initiatives and awareness to manage C&DW in a culture that does not contain the aspect of saving resources and/or its optimum use (Orji, 2019). The limited demand for recycled products, negative attitude or behavior from stakeholders and higher cos compared to alternative disposal methods is forming a barrier (Orji, 2019).

Strategies to overcome these barrier are the application of Building Information Modelling (BIM) software, and material passports (Orji, 2019).

**A11 Examining barriers to organizational change for sustainability and drivers of sustainable performance in the metal manufacturing industry (org. strategy, org beh, financial, technological, supply chain, policy)**

Once focusing on organizational change to sustainable performance, the study by Orji (2019) offers insights into barriers occurring in the metal manufacturing industry. A sufficient budget, the development of infrastructural support and facilitating for sustainable performance, access advance technology for sustainability, enforcing government regulations and effective legislation are driving factors. Other driving factors are public awareness on sustainable products, integrating performance in proactive plans, implementing waste management and ensure the organizations environmental competences (Orji, 2019).

Sufficient barriers are the insufficient commitment of the top management, financial constraints, inefficient technology and legal framework, a lack of stakeholder awareness, preferences of buyers and suppliers, insufficient environmental competences, a lack of waste management, inadequate proactive plans, a communication gap, a lack on worker's training on sustainable operations and the employee welfare package (Orji, 2019).

Besides identifying barriers, the study by Orji (2019) rank barriers on impact. Inefficient technology and financial constraints is ranked in the first level. A lack of awareness amongst stakeholders is ranked in the second level. The thirds levels includes the insufficient environmental competences, a wide communication gap and insufficient commitment of the top management. Worker's training on sustainable operations is the barrier categorized in the fourth level. The final and fifth level includes a preference of suppliers and institutional buyers, inefficient legal framework, a lack of sustainable waste management and inadequate proactive plans.

**A12 Trade restrictions on minerals and metals (Government policy)**

From governmental perspective do import-and-export taxes influences the total implied rate of protection of processed metals which in turn will increase the costs of sheets and wires. Consequently, this will result in a higher end-product price. Export restrictions can contribute to a shortage of the supply of materials and strong swings of prices (Korinek, 2019).

For import tariffs this is different. World Trade Organization (WTO) members have bound their tariffs to a fixed percentage. Between 2009 and 2015 their was a significance annual increase in export tariffs by approximately 7.2% due to export tax and licensing requirements. 30% of the export restrictions measure is on conservation of natural resources. Export tariffs on raw material alu(Hool et al., 2022)minum is approximately 13.5% and can grow to 50%. Import tariffs are significantly lower and approximately 12% on raw material aluminum.

**A13 How companies improve critical raw material circularity: 5 use cases (supply chain, financial, tech, customer)**

The study by Hool et al., (2022) identified motivations, success factors and strategies how companies can improve critical raw material circularity in five cases. The firs case describes driving factors as economic viability, strengthening tooling business and customers and closing the recycling gap. Other factors that generated success circularity are long-term contracts, long-term experience, and know-how, innovative platform on techniques, global acting division with R&D specialists to foster new sustainable technology (Hool et al., 2022).

The second case describes that a growing market allows for economies of scale. The third case identified government incentives and the alignment with the company's environmental vision. Other factors are setting up a collective infrastructure, disassembly and EoL collection on vertical level, national standardization of certification of recycling procedures and government support to invest in recycling technologies (Hool et al., 2022). The fourth case describes a strong fluctuation and an unstable supply chain. In contrast to the previous case, the fifth case describes an improved supply security. Other success factors, are an improvement in the relationship between product supplier and product users and a limited number of actors and long term contracts (Hool et al., 2022).

**A14 Supply network collaborations in a circular economy: A case study of Swedish steel recycling (supply chain, org. behavior, org. strategy)**

Supply chain collaboration is not only vital for economic performance, but also for realizing ecological performance. Several factors drive this collaboration process such as access to external knowledge, information sharing and government support. In contrast, do factors such as a corporate culture mismatch between internal and external cultures (e.g. old habits and ways of thinking), a lack of alignment between stakeholders and power imbalance (Berlin et al., 2022). Also, should organizations act holistically rather than silo thinking. Long-term collaboration arise in the scrap market due to complexity and heterogeneity of exchange in general, due to variations in quality and quantity. Geographical distance is in this study described as a barrier (Berlin et al., 2022).

**A15 A cross-disciplinary, cross-organizational approach to sustainable design and product innovation in the aluminum industry (Org. strategy, behavior, supply chain, tech. and product design)**

Norway has one of the lowest environmental footprints in primary aluminum production thank to hydropower due to geographical location, long-term investors and collaboration. While the global aluminum demand is increasing, product innovation are slowing (Fragapane et al., 2022). This is mainly occurring due to characteristics of the aluminium industry. Actors with high technical expertise of machines are mainly are situated a long distance from the end-user and are unaware of the end-current current and future needs. Therefore are investments and investigations in new-aluminum alloys, treatments and processes accompanied by high financial and time risk (Fragapane et al., 2022).

Cross-disciplinary and cross-organizational collaboration are valuable in cultivating knowledge on sustainability and value creation of aluminium. Replacing traditional aluminium with a more sustainable alternative is commonly criticized or considered skeptically. Creating awareness in the value chains for decision makers is vital. The traditional aluminium approach focuses on solving problems and creating solutions with a production-centric or human perspective. This should shift towards a more environmental-centric approach. This could be developed by cultivating and sharing knowledge about circular value creation and sustainable supply chains (Fragapane et al., 2022).

The study by Fragapana et al., (2022) identified via four cases various barriers and enablers. In the category cross-disciplinary and cross-organizational collaboration the following enablers are identified: the co-development of ideas in prototyping and testing, 3D-visualization, close dialogue between project leader and designer, workshops are enabling factors. Besides enablers, does the study include several barriers such ash, components that include innovation risk, an reluctant industrial culture and industrial standards are mainly fixed.

**A16 Exploring the implementation of a circular economy strategy: the case of a closed-loop supply of aluminum beverage cans (organizational beh, strategy, tech, financial, supply chain, government, customer beh.)**

The study by Stewart (2016) investigated challenges in the field of stakeholders management, resource management, financial perspective and regulations. More specifically, did the study focus on the strategical and the business model perspective of the Carlsberg Group in the UK. An organization who is willing to implement a circular strategy can expect challenges in terms of resource management and stakeholders management as single company cannot establish circular systems on their own. Collaboration and alignment issues can occur, disinterest for non-core business activities, powerful resistance form stakeholders, consumer behavior, geographical dispersion, non-adapted reverse logistics infrastructure, availability, quantity and quality mismatch, delivery time of resources and complexity of materials form major barriers (Stewart et al., 2016).

From regulatory perspective can the trade and exchange of waste may be regulated. Also, can financial factors, such as business model investments and financial gains impact the circular strategy. Environmental impact not monetized and internalized nowadays. The study presents a theoretical model, which consists of the need to cooperate with companies in the value chain, dependency on consumer behavior, resistance from powerful stakeholders and investors in the current ecosystem, and the need to include environmental impact (Stewart et al., 2016).

**A17 Consumers' values and behaviour in the Brazilian coffee-in-capsules market: promoting circular economy**

The study by Abuabara et al., (2019) describes the role of consumers as both informers and partners. The green values and behavior of consumers are important in the long-term sustainability.

**A18 Win-Win: Anthropogenic circularity for metal criticality and carbon neutrality**

Over the last 50 years resource extraction has quadrupled and predictions state that it will double again with the rise of developing nations. Metal production is responsible for 7.9% of global carbon emissions (Zeng, 2023). Aluminium has high potential in significantly reducing carbon emissions. Once analyzing the global anthropogenic stock consisting of in-use, waste and landfill metals it can be stated that even for aluminium that reserves are rapidly being mined, especially in China (Zeng, 2023). Circularity has not only potential to reduce resource consumption, but also to energy savings. The primary production of aluminium is the most intensive process under investigation.

**A19 Global governance for the decarbonization of energy-intensive industries: Great potential underexploited**

The study by Oberthür et al., (2021) indicates barriers such as mature low- $CO_2$ technologies, a high CAPEX, long investment cycles and technology risk, cost and competitiveness, complex global value chains and a lack of policy frameworks. Four key industries that are responsible for a bulk of energy consumption and greenhouse gases are the following industries: iron, aluminium, steel and cement. These key industries account for 70% of industrial emissions. For aluminium, 10 companies produce almost half of the world aluminium. China, EU, USA, Japan and India dominate this industry. With China who produces 50% of global steel and aluminium (Oberthür et al., 2021).

New technologies are often not commercially proven and therefore form a barrier for investments. These capital investments require long investment cycles (10-30 years), forms high risks and may necessitate longer operational shutdowns to integrate changes in the production process. New technologies may also carry higher operational costs than established technologies. The complexity of tracking products and its end use if difficult and recycling and upcycling is expensive (Oberthür et al., 2021).

International institutions who have influence on this integration are the UNFCCC/PA, IEA, UNIDO, G20, TWO, World Bank, CSI/GCCA and ICCA. The PA has a lack of sectorial specification, where the PA implies a global decarbonization vision it gives multinationals room to interpret differently. The PA requires to have a medium-term climate action plan and to elaborate long-term low greenhouse gasses emissions development strategies, but these are not focused on energy intensive industries such as iron, aluminium, steel and cement (Oberthür et al., 2021).

The G20 has attempted to phase out subsidies and enhance regulations on anti-dumping and cut over-capacity, but this does not come close to effective international emission limits for these energy intensive industries. WTO has significantly supported countries that would like to stick their import base and exclude unfair treatment of import. The UNFCCC/PA, CSI and ICCA contribute to increase transparency and accountability (Oberthür et al., 2021). From financial perspective, do several provide financial support such as UNFCCC/PA, World Bank and Unido. From technological perspective, did the UNFCCC/PA, UNEP and UNIDO have targeted several developments. The UNFCCC/PA supports technological development, but is not known for mainly focusing of decarbonization of energy intensive industries. The IEA has contributed through technological collaboration programs (Oberthür et al., 2021).

An international decarbonization vision to adapt the companies environment, setting rules such as emission limits and carbon pricing to facilitate action, stimulating transparency and accountability for monitoring the implementation, offering financial support for technologies and technology transfer. Also is there a role for governmental organizations to promote knowledge and learning (Oberthür et al., 2021).

**A20 A green COVID-19 recovery of the EU basic materials sector: identifying potentials, barriers and policy solutions (technological, customer demand)**

The best available commercial process consumes about 65.6 GJ/t of aluminium. Additionally 14 GJ/t if carbon- based anodes are seen as electric source. In the production where Bauxite is transformed not Alumina, thermal energy is consumed. Thermal energy is commonly supplied by natural gas, but can be electrified, given the low temperature of the Bayer process (180 degrees Celsius). Alumina is processed via electrolysis, making aluminium production relatively intensive (46.5 GJ/t). Optimization electrolysis technologies, which reduce energy demand by 15%, have been implemented on an industrial scale in the Norwegian plant Hydro. Carbon anode consumption is the main source of emissions, Even when using decarbonized enelrical energy, emissions of about 3-4 $tCO_2$ per ton aluminium remains. Carbon-free anodes are currently not implemented on industrial-scale due to market readiness.

For secondary production, the distinction it is important to make the distinction between recycling new scrap and old scrap. Remelting of relative pure alloys consumes 1.4 GJ/t and emits 0.15 GJ/t of product. Recycling of compositions which require pre-treatment and are often limited through downcycling, consumes a higher amount energy usage (2.2 GJ/t) and emissions intensity of 0.25 $tCO_2/t$.

Recycling is limited by the availability of and purity of scrap. The availability of post-consumed scrap is predicted to grow. A significantly higher share of demand could be covered by recycled materials, but public support might be needed for the implementation of enhanced sorting technologies.

The study by Chiappinelli et al., (2021) ranks barriers to integrate technologies for the recycling package. The main barrier is the lack of effective and predictable carbon pricing mechanisms. The limited availability and accessibility of green electricity and a lack of regulatory framework are other hindering factors. Market readiness fo r low technologies and a lack of infrastructure for hydrogen, $CO_2$ and electricity form market and technological barriers. From customer perspective, there is a lack of demand for recycled and clean materials (Chiappinelli et al., 2021).

**A21 Life cycle modelling of end-of-life products: Challenges and opportunities towards a circular economy**

The study by Kie et al., (2019) adopted a system dynamics approach to stimulate the relationship between different life cycle phase of alumimnium canes (material extraction, production, manufacturing, use and recycling). The objective of the study was to identify success factors influencing circularity between a simple and complex product. Factors such as high material efficiency, low complexity with recycling quality, high consumer awareness and fast turnover rate are identified as success factors (Soo et al., 2019) .

For the complex product only targeted materials have high recycling efficiency, there is high complexity withy heterogenous recyclable mixture, lower consumer awareness and a slower turnover rate. For complex products there is a separation required for materials at EoL, this results in higher contamination levels and thus reduces recycling efficiency (Soo et al., 2019). What stands out is the effect of public education on recycling rates of aluminium cans, which increased by 30%. Further, does the longer use life have significant effect on feedstock of raw material to the product market demand. Causing the product recovery system to become unstable, due to uncertainty in scrap availability. For aluminum canes there is an equilibrium state after an delay for 800 days (Soo et al., 2019). For aluminium in buildings as imagined this scenario is different.

Once investigating the key factors influencing the products circularity it can be stated that aluminium scrap has a high economical value what drives the collection rate. Consumers awareness influences, fast turnover rate of the product who provides market stability for supply and demand for recycled products directly influences the efficiency of the collection system (Soo et al., 2019).

## I – Concepts for indicator development

**Organizational behavior**

Organization behavior can be subdivided into several specific indicators. Engaging employees in the sustainable transition is one of the major important subfactors. Moreover, is employee awareness on business type, construction and demolition waste and benefits of a sustainable design vital to stimulate the behavior of an individual. Employee are not always conscious on the need to change or show disinterest in non-core business activities. Top managers have direct effect in stimulating the individual by sharing environmental values and authentic concerns about the firms potential impact. Resistance from powerful actors can also form a barrier in this case. This process can be defined as management commitment towards sustainability. Competences of employees also matter in determine the firms organization behavior and development of these competences. From supply chain perspective are industrial symbiosis relationship (ISRs) depending on the firms openness and willingness to establish these collaborations. The cultural variable where there is a collective believe that "*waste could not be eliminated*" negatively affects the openness and willingness and can result in organizational resistance. Globally, firms experience shortages on knowledge on how to ISRs, potential partners and on handling construction and demolition waste. Besides, there is a lack of motives and incentives to manage waste. Focused more on the induvial is there a significant affect from the employee welfare package for implementing sustainability. This means that employee who generate less economic value, can significantly show more resistance. From general perspective, can organizational behavior form support or resistance for sustainable change in different layers of the organization of between the collaboration of firms in the supply chain.

**Technology**

Development of technologies, quality and quantity of waste/scrap to use recycled products, technical infrastructure for recovery, technical obsolescence, techniques to improve performance, digital programs and platforms, source separation of waste, contamination free supply of materials, material passports, support/facility of infrastructure, 3D visualization and green energy accessibility and availability.

**Financial**

Environmental costs and competitiveness, market and economic uncertainty, unclear economic viability for recovery, lightweighting and component reuse and value opportunities, higher labor costs for repair and resale, financial competition with cheap metals and plastic, economic benefits (value creation ISN, decrease in raw materials costs, reverse logistic potential, costs/risk for treatment and storage, waste price, low landfill costs, high energy costs, increasing market potential and higher CAPEX), supportive insurance, commercial and marketing expenses, providing sufficient budgetary allocation and improve supply security.

**Product design**

Optimization of product design for recoverability and collection, design according to recycling requirements, shareability, serviceability, complexity and the design of building on end-of-life (EoL).

**Organizational strategy & policy**
Involvement of market/retail to implement reverse logistics and all organizational areas, a lack of knowledge/expertise of product-service-system transition (PSS), adoption of company's core values to sustainability trend to remain competitive, manager to pioneer/present technologies/manpower between software and product in IT, organization infrastructure for recycled products, inventory of accessible resource at regional/national level, a strategy for using waste material (identification, proactive plans ,green energy and technology), information on sustainability to top management, business protecting current market share, using a tenant company, the use of platforms and digital systems, shareholders involvement, communication routes, internal structures, geographical position, raise awareness, global R&D department, tight relationships and contracts with suppliers, maintenance through lifetime, product as a service, transparency and power imbalance, procurement committee, disinterest in non core business activities, providing containers to collect aluminium.

**Government policy**
International standards, lack of regulations, inconsistent legal framework, administrative burdens, government officials awareness (procurement policy for design, market, providence of training, tax, funds, laws, incentives, coordination, cooperation and subsidizing), export tariffs, import tariffs, control for buyers to buy scrap and sectoral guidance (roadmap, guidance, carbon pricing and emission package).

**Supply chain management**
Increase collection system, risks for leasing, suppliers environmental concerns, unknown quantities and qualities for EoL products, building, landfills and infrastructure, physical location, imposition, variability and recovery of EoL products, communication and knowledge in contamination, interaction through open-innovation (lack of information sharing, expertise, infrastructure (consulting ,equipment and logistics), lack of reuse markets and supply chains, deconstruction times of buildings, recycling rates metals, ethical supply chain management (labelling, traceability, fair trade and transparency), horizontal and vertical collaboration (tight relationships and long term contracts), shifting from profit sharing and economical driven organization, EoL of buildings not taken into consideration, BIM, material passports, training, co-development of ideas and prototyping, knowledge of recycled materials in construction is concentrated, awareness in supply chain, resistance, teaming up with organizations, disinterest in non-core business activities, newer entrances show more R&D interest.

**Customer demand**
Price of sharing, trends of dematerialization, cultural, personal and social aspects related to collaborative consumption, lack of consumers consciousness, introducing use of recycled materials, leasing, public acceptance on quality of recycled products, consumers desire for new and superior products, trend to repair, not demanding sustainable products, limited demand for second-hand building materials, access of information to consumers, increasing aluminium demand, lower awareness of users current future needs, resistance, choices and green values of consumers, programs to encourage consumers, commit consumers by informing theme about recycling programs (creation of demand), complex products: only targeting have recycling related, require material separation at EoL.

## J - Results: financial, government policy and supply chain management

**Financial**

The financial factor contains three distinct indicators:1) market and economic uncertainty, 2) economic costs, and 3) supportive measures. Each of the three indicators was analyzed individually to better understand the factors. Market and economic uncertainty and economic costs are approached from the perspective of the sub-supplier and construction companies. Supportive measures are approached from the perspective of the sub-supplier, supplier, and construction companies. Figure 14 illustrates the financial role.

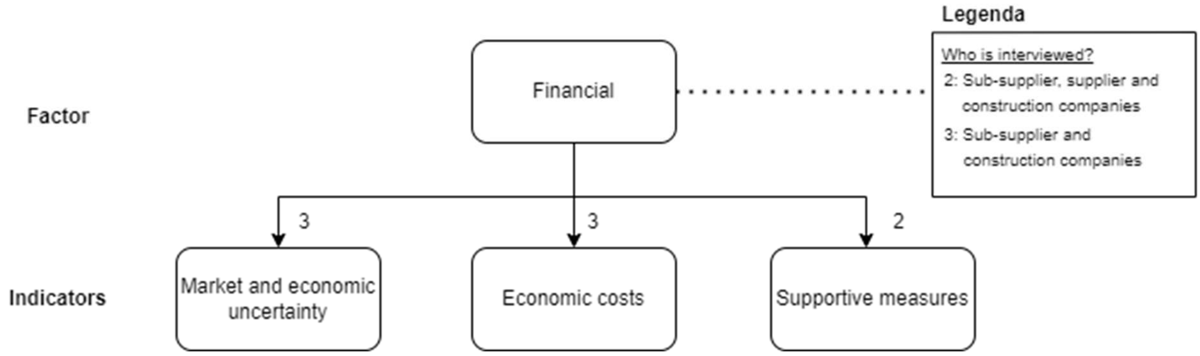



*Figure 14 - Financial role*

**Market and economic uncertainty**

Respondents from the sub-supplier highlighted that the integration of recycled aluminium (an aluminium alloy that typically consists of 30-95% scrap) is a long-term process. Currently, it involves a higher cost price compared to the primary mined aluminium sources from bauxite. Quality insecurities result in market uncertainty regarding their application and unknown financial viability. Additionally, the respondents mentioned that a higher scrap percentage in the composition resulted in a higher purchase price in the market. The respondents were skeptical about the profitability of a CBM.

The Mentioned is that end-clients (clients for construction companies) for both residual and non-residual buildings do not sufficiently prioritize sustainability and circularity materials in tenders. Specifically, the environmental impact of a product throughout its life cycle is not adequately compared with its costs or ethical value. From the perspective of construction companies, end clients should focus on the Total Cost of Ownership (TCO). The TCO refers to a building’s lifetime cost from construction to deconstruction.

However, it is possible to integrate recycled aluminium open doors into government tenders and create a differentiative position in the market. This would be considered a beneficial and strategic step towards a more sustainable supply chain and financial viability. This would make the supplier more resilient to potential governmental regulations that could soon be implemented.

" *Recycled aluminium can open doors in tenders and create a differentiative position in the market* "

**Sub-conclusion**
The integration of recycled aluminium comes from a dual perspective. On the one hand, economic viability is uncertain because of higher costs and quality issues. On the other hand, it has the potential to move the organization to a differentiative position in the market, which includes advantages in tenders. This dual perspective makes this indicator both a *driver* and a *barrier*.

**Economic costs**
Respondents from the supplier mentioned that aluminimum alloys produced using renewable energy technology are considered as 10-15% more expensive than the average price for primary mined aluminium in Europe. An alloy with a composition of 30% pre-and post-consumption scrap is estimated to be 10% more expensive. The purchase price for alloy containing 70-95% scrap in their composition is unclear.

" *Recycled is currently, more expensive than primary mined* "

In the long term, respondents predicted that the price of recycled aluminium is likely to decrease as market demand increases. This could be caused by the standardization of the technical infrastructure. Another beneficial factor is that recycled aluminium typically has a lower market value than primary-mined aluminium; however, this excludes factors such as demand and technical infrastructure.

**Sub-conclusion**
Recycled aluminium is currently more expensive than the primary mined aluminium from bauxite, which makes the indicator identifiable as a *barrier*.

**Supportive measures**
A notable observation from the interviews was that none of the respondents described that their organization did not have a fixed budgetary allocation for the integration of sustainability or circularity. This integration is incorporated into strategic and operational decision-making processes. For instance, respondents from the sub-supplier mentioned an example. They are currently striving to explore more sustainable alternatives when replacing smelting equipment with preconsumed scrap. However, the respondent stated that the immaturity of alternative technologies often renders them unmarket-ready or sufficiently advanced. Currently, it is unrealistic to completely replace mature fossil fuel-based technologies with sustainable alternatives. For instance, hydrogen-fueled smelters are market-ready or dependable enough to warrant full-scale investments.

One respondent from the supplier mentioned that the organization has a close collaboration with the bank, which could potentially cover sustainability and circularity investments. Additionally, the organization utilizes government subsidies targeted at stimulating the integration of sustainability; however, these are primarily focused on the integration of green technology for sustainable energy. There is no mention of subsidies for the integration of recycled aluminium or adapting the core business to the trend of sustainability. The organization aims to reinvest 10% of its profit into sustainability initiatives, encompassing the CSR pillars of people, the planet, and profit.

*“ We are willing to invest in sustainability ”*

From the perspective of construction organizations, one respondent mentioned that they were unable to pay more for a sustainable or circular material than a regular one. Additionally, the respondent described full-time employees (FTEs) as part of their budgetary allocation towards sustainability. However, it was observed that respondents from construction companies remained vague when questioned regarding this indicator.

“ *We are not able to pay more for a sustainable or circular material ”*

**Sub-conclusion**
Respondents from the sub-supplier and supplier are clearer about budgetary allocation for sustainability and circularity integration. Therefore, this indicator was identified as a *driver*. From the perspective of construction firms, respondents remained vague regarding budgets for sustainability or circularity. Therefore, this indicator was identified as a *barrier*.

**Government policy**
The government policy factor contains one distinct indicator. This indicator includes both regulations and interventions. Specifically, does this refer to how respondents interpret the government's role in integrating circularity into organizations. This analysis considers the perspectives of the sub-supplier, supplier, and construction companies. Figure 15 illustrates the governmental policy role.

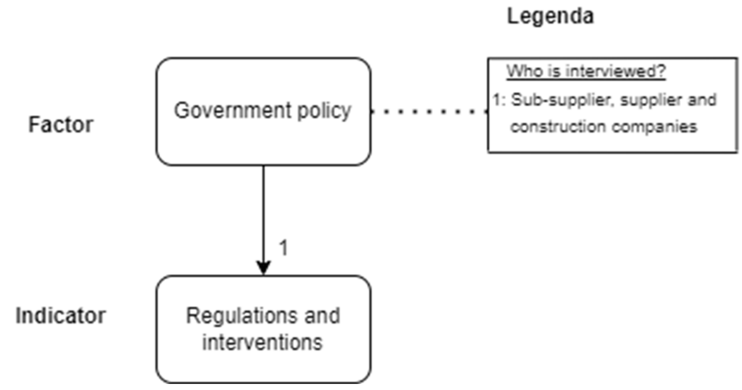



*Figure 15 - Government policy role*

**Regulation and interventions**
A respondent from the sub-supplier expressed concern that certain regulations pose obstacles for organizations. The current integration of plastic disposal cups forms a barrier to the organization. They described that government policy hinders the integration of circular practices within the organization because of limited support. Another sub-supplier respondent pointed out that governments do not yet obligate circular tenders. Additionally, the government should limit export regulations to promote aluminium smelting in the Netherlands. This could prevent environmentally harmful practices in industrialized countries. Material passports to enhance supply chain transparency has also been suggested.

"*Action on sustainability starts when there is regulation*"

Respondents from the supplier mentioned that the government hindered circular business development. The government should drive sustainability and circular change; however, currently, there is limited support for these concepts. Governments should rapidly include award criteria for large-scale tenders and increase regulations in the accountability of companies regarding how they deal with waste collection, separation, reduction, and $CO_2$ emissions. There are insufficient restrictions to support sustainable and circular transitions in organizations. Respondents from the supplier expressed limited insights regarding governmental support and regulations related to the integration of circular practices. Another respondent stated that government regulations should aim to enhance the availability and quantity of recycled aluminium in the market through a long-term plan spanning more than 50 years. This plan should include transparency and an incremental approach to change the industry

“ *There is a GAP in the translation of governmental circular ambitions to the practical field* ”

**Sub-conclusion**
Overall, the participants described a lack of governmental regulations and interventions to integrate sustainability and circularity in general and tenders. This unexploredness would makes the indicator identifiable as a *barrier*. because it impedes a company’s ability to effectively integrate CBM.

**Supply chain management**
The supply chain management factor contains one distinct indicator. This indicator included collaboration, material sourcing, and recycling. Specifically, does this refer to how respondents interpret the role of supply chain management towards integrating circularity in organizations. This analysis considers the perspectives of the sub-supplier, supplier, and construction companies. Figure 16 illustrates the supply chain management role.

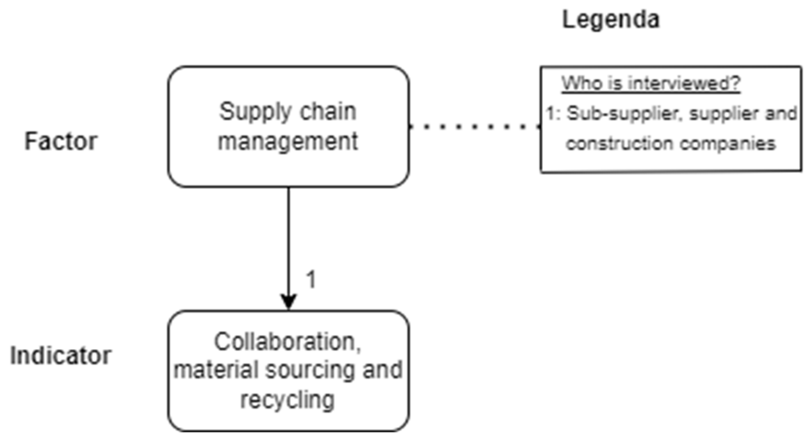



*Figure 16 - Supply chain management role*

**Collaboration, material sourcing and recycling**
One sub-supplier respondent pointed out that supply chain collaboration for integrating recycled aluminium is an area that has not been fully explored. Apart from coating tests, there are limited initiatives to test these alloys from a customer’s perspective. To make informed decisions about the definitive integration of recycled aluminium, organizations could collaborate within the supply chain to conduct proper testing and gain necessary information. This could also involve pilot and prototype testing.

A respondent from the sub-supplier mentioned that their aluminium recycling process was influenced by trust in cooperation through the supply chain. For instance, some firms are not always honest in terms of the weight and quantity of the waste they sell. Trust and transparency can contribute to the improvement in the quality and sustainability of the aluminium smelting process. This can be achieved by ensuring a better alignment and insight into the contamination levels of scrap. Currently, organizations do not utilize technological waste-exchange platforms to procure scrap. The respondents mentioned that they collected per-consumed scrap because of the consistency of the waste stream. The waste streams from post-consumed scrap are uncertain and vary. This limited their collaboration with supply chain organizations that produced pre-consumed scrap.

A supplier respondent highlighted the existing limitations of supply chain collaboration for their organizations. Moreover, employees have limited direct knowledge of how to organize and leverage these initiatives effectively. Another respondent mentioned limited collaboration with familiar or anchor companies that are actively involved in aluminium modification in the construction sector.

Additionally, one respondent mentioned the concept of a sustainable residual building. This involves the use of remnants of sustainable buildings. This concept has the potential to address certain quality challenges in recycled aluminium. However, challenges such as low transparency due to a conservative culture in the construction sector need to be addressed. Notably, the interview data indicated that aluminium has the potential to be recycled and reused multiple times without loss of quality. This applies not only to aluminium components integrated into buildings but also to their repurposing and reintegration into new building materials. BIM software is also mentioned as a tool with the potential to provide insights into the quantity and quality of aluminium used in building design and construction.

*“ Supply chain collaboration could turn barriers into enablers ”*

**Sub-conclusion**
In addition to the coating tests, the respondents mentioned the absence of supply chain collaboration to test recycled aluminium. This is particularly true from the perspective of customers. This makes supply chain collaboration unexplored, and has potential. Therefore, this indicator was identified as a *barrier*.

## K - Distribution of the codes

The interviews were recorded, translated into text, and imported into the Atlas qualitative data analysis software. Code generation was organized by carefully and repeatedly listening to the recordings and attaching labels to text fragments. This process resulted in 610 fragments (codes). Additionally, the codes were categorized into overarching groups. This process led to the identification of drivers, barriers, and enablers experienced by the respondents. Finally, the categories contain the following codes*:

1. Organizational strategy and policy (131)
2. Technology (109)
3. Organizational behavior (94)
4. Customer demand (93)
5. Financial (54)
6. Government policy (52)
7. Supply chain management (46)
8. Product design (22)

The Pareto analysis describes many codes that could be a cause or problem for CBM integration, and shows the most significant factors that influence CBM integration (Tague, 2005). In this case, it provides insights into the number of codes per factor (left vertical axes), cumulative numbers of codes per factor (right vertical axes), and names of the factors (horizontal axes). The cumulative frequency of the codes can be determined by following the orange line on the right vertical axis. This analysis revealed variations in code categories. Notably, the first four factors contained approximately 73% of the identified codes. This means that these factors were more frequently mentioned by the respondents than the other remaining factors. The distribution of codes is considered when the results are presented in the following section. This indicates that the first four factors are explained more extensively.

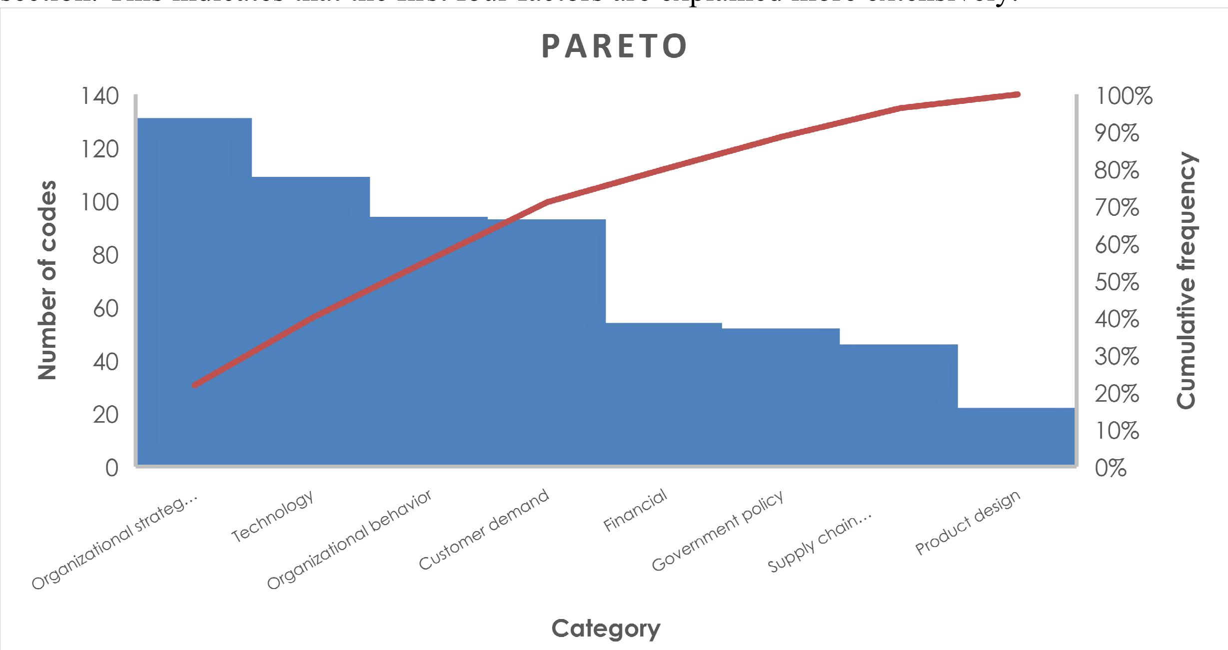



*Figure Distribution of codes (please note: the distribution is absolute and categories may not be substantiated by the same number of interview questions)*

## L - Discussion: financial, government policy and supply chain management

**Financial**

Market and economic uncertainty and economic costs

Respondents from the sub-supplier indicated that the transition to integrate recycled aluminium as a substitute for primary mined aluminium is a long-term process. Currently, shifting towards recycled aluminium increases the economic costs. Specifically, alloys composed of 30% recycled aluminium carry an additional 10-15% in cost compared to a primary aluminium alloy. The economic costs of alloys with higher scrap content remain uncertain; however, as these recycled alloys mature and demand increases, a reduction in prices is expected. Additionally, quality uncertainties introduce challenges in practical applications. The respondents expressed skepticism about the profitability of the business model. However, applying recycled aluminum can create opportunities to secure long-term government tenders. This can create a unique market position and develop resilience to regulatory changes. Therefore, market and economic uncertainty is defined both a driver and barrier for CBM development. Economic costs is defined as barrier, supportive measures as a driver for the supplier and driver and barrier for the sub-supplier and construction companies. Higher costs for recycled materials and the competition of cheaper alternatives have been consistent with the state-of-the-art (Dominish et al., 2018; Hool et al., 2022; Torres-Guevara et al., 2021; Winterstetter et al., 2021). The recycling market is characterized as having a limited number of companies who have significant influence on prices and material purchase, which negative effect pricing dynamics for recycled materials (Caldera et al., 2020). Additional, testing, investments, and investigations aimed at exploring new aluminum alloys, treatment methods, and processes are associated with financial and time risks (Fragapane et al., 2022).

**Government policy**

Regulations and interventions

Respondents from the sub-supplier mentioned that they experienced no governmental support in limiting the export of aluminium scrap. This makes it economically more beneficial for organizations to export scrap instead of selling it to smelter organizations in their own country. Limited export regulations negatively affect the aluminium scrap waste stream and, therefore, the infrastructure of recycled aluminum. Supplier respondents confirmed the hindering role of the government in CBM integration. Mentioned is that they did not experience any regulatory or financial stimulation. Additionally, construction firms and suppliers mentioned that large-scale tenders in the construction sector do not weigh award criteria for circular applications. This makes decision making more concentrated on economic factors rather than environmental factors. Sustainability is an addition and not a strict requirement. In addition, regulations regarding waste treatment and $CO_2$ emissions are lacking. Overall, respondents mentioned the government's role as a barrier to CBM integration. Specifically, organizations experienced limited financial or regulatory support to make this transition. Administrative burdens are not mentioned by the respondents. Therefore, this indicator is defined as a barrier for CBM development. The literature confirmed that there is often an absence of regulations and supportive measures to create an economically viable environment for recyclers (Horizon, 2016). This negatively affects the efficient collection and recovery of various types of waste streams. In addition, regulations and legal barriers increase administrative burden, which negatively impacts the marketability of recycled materials (Johansson et al., 2017). Additionally, there is a role for the government to stimulate the creation of infrastructure and support the accessibility of technological equipment (Caldera et al., 2020), which makes it identifiable as driver, barrier or enabler. Neves et al., (2019) described government policy to be a driver.

**Supply chain management**

Collaboration, material sourcing and recycling

Noticeably, is mentioned that the relationship between the sub-supplier and supplier is based on principles such as long-term trust and quality. There is transparency in the primary material exchange and opportunities to shift towards recycled aluminium. The respondents had a certain level of awareness of sustainable change and its benefits. One out of three respondents from the sub-supplier and construction companies was intrinsically motivated and three out of five were from the supplier. On both sides, there are issues regarding the profitability of recycled aluminium. Additionally, the sub-supplier and supplier are open and willing to collaborate because of their long-term trust. No connection exists between the sub-supplier and construction companies to integrate the circular initiatives that can be developed by the supplier. This indicator is defined as a barrier to CBM development because there are limited initiatives with supply chain partners to integrate circularity.

The literature mentioned that long-term relationships are important in sustainable supply chain management because of the variations in quality and quantity (Berlin et al., 2022; Stewart et al., 2018). The presence of a long-term is confirmed by respondents from the sub-supplier and supplier between the two organizations. In addition, the relationships between waste-exchanging organizations are often characterized by a low level of awareness, resistance to information sharing,  lack of trust, and uncertainty in profitability(Fragapane et al., 2022; Neves et al., 2019). Another simplified challenge is the lack of openness and willingness to collaborate (Neves et al., 2019). Existing casese in waste exchange presented that collaboration in the supply chain can also have an enabling or driving effect (Neves et al., 2019; Stewart et al., 2016).Respondents from the sub-supplier and supplier were confirmed to have a certain level of awareness of the necessity for sustainable change. Information sharing is perceived as transparent between the two organizations, and trust is one of the key characteristics of the relationship. In contrast, respondents expressed concern about the profitability of a CBM for alumininium. This creates uncertainty regarding the willingness to integrate. The relationship between suppliers and construction companies has unexplored potential.

**Supply chain management**

Collaboration, material sourcing and recycling

Noticeable, is mentioned that the relationship between the sub-supplier and supplier is based on principles as long-term trust and quality. There is transparency in the primary material exchange and opportunities to shift towards recycled aluminium. The respondents had a certain level of awareness of sustainable change and its benefits. One out of three respondents from the sub-supplier and construction companies was intrinsically motivated, and three out of five from the supplier. From both sides, there are issues regarding the profitability of recycled aluminium. Additionally, the sub-supplier and supplier are open and willing to collaborate because of their long-term build trust. No connection exists between the sub-supplier and construction companies to integrate circular initiatives that can be developed by the supplier. This indicator is defined as an *enabler* for CBM development, because there is a strong foundation between the sub-supplier and supplier.

The literature mentions that, in sustainable supply chain management, long-term relationships are important because of variations in quality and quantity (Berlin et al., 2022; Stewart et al., 2018). The presence of a long-term is confirmed by respondents from the sub-supplier and supplier between the two organizations. In addition, the relationships between waste-exchanging organizations are often characterized by a low level of awareness, resistance to information sharing, lack of trust, and uncertainty in profitability (Fragapane et al., 2022; Neves et al., 2019). Another simplified challenge is the lack of openness and willingness to collaborate (Neves et al., 2019). Respondents from the sub-supplier and supplier are confirmed to have a certain level of awareness of the necessity of sustainable change, information sharing is perceived as transparent between the two organizations, and trust is one of the key characteristics of the relationship. In contrast, respondents expressed worries about the profitability of a CBM for aluminium. This creates uncertainty in the willingness to integrate. The relationship between suppliers and construction companies was superficial and has unexplored potential.

## M - Drivers, barriers and enablers according to the state-of-the-art and empirical study

| Factor | Indicator | Role (SLR*) | Role (ES*) | Note (ES)* |
|---|---|---|---|---|
| Organizational strategy and policy | Market involvement | Barrier | Barrier | |
| | Knowledge and competencies | Enabler or Barrier | Barrier | |
| | Sustainability strategy | Barrier | Enabler | |
| | Management commitment | Driver or Barrier | Enabler | |
| Technological | Quality and composition | Barrier | Barrier | |
| | Technological infrastructure for waste management | Driver or Barrier | Driver* | SS=Driver and CC=Barrier |
| | Technological infrastructure for recycled aluminium | Barrier or Enabler | Barrier | |
| Organizational behavior | Awareness | Barrier | Driver | |
| | Intrinsic motivation | Driver | Driver* | SS=Barrier and CC=Barrier |
| | Employee involvement | Barrier | Driver | |
| Customer demand | Customer behavior and demand | Driver or Barrier | Driver or Barrier | |
| Financial | Market and economic uncertainty | Barrier | Driver or Barrier | |
| | Economic costs | Barrier | Barrier | |
| | Supportive measures | Driver or Barrier | Driver* | SS=Driver and CC=Barrier |
| Government policy | Regulations and interventions | Driver, Barrier or Enabler | Barrier | |
| Supply chain management | Collaboration, material sourcing and recycling | Driver, Barrier or Enabler | Barrier | |
| Product design | Technical and functional design | Driver or Barrier | Driver | |

**Note: ES= Emperical study and SLR= Systematic literature review*