Value co-creation through leveraging drivers and tackling barriers for Circular Business Models:

A direct stakeholder perspective from the lithium-ion battery industry

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Thesis submitted for the Master Business Administration

3rd December, 2023

Abstract

This paper strives to construct a value co-creation process that supports in transitioning towards a circular economy. This process is achieved using insights from different stakeholders that operate within the same industry: the industry for lithium-ion batteries. Thirteen relevant stakeholders have shared their insights in this paper by sharing their perspectives in direct interviews. The first step in each interview is to look at each stakeholders' drivers and barriers that may assist or hinder within this transition. Secondly all thirteen stakeholders have contributed to this paper by shaping the value co-creation based on their ideas on what this should look like, what roles should be taken and what responsibilities should be agreed on. Furthermore, examples of value co-destruction were discussed. The results support existing theory on value co-creation by applying a direct stakeholder perspective in an underexplored industry and coming up with an example of how value co-creation can manifest in this transition. Additionally, the findings help companies in the same or similar industry to understand a transition towards circularity better with the help of stakeholder involvement.

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1. Introduction

Sustainability plays a crucial role in B2B (business-to-business) relationships, as is found by OECD's report that states that 75% of B2B buyers are willing to dismiss supply chain partners that do not meet their sustainability criteria (Kapitan et al., 2019). Furthermore, to transition towards a Circular Economy (CE), regulations are put in place (Europese Commissie, 2020) like battery passports or increased procurement reporting (Dunn et al., 2022). Moreover, methods are studied to find out how to close or shrink the material loop of frequently used energy sources (Duarte Castro et al., 2022; Luo et al., 2023) in a world that is subject to supply side shortages or concentrated supplier pools (Rajaeifar et al., 2022; Sadik-Zada et al., 2023). Actors operating within these environments are thus entangled in complex webs.

Businesses face various of these situations that compel them to adopt sustainable practices, despite encountering hurdles and discouragements. Existing research has already dived deep into these so-called drivers and barriers for sustainability practices for many other industries (Gabzdylova et al., 2009; Tunji-Olayeni et al., 2020).

One approach businesses can take is transitioning to a circular business model (CBM). CBMs for energy service providers like lithium-ion batteries have already been proposed in past research, making this a good starting point for further exploration (Olsson et al., 2018). Value creation is an example of further research that attempts to understand how value can be created in a CE to obtain economic, environmental and social benefits with these CBMs (Lüdeke-Freund et al., 2019; Ranta et al., 2018).

Currently the company-centric understanding of value creation is prevailing and it has been criticized for its failure to address the main principles of a CE (Kirchherr et al., 2017b). This narrow view must be broadened by understanding collective activities that involve multiple stakeholders (Eikelenboom et al., 2022). Within this ecosystem, multiple actors integrate resources and exchange services in order to co-create value (Merz et al., 2009; M. Rahman et al., 2019). This integration of resources and exchange of services does not necessarily lead to value co-creation as it can lead to a decrease in at least one of the systems' well-being. This is when we speak of value co-destruction (Schulz et al., 2021).

It is of theoretical importance to extend the knowledge in this gap to address the mentioned challenges. Sustainability regulations are becoming more and more strict (Europese Commissie, 2020). Supply chains face more and more challenges due to scarcity and complexity (Igogo et al., 2019; Rajaeifar et al., 2022). On top of this, B2B relationships are being extensively evaluated by sustainability criteria (Kapitan et al., 2019; Tapaninaho & Heikkinen, 2022). From a practical perspective the importance is highlighted by the world's growing dependence on renewable energy systems (Dai et al., 2021). Better understanding proper sustainability practices within these stakeholder ecosystems allows for better coping with this growing dependence.

The study is theoretically positioned within the framework of stakeholder theory, stakeholder value creation and sustainable business models. Stakeholder theory provides a comprehensive lens to examine the interests, perspectives, and roles of various stakeholders involved within the industry, including manufacturers, suppliers, consumers, regulators, and local communities (Freeman, 2010). Stakeholder theory further emphasizes that the interests of all stakeholders should be considered and balanced and by fulfilling these responsibilities, they can create value for both their business and their stakeholders (Freeman, 2010; Freudenreich et al., 2020; Tapaninaho & Heikkinen, 2022).

The sustainable business model framework offers a conceptual foundation to understand the integration of sustainability principles within the business strategies and operations of manufacturers (Freeman, 2010; Freudenreich et al., 2020; Tapaninaho & Heikkinen, 2022). By taking this theoretical perspective, this study analyses the drivers, barriers and value creation of circular business models (CBM) from a stakeholder-oriented and sustainability-driven perspective.

This study aims to analyze barriers and drivers of adopting CE practices in the energy services industry and how these can be leveraged/tackled to create value, all from a stakeholder perspective. It aims to answer the following two research questions:

"What are the drivers and barriers of implementing circular business models in the energy services industry from a stakeholder-oriented perspective?'

"How does leveraging these drivers and tackling these barriers co-create or co-destruct value within the ecosystem of energy services?"

This study employs a qualitative research approach. It specifically uses direct stakeholder interviews, to gain in-depth insights into what drivers and barriers could be in a collaboration that involve CBMs. In addition, when discussing these barriers and drivers, the study attempts to understand how these can be tackled and/or leveraged to co-create value.

The study provides several theoretical contributions. Topics like drivers and barriers for circular business model adoption is heavily researched within several industries (Govindan & Bouzon, 2018; Rahman, Aziz, & Sidek, 2015). Circular business models are identified within the lithium-ion battery industry (Albertsen et al., 2021; Olsson et al., 2018) and the drivers and barriers for adoption are evaluated from an expert's point of view (Wrålsen et al., 2021). The study at hand will looks further by taking the proposed CBMs and exploring the drivers and barriers from a direct stakeholder perspective that operate within the same ecosystem. Together with these insights, the research combines the perspectives of these relevant stakeholders to cooperatively explore how value should be co-created within the ecosystem. How value co-destruction may occur is simultaneously explored.

The interviews rely on the stakeholders' expertise and experience within the field to obtain a good collection of how both can manifest within the ecosystem. These different insights are collected to draw up a conclusion that thickens the theory on both value co-creation and co-destruction by understanding industry specific dynamics. This can enhance understanding of contextual factors. Additionally, through the stakeholder interviews, the study provides theoretical contributions in the form of nuances and factors specific to the industry that may not have been adequately addressed in current theory. Moreover, the stakeholders that were proposed by Wrålsen (2018) have gained more context through this research. This can assist in stakeholder theory about power dynamics or relationship management that are necessary in value co-creation or co-destruction.

As an industry relevance this study addresses a pressing issue and provides valuable insights for industry practitioners, policymakers, and other stakeholders (Luo et al., 2023). Insights on value co-creation helps players within the industry understand the benefits and advantages (drivers) of embracing circularity and understand limitations and potential obstacles (barriers) which enables them to make informed decisions and develop strategies that align with stakeholder interests and sustainability goals (Pera et al., 2016). The study does this by creating a blueprint for the co-creation of value with specific roles and responsibilities for each relevant stakeholder.

The remainder of this article has the following structure: the theoretical background expands on value co-creation and co-destruction, stakeholder ecosystems and drivers and barriers. Next the methodology of the stakeholder interviews are described. Lastly the article presents the results and their implications along with the identification of limitations of this work that can be further explored through future research avenues.

2. Theory

The following chapter dives deeper into the theory that is used for this paper. Subjects like stakeholder management, stakeholder ecosystems, circular business models and value co-creation are discussed.

2.1 Stakeholders

Economic actors are not in isolation, but are operating in a collaborative environment with complex networks of relationships with all kinds of resource providers (M. Rahman et al., 2019; Vargo & Lusch, 2004). An organization's ability to facilitate joint value creation is based on building constructive and enduring relationships with stakeholders, in short, managing for stakeholders. The goals, interests and outcomes are positively dependent (Kujala & Korhonen, 2017). Within the context of sustainable B2B operations, the operating businesses must understand the interests of a diverse group of stakeholders such as customers, employees, suppliers, regulators, governments, and stockholders (Rahman, Aziz, & Sidek, 2015).

2.1.1 Collective stakeholder ecosystem

Studies have interpreted the interplay of stakeholders as a service ecosystem in which multiple actors (stakeholders) participate in the creation and offering of value propositions (Schulz et al., 2021). A service ecosystem represents an actor-to-actor network. It can be characterized as a self-contained, self-adjusting system of mostly loosely coupled social and economic (resource-integrating) actors connected by shared institutional logics and mutual value creation through service exchange (Lusch & Nambisan, 2015; Schulz et al., 2021). Collaboration among actors ensures mutual benefit and survival, which fits to network and cluster theory (Sedoglavich & Dabić, 2016). The importance of stakeholders is mentioned in Stakeholder theory by Freeman (2010) as well. Within this theory the interests of all stakeholders should be considered and balanced and by fulfilling these responsibilities, they can create value for both their business and their stakeholders (Freeman, 2010).

The mechanisms that coordinate the service-for-service exchange between actors in the ecosystem are called institutions, and institutional arrangements. Institutions refer to rules, norms, practices and beliefs. These institutions can enable action, or prevent it. Institutional arrangements refer to a collection of institutions (Schulz et al., 2021).

The exchange of services is often facilitated. This is done by a service platform. This platform can be tangible (think of materials and hardware) or intangible (digital artifacts). In other words, these are operating as mediators, enablers, facilitators or distribution mechanisms for service provisioning (Haki et al., 2019).

An example of what this can look like can be found in the paper Wu et al. (2019). In this paper the healthcare service ecosystem in China was analyzed. The ecosystem consisted of several different roles for many different stakeholders, each contributing to value creation within the ecosystem. National regulatory authorities strengthen the safeguarding of the security of medical big data. Medical laboratories in the ecosystem provide support in technology services through support of screening, examination, diagnosis, evaluation and decision to clinical diseases, thus changing the modes of medical resources. The actors from the supporting population in the ecosystem provide services like payment and supply. These actors can be suppliers, health managers or payment platforms (Wu et al., 2019). This papers strives to make similar insights into how value is co-created in the energy services industry in relation to CE.

2.1.2 Value co-creation and co-destruction

Value creation has become a topic of interest in current CE research (Freudenreich et al., 2020; Kujala & Korhonen, 2017; Ranta et al., 2018; Tapaninaho & Heikkinen, 2022). For companies to achieve proper sustainability performance within a CE, the value propositions and value creation process should be radically adjusted (Geissdoerfer, Morioka, de Carvalho, & Evans, 2018). Value proposition is a strategic tool for communicating how a company aims to propose value to customers (Payne, Frow, & Eggert, 2017). Value creation corresponds with the activities related to products, services, processes, resource and energy efficiency and waste management to create value (Abid et al., 2022).

Value creation can be both a goods-dominant logic perspective and a service-dominant logic. The research at hand uses a service-dominant logic approach where we speak of value co-creation. This looks at resource integration and service exchange among the actors of the service ecosystem (Schulz et al., 2021).

Current theory about value co-creation mentions two important things. First is that past research has emphasized that the current knowledge of CE value creation is insufficient (Eikelenboom & de Jong, 2022). Second is that the definition of value creation is often confined to a one-dimensional objective of creating economic value for shareholders. Value creation has the possibility to broaden its perspective and understanding the functioning of business. In a new view, value creation should be focused on stakeholder value where different values are presented that reflect different stakeholders' interests (Busch et al., 2018; Schulz et al., 2021). Allowing multiple stakeholder perspective means integration of long-term visions and targets for collective value (Tapaninaho & Heikkinen, 2022). In addition, service exchange among actors does not necessarily lead to only a value increase among all actors (Schulz et al., 2021). When one of the system's well-being is declined, we speak of value (co-)destruction (Smith, 2013). A decline in well-being can be manifested in negative feelings such as anger or frustration. An additional form this decline in well-being can take is the loss of resources which can be financial or physical (Sthapit & Björk, 2019). Another form is if there is a lack of resources to integrate or the believe of such by one interacting actor or when one actors is unwilling to integrate these resources (Laud et al., 2019).

2.2 Implementing sustainability practices

To implement sustainable business practices, companies may have to undertake significant changes to their strategy. Every stakeholder has their own driver to get involved or barrier preventing their engagement (Simula et al., 2009).

2.2.1 Drivers and barriers for implementing sustainability practices

Research has examined the drivers for implementing sustainability practices for B2B and B2C businesses alike (De Jesus & Mendonça, 2017). Alice Karanja et. al. (2020) found drivers of consumers to adopt clean cooking options. Found drivers include regulatory frameworks that generate emission targets or waste management regulation and thereby creating legal obligations for businesses (Karanja et al., 2020). Solomon Olusola Babatunde et. al. (2020) found drivers of incorporating sustainability within public-private partnership infrastructure projects such as more demand for-friendly products or increasing environmental awareness amongst consumers. For a seller perspective driving this adoption of sustainable practices can be a competitive advantage through improving brand and customer loyalty (Babatunde et al., 2020; Karanja et al., 2020).

However, when transforming to a CBM, businesses can encounter barriers that impede the implementation. These barriers include lack of management commitment, organizational inertia to change, strategic concerns regarding costs and performance measurement, functional issues in purchasing and supply, insufficient training, government regulations, increased purchasing costs due to a limited pool of qualified suppliers, customer perceptions of high costs, media influence, sectoral challenges, policy and market issues and technological limitations (Rahman et al., 2015).

Furthermore, research has explored that these drivers and barriers can be managed through stakeholders, which stresses the importance of understanding the playing field. Example of this research is done by Lopes de Sousa Jabbour (2020) who has found that facing drivers and barriers requires coordination of stakeholders, resources and capabilities (Lopes de Sousa Jabbour, Vazquez-Brust, Chiappetta Jabbour, & Andriani Ribeiro, 2020).

The surface has been scratched regarding drivers and barriers. This will need to be further explored within other industries. The study at hand will investigate what the drivers and barriers are to embrace a CBM in the energy services industry. It is of importance to first define what a CBM in this industry looks like, which is further explored in the next paragraph.

2.2.2 CBM in energy service industry: Lithium-Ion batteries

The research narrows itself to one connected ecosystem within the energy services industry. This allows for better integration of findings. Within existing theory for energy services, there is a seemingly increasing interest into the lithium-ion battery industry. Stakeholders for circularity and CBMs in the industry are formulated in past research (Albertsen et al., 2021; Olsson et al., 2018; Wrålsen et al., 2021). This makes it a great stepping stone for the purposes of this research. The sustainability of lithium-ion batteries (LIBs) is of great significance as well due to the increasing number of spent batteries and the need for environmentally friendly recovery of valuable materials (Kim et al., 2023; Luo et al., 2023). Current research focuses on optimizing recovery processes, evaluating emission footprints, conducting Life Cycle Inventory (LCI) and Life Cycle Assessment (LCA), and exploring circular business models for LIBs (Albertsen et al., 2021; Erakca et al., 2023).

However, even the identified Circular Business Models for batteries are still partially researched. Further research on value creation is crucial for managing the complex value chains and interconnected activities of LIBs. Circular Business Models aim to create, deliver, and capture value within closed material loops, incorporating social and environmental values alongside economic considerations (Lewandowski, 2016). Four CBMs have been identified: product-as-a-service, product life extension models, resource recovery business models and circular supplies (Vermunt et al., 2019). Each CBM aligns with different strategies in the 4R framework: reduce, reuse, recycle, and recover (European Commission, 2008; Kirchherr et al., 2017).

In the context of LIBs for electric vehicles (EVs), two proposed business models involve refurbishment and second use before recycling (Olsson et al., 2018). Another research proposed several CBMs for EV LIBs to experts to rank these. The experts considered a CBM with 'remanufacturing + reuse + recycle + waste management' to be the most suitable followed by a CBM with 'product life extension' and 'resource recovery' (Wrålsen et al., 2021). Strategies to slow the loop of LIBs included intensifying first use, sharing idling capacity, repair and upgrading, reuse, refurbishment, remanufacturing, repurposing, and recycling (Kurdve et al., 2019).

This can however be difficult to manage for stakeholders, as the firm must recognize which stakeholders need what, and which stakeholders require more attention and priority in the value creation process (Kujala & Korhonen, 2017). The question of which stakeholders are important can be derived from research by Benedikte Wrålsen (2021). For lithium-ion batteries important stakeholders for end-of-life management include governments, customers, battery manufacturers, waste managers/recyclers and suppliers to name a few (Wrålsen et al., 2021). Because the stakeholders are known, the questions remains how value is created for these stakeholders in embracing these CBMs in a CE.

2.3 Stakeholder vision on drivers, barriers and value co-creation in adopting CBMs

Based on the empirical phenomena discussed above, a status quo can be made regarding the drivers, barriers, and value creation of implementing circular business models in the lithium-ion battery industry from a stakeholder perspective. Research has been done on what CBMs exist for LIBs (Olsson et al., 2018), methods for recycling are found (Duarte Castro et al., 2022; Luo et al., 2023) and drivers and barriers for embracing CBMs have been identified by Benedikte Wrålsen (2021) using a Delphi Panel method with experts. There is not yet an empirical in depth understanding from the viewpoint of direct stakeholders of the battery manufacturers on these drivers and barriers. Furthermore, as explicitly stated within the research of Benedikte Wrålsen (2021), there is not yet an empirical understanding of the value creation and capture of circular business models from the perspective of direct stakeholders within this industry.

By integrating stakeholder perspectives on drivers and barriers for adopting CBMs a B2B actor can ensure that a transition is made to a CE that addresses their concerns and priorities which increases the support and engagement of stakeholders within the ecosystem (Babatunde et al., 2020; Karanja et al., 2020). When understanding the barriers of this adoption, the transitioning B2B actor can overcome resistance to change and develop strategies to overcome these. Furthermore, understanding the insights of stakeholders allows the B2B manufacturer to understand revenue streams, cost-saving opportunities and insights in the new CBM. This allows maximum value co-creation for stakeholders while limiting co-destruction (Kapiriri & Razavi, 2021). When looking at long-term business resilience, the B2B business within the ecosystem can develop a business model that considers the long-term sustainability of operations. It helps in anticipating future trends, regulatory changes and evolving stakeholder expectations. Also, by taking a multi-stakeholder approach, different concerns can be taken into consideration. Customers may be concerned about quality or affordability, suppliers may have concerns about the availability of recycled materials, and (battery) manufacturers may worry about job security or changes in work processes (Busch et al., 2018; Lopes de Sousa Jabbour et al., 2020).

By integrating both drivers and barriers analysis with value creation, one can gain a comprehensive understanding of opportunities and challenges. This generates an opportunity to develop effective strategies and recommendations that leverage the drivers, tackle the barriers while maximizing value co-creation in the new CBM. We explore what these drivers and barriers are for implementing circular business models. With the support of this knowledge, we explore how the value should be co-created, and how value could be co-destructed.

The integration is visualized in the conceptual framework below (figure 1). The drivers and barriers have been briefly touched upon by expert interviews in research by Benedikte Wrålsen (2021). These are going to be validated in this research by the stakeholders that are operating within the ecosystem of lithium-ion batteries. Further discussions will be held with these stakeholders on how tackling these or leveraging these will co-create value within the industry.

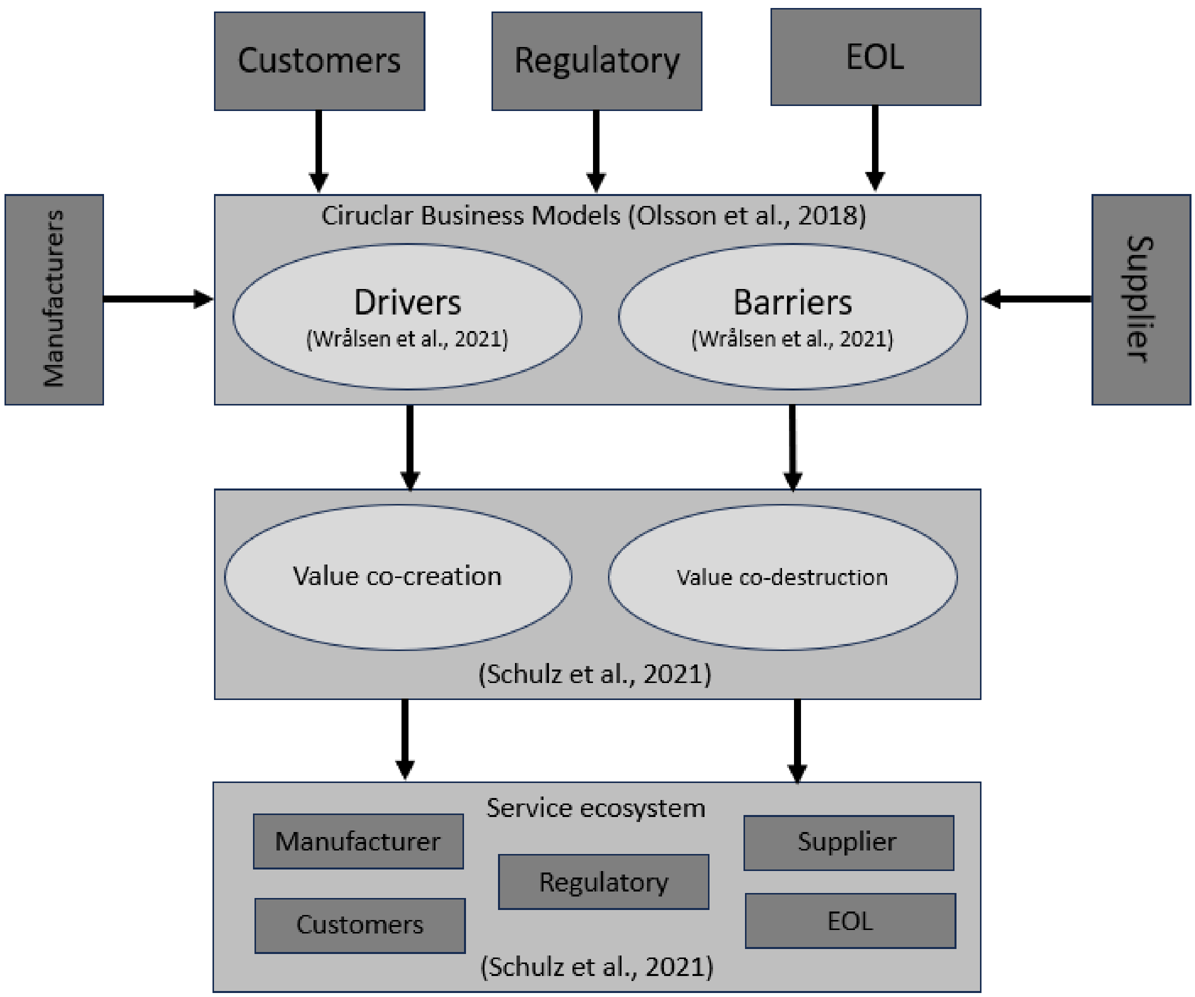

Figure 1: conceptual framework (stakeholder, drivers and barriers adapted from Bendikte Wrålsen, 2021)

3. Methods

This chapter will take a look at the research questions and the methodology to answer them.

3.1 Research design

Studies about drivers and barriers from a stakeholder perspective have attempted to gain insight through a systematic literature review (Govindan & Bouzon, 2018) or through the usage of surveys (Babatunde et al., 2020) or by conducting interviews with the direct stakeholders (Karanja et al., 2020) to better understand drivers and barriers.

Like the study of Karanja et. al., this study employs a qualitative research approach , specifically using direct stakeholder interviews, to gain in-depth insights into the drivers, barriers and value creation aspects of implementing circular business models in the lithium-Ion battery industry. Using interviews allows for deeper understanding of the topics and allows for flexibility in probing questions (Rosenthal, 2016; Sperber et al., 2023). For this research the flexibility of in-depth interviews supports in understanding the views of different stakeholder groups. The stakeholders are derived from the study by Benedikte Wralsen (2021) as well as through conversations with companies operating within the battery industry which shall remain unnamed. Identified important stakeholders in the lithium-ion battery industry are governments, customers, battery manufacturers, waste management and recyclers and suppliers (Wrålsen et al., 2021).

The interview questions are created based on the research questions for this study. This gives the interview questions a good foundation for the foundation. The research questions are:

"What are the drivers and barriers of implementing circular business models in the energy service industry from a stakeholder-oriented perspective?' and "How does leveraging these drivers and tackling these barriers co-create or co-destruct value within the ecosystem of the energy service industry"

The interview questions are further supported by the existing knowledge in theory. Common barriers or drivers found in studies by Babatunde (2020) or by Wrålsen (2021) were helpful in constructing general directions during the interview. Furthermore, the interview often reflects on the existing CBMs that were proposed by Olsson (2018) to have a more illustrative and concrete discussion.

Lastly the research will acknowledge the importance of collaboration within an ecosystem (M. Rahman et al., 2019; Vargo & Lusch, 2004). The direct stakeholders' view is necessary to understand on their perspective in this playing field. These actors within the ecosystem can tell from their own experience how these barriers and drivers affect them directly for embracing a CBM. Having this view from different perspectives in the direct playing field helps in drawing up opportunities for transitioning towards a CE in the industry.

3.2 Data collection

We use the frame outlined in Figure 1 to guide the data collection and analysis. This is also a supporting framework for systemizing the perceptions of key stakeholders within the lithium-ion industry.

The respondents were recruited through contact with the initial battery producing company operating within the industry. Respondents were chosen based on their relevance as a stakeholder as well as their level of engagement within the lithium-ion battery industry. This ensures the collection of rich information from different perspectives on how this transition is viewed and faced.

As many as possible stakeholders are approached, which leads to a balanced mix of respondents from each stakeholder group. No more interviewed stakeholders are approached when no more can be found that are willing to collaborate or when the respondents stop giving new insights thus leading to theoretical saturation (Nascimento et al., 2018). The profiles of the respondents can be found in table 1 below:

Table 1
Interviewee profiles

Interviewee notation	**Type of stakeholder**	**Relevant experience in**	**Years within industry**
EOL A	End-of-Life management	End of life batteries management Closing the loop	3+
EOL B	End-of-Life management	Waste management	4+
EOL C	End-of-Life management	Waste management	20+
Customer A	Battery customer	Procurement Batteries	3+
Customer B	Battery customer	Procurement Batteries	3+
Supplier A	Supplier	Sustainability and quality management	32+
Supplier B	Supplier	Packaging account management	4+
Regulatory A	Regulatory	Senior policy officer energy transition	4+
Regulatory B	Regulatory	Environment specialist for a municipality and environment specialist	20+
Regulatory C	Regulatory	Senior Policy Officer, Ministry of Economic affairs and Climate	1+
Manufacturer A	Manufacturer	Mechanical engineer	5+
Manufacturer B	Manufacturer	Regional sales manager	3+
Manufacturer C	Manufacturer	Strategy manager	4+

As stated, the interview questions are designed to explore their perspectives on the drivers, barriers and value co-creation aspects related to circular business models. The interview questions are open-ended which allows the interviewees to share their experiences, opinions, and insights in their own words. Most interviews were done through Microsoft Teams due to logistical reasons. Each interview lasted between 30 to 75 minutes. The interviews were conducted between June-September 2023.

The interview protocol is based on the research objectives. For example, what the stakeholders understanding of a CE is in the industry? What they think the future is for CBMs in lithium-Ion batteries. What challenges they see for adopting CBMs within the ecosystem. What according to them are drivers for adopting these CBMs. Lastly open conversations are held to potentially get deeper understanding of how this transition towards the CE creates or destroys value for them. How this ecosystem will function in collaboration with them involved. The interviewees will be informed about the objective of the interview, the interview protocol and the fact that it gets recorded for transcription purposes.

From each stakeholder group respondents are identified that are engaged in the industry's ecosystem and thus have a good understanding of the drivers and barriers that exist when adopting a CBM as well as how this transition creates or destroys value for them. The respondents mostly operate from the Netherlands, except for the customers. These operate outside of Europe.

3.3 Analysis

This study uses a reflexive thematic analysis to identify themes, sub-themes and codes. A thematic analysis is a powerful and flexible qualitative method to understand. (Braun & Clarke, 2006; Shakerian & Gharanjik, 2023). This is fitting as this research is looking for a deep understanding of drivers and barriers of stakeholders and what creates value for them. Having a flexible method, makes it more applicable to understand different stakeholders' perspectives. A thematic analysis uses a six-stage process (Braun & Clarke, 2006). First the interview transcripts are read and re-read. This allows for familiarization with the data which creates an initial list of ideas (Braun & Clarke, 2006).

From this the data set is further analyzed to identify a list of codes. A code is a representation of a basic element of the data that is accessed in a meaningful way. The next stage is about segregating the codes into potential themes and sub-themes. The extracted data is extracted within the identified themes. The theme represents a patterned response or meaning within the data set. Then the stage follows in which the themes and sub-themes are again reviewed to ensure they reflect the dataset.

Finally, the themes are named based on an identification of the essence discussed within that theme. Further quantitative analyses is made up from the raw data itself. For example, how many times certain drivers and barriers are mentioned by the stakeholders themselves. Additionally, interesting insights come from how many times, what stakeholders mentioned certain value creation aspects of CBMs.

4. Results and discussion

This chapter describes the results from the 13 interviews that were done, including some additional comments that were presented by interviewees after the interviews. The quotes from the interviews are presented with the notation of the stakeholder as found in table 1, to indicate who gave the quote. The results are presented by the four categories that this study focuses on: drivers, barriers, value co-creation and value co-destruction. Further comments are given on each category to discuss the results.

4.1 Drivers for circular business models

During the interviews, all the different stakeholders were asked what they thought the most important drivers are to implement a CBM for LIBs. When the stakeholders mentioned the chosen drivers, they were asked to elaborate on why these drivers drive the adoption of a CBM. Table 2 shows the drivers that were mentioned during the interviews, which kind of driver was most often mentioned, and what stakeholders mentioned which driver. The categories for these drivers are derived from Benedikte Wrålsen (2021) and Guldmann et al. (2020).

Table 2
Drivers for circular business models according to stakeholders in the lithium-ion battery industry.

Type of driver	Mention by stakeholder	Frequency
Regulation	**All stakeholders**	**7**
	EOL	1
	Manufacturers	1
	Regulatory	3
	Suppliers	1
	Customers	1
Raw materials	**All stakeholders**	**7**
	EOL	1
	Manufacturers	2
	Regulatory	3
	Suppliers	1
Social	**All stakeholders**	**4**
	Manufacturers	2
	EOL	1
	Customers	1
Branding	**All stakeholders**	**4**
	Regulatory	1
	Manufacturers	1
	Customers	2
Technical	**All stakeholders**	**3**
	EOL	1
	Manufacturers	1
	Suppliers	1
Total		**24**

All the stakeholders agreed on the fact that regulation is an important driver for adopting circular business models. This implies that the regulatory landscape plays a big role for actors within the ecosystem to transition to a more circular business model. The stakeholders stress that the drive from regulatory is most prominent because regulation does not affect one single actor, rather the entire chain significantly:

"Because of new reporting requirements, customers also need to know from their suppliers how sustainable they are. This affects the user's side and also the behaviour of the manufacturer and the supplier. A manufacturer has to look at their customers as well as at their supplier base." – Manufacturer C

This drive is further strengthened by the fact that there are currently a lot of new regulations that are being put in place for this industry. This means that actors within the ecosystem have to really remain flexible, as well as up-to-date when it comes to these changing regulations:

"… you may have heard, but the Battery Passport initiative is something we have lately invested into and causes a lot of drive for businesses to look at their business model" – Regulatory C

And

"We currently have a market where there are plans being made beyond 2030 which means we are being pressured more and more. That requires future thinking" – Supplier B

Other stakeholders within the regulatory landscape mentioned as well that, especially within Europe there are many ongoing discussions within the regulatory landscape to further drive the adoption of circular business models (Regulatory respondent A & B). This pressure is confirmed by a party that uses batteries for integrations in their products (Customer A).

'Raw materials' is another often mentioned driver by the stakeholders when discussing a transition to a CBM. This covers drivers that positively influence the flow of raw materials that are used within the lithium-ion batteries. The only stakeholder that did not mention this as a driver was the customer group. Although these drivers all have to do with raw materials, the drive is very differently interpreted depending on the stakeholder that is asked. Regulatory stakeholders will often mention the availability of the raw materials that are at stake, due to the supplier pool being very concentrated. Another reason is because geopolitical relations are at stake in current times:

"The demand for raw materials seems to grow exponentially. However, we live in a time of great geo-political pressure… these pressures really put a lot of emphasis on shrinking material availability and drives business to deal with this security of supply" – Regulatory C

And

"As a starting point, it is really affected by the raw materials. It is not in supply everywhere and it is very dependent on a concentrated supplier pool of countries" – Regulatory A

Other stakeholders will mention how it is economically driven to set up a circular business model to obtain the raw materials back:

“The largest part of the battery is the cells when looking at its weight. It is very important to win those materials back” – Manufacturer B

And

“The incentive starts at raw materials. These will no longer cost as much money” – EOL A

Other mentions regarding raw materials were that a circular business model optimizes the flow of raw materials to reach optimization (Supplier A) and another mentioned that it’s cheaper for companies to closely track the flow of materials (Manufacturer C).

When looking at the next driver for adopting a CBM, we see that there are four mentions of social pressure as the most important driver. This driver category indicates an external social driver for the actors of the ecosystem. The category is mostly represented by those manufacturing the battery, as well as those that are involved in buying the battery and integrating it in vehicles. They mention that questions surrounding sustainability and recycling are getting asked more and more often by customers or end-users compared to previous years. The manufacturers or those stakeholders that buy the batteries to integrate it into a system want to have a good answer to these rising quantity of questions. A well thought-out transition to a CBM can assist in this.

“We are talking to end-users that seem to think lithium-ion batteries are not necessarily the best. They ask more and more questions whether there is already some work done into that area… there is no good answer yet.” – Customer A

And

“I talk to our customers at business fairs. These questions surrounding these topics start to pop up more and more. It’s good to have a good answer and a decent process” – Manufacturer B

It seems that the rising social pressure triggers the adoption in order to satisfy more frequently asked questions. It would be beneficial to have a good process in place to satisfy these questions even more. Limiting waste can be beneficial to this as well, which is a specific social pressure according to EOL A.

The next big driver to adopt a CBM is brand image. This refers to a more internal drive to position the company in an improved manner. Whether this is an extension of the ‘social’ category is of course debatable. The category is again mostly represented by the manufacturers of batteries and those that integrate it into systems. The stakeholders that use the batteries in their systems often mention how green practices fit their products:

“It is one of our company values I guess. So the whole company here at (customer name) is environmentally focussed. Our goal is to have zero landfill. We as a company are really trying to become a net 0 carbon company.” – Customer B

And

“As an electric vehicle provider, we want to be seen doing good. It fits our product. We want to actively promote it on our website, where the materials are sourced from, how long they last. It is also a waste of energy if a battery outlasts the usage of the vehicle we believe.” – Customer B.

A manufacturer stresses that circular business models are still in its infancy. Because of this, it is a good reason to adopt this to excel above others within the industry:

"We can distinct ourselves from other suppliers. We can show that we excel in quality and on sustainability. That our product lasts, but also that we focus on these kinds of topics. That we do not waste too much. If we start while it is in its infancy, we can keep ahead." - Manufacturer A

This drive is confirmed by regulatory stakeholders to be a very important one (regulatory C).

The last category of drivers are the drivers that have a more technical side to them. These can have to do with technologies that are starting to make their introduction that make adoption of CBMs easier. Another technical driver is that certain CBMs become more and more economically viable. Examples mentioned by stakeholders are:

"More and more batteries, especially those used in vehicles are getting to a point where they have reached their end-of-life. End-of-life parties will have access to a larger pool of retired batteries and this volume allows optimization of end-of-life processing." – Manufacturer 1

And

"Lithium-ion batteries from cars are more and more common, and have relatively less variation. This allows for setting up better processes that are more safe." – EOL 3

These quotes indicate that technical advances are making their way in order to optimize these processes even more. This positively affects pricing for recycling as well as opportunities for repurposing (EOL 1 & 3).

The technical advances not only have impacts for the batteries themselves. It also positively affects a business towards a CBM that improves on material usage. Testing of packaging and materials is important for the logistics of batteries because batteries are considered dangerous goods. While the testing technologies of these are improving, greener and less materials can be utilized (Supplier B).

Theory provides several CBMs and drivers to adopt these in this industry. The expert's point of view regarded regulation as the most important driver. This is the same from the stakeholder's view as can be found in this chapter. However, what seems to be very different from other theory is that in the stakeholder perspective, the pressure on raw materials plays a big role. In this research this driver takes a second spot on the ranking of most important driver. What else largely differs is that in this research, as opposed to research by Benedikte Wralsen (2021), the consumer behaviour is not regarded as the weakest driver in the collection. The stakeholders have stated social pressures several times during the interviews giving direct indications of how consumer behaviour shape the need for CBMs. This could have to do with that this research takes data from direct stakeholders that are involved in selling to consumers. The findings are not in line with other theory surrounding drivers for CBMs in all industries in general (De Jesus & Mendonça, 2017). This theory suggested that economic and financial market drivers are the strongest, which is not the conclusion from this research.

4.2 Barriers for circular business models

When the interviewed stakeholders elaborated on the drivers, they were asked what they thought the most important barriers are to implement a CBM for LIBs. When the stakeholders mentioned the chosen barriers, they were asked to elaborate on why these barriers hinder the adoption of a CBM. Table 3 shows the barriers that were mentioned during the interviews, which kind of barrier was most often mentioned, and what stakeholders mentioned which barrier. The categories are derived from (Guldmann & Huulgaard, 2020).

Table 3
Barriers for circular business models according to stakeholders in the lithium-ion battery industry.

Type of barrier	Mention by stakeholder	Frequency
Technical	**All stakeholders**	**11**
	EOL	3
	Manufacturers	2
	Regulatory	6
	Customers	1
Cost	**All stakeholders**	**10**
	EOL	3
	Manufacturers	3
	Regulatory	2
	Suppliers	1
	Customers	1
Regulation	**All stakeholder**	**8**
	EOL	2
	Manufacturers	1
	Regulatory	3
	Customers	2
Safety	**All stakeholders**	**7**
	EOL	2
	Manufacturers	1
	Regulatory	1
	Customers	3
Volume	**All stakeholders**	**7**
	EOL	1
	Manufacturers	2
	Regulatory	2
	Customers	2
Cultural	**All stakeholders**	**3**
	Manufacturers	1
	Suppliers	2
	All stakeholders	**3**

Logistics	EOL	1
	Regulatory	1
	Customers	1
Total		**51**

The most often type of barrier that the stakeholders agree on is that it is technically hard to adopt a CBM. This can mean that there is simply too much technical variations amongst batteries which disrupts a good system for the ecosystem as a whole (Customer A, Regulatory A & C). Another technical barrier is that it is simply very hard to put in place a good recycling process that wins back as much material as possible:

"There will always be losses on the raw materials. This is because we do get Black Mass from the recycling, but there is always some metal in it. We will get copper back, but there is always some mess stuck to it, it will not be so pure as you want it to be. If you want it to be that pure, the technology is not far enough to obtain it 100% pure"– EOL A

And

"You will simply not get a ready-made product back with our current recycling technologies. If you want something that closer resembles that, you will have to implement very complex chemical processes" – Regulatory B

The manufacturers mention very different things. One manufacturer states that for some batteries it can be very hard to say something about the state of health of a battery. This is crucial for reusing materials or for repurposing the battery (Manufacturer C). Another manufacture stakeholder mentions that for some recycling regulations, there simply does not exist the technique yet (Manufacturer A).

Information on technology makes up this category according to two stakeholders. Technical information regarding developing second-use batteries or recycling practices is very dispersed within the ecosystem (Regulatory C). Additionally, there exists no proper calculation models for reusing certain types of batteries (Regulatory B).

Other barriers are that current technical developments focus more on getting more energy from the battery while lessening the weight while developments do not prioritize reuse or sustainable practices (Regulatory B) or that substitutes for current critical raw materials are not properly developed (Regulatory A).

Costs can prove to be a blockade in the transition as well, having the second amount of mentions when it comes to barriers. All stakeholders have mentioned the cost aspects to be a big barrier in the adoption of CBMs. This can mean that in the current stage there is not enough known about CBMs in this industry for it to be cost-effective yet (EOL A & C and Manufacturer A & C). Another cost barrier is that it is cost-ineffective to test EOL batteries for repurposing or to properly dismantle in order to recycle to its fullest extent (Regulatory A, Supplier A). The following quotes are telling:

"When the case is that the end-of-life batteries are returned, and there are no logistics to properly recycle them, or to properly second-use them, then it becomes more of a liability. There is no incentive in that case" – Regulatory A

And

"You really have to take apart those batteries, really test them. That is very time-intensive… You have to pass this on in your pricing as well towards customers. Maybe it's an issue in our current economic system?" – Regulatory A

And

"You can get materials back, but these are in fact cost-bleeding" – EOL Stakeholder C

While regulations have proven to be a big driver in the adoption for CBM, some stakeholders mention that they can prove to hinder transitions. This can be due to the absence of clear regulations that push the transition (Customer B, Regulatory A, and C, EOL C).

"I don't know if you mean repurposing. Where an end-of-life battery is used for a second purpose. That is not something that falls under the law I think" – Regulatory C

From this it becomes clear that there needs to be a clear structure in order for actors in the ecosystem to take action. While the laws can be pushing, they can also serve as good guidelines (Customer B). Other stakeholders mention the needs for these proper guidelines and certifications with the following quotes:

"It does mean that the government must lay down a proper structure to make the replacement and reusing of batteries reasonable… ICT has CENELEC, batteries do not have that yet within our ecosystem." – EOL C

And

"What that second life use would be and I mean the sort of regulations around that surrounding testing and how they're managed and when they are classified as now being a second life battery. For me those are unanswered questions at the moment" – Customer B

And

"During conversations on the topic, there is the involvement of the fire department. They would like to help to think on how batteries can be used for second applications, but they do not have the manpower for that, and on the other side the knowledge has to be garnered and agreements have to be made. Who is going to deliver these certificates? What institutions are responsible for this? I do not think we have that at the moment" – Regulatory Stakeholder C

Another stakeholder mentions that the building of proper recycling facilities contradicts current laws on emitting nitrogen which serves as a big barrier (EOL Stakeholder A). Regulatory stakeholder A mentions that there is currently more momentum for energy transition rather than circularity.

Safety barriers were mentioned 7 times during the stakeholder interviews. There is the notion that currently it is not safe yet to adopt a circular business model. This can be for example by using less materials, or less strong materials affecting safety during usage (Regulatory Stakeholder A) or logistics (Customer B). It can also mean that for the repurposing business model, there is simply a lot of risk when it comes to the battery itself in its second-life application (Manufacturer C, EOL C, Regulatory A). The following quotes summarize this:

"You need to know the history of a battery. You need to know how it operates compared to its original usage. If you do not know this you simply buy a very big risk in terms of safety" – EOL C

And

"You see it with batteries as well. There is simply a very big risk aspect to it. It has a certain life cycle and maybe it can last 10 years beyond that… maybe 20… but the safety risk poses a very big barrier to really implement that" – Regulatory A

Safety can also be a barrier for circularity in terms of safety being a bigger priority than circularity. This means having to make sacrifices in circularity in order to improve safety (Customer A, Regulatory A).

The next important barrier that hinders a transition to a circular business model is volume. This has to do with the quantity of second-use batteries being too low, or the demand for these batteries being too low. This is closely linked to the costs barrier when thinking of economy of scale. However this barrier was mentioned very often on its own, making it logical to give it its own category. The following examples will showcase how this poses as a barrier within this ecosystem.

One very important indication of how volume, or lack thereof, can be a barrier is because you need scale in order to set the second-use market in motion. That is not the case yet (Customer A and B). A bigger scale of supply second-use batteries can be a catalyst to set up demand for second-use market (Regulatory B & C).

"The market needs to come into existence. It is a relatively new market and it needs to find its way. Looking at volume, this is very hard, because most batteries can take up to 15 years to reach their end-of-life." – Regulatory B

And

"We only had our vehicles in use for the last two years. We have not reached the end of the product cycle yet. So the volume is not there yet" – Customer A

Other mentions of how this volume plays a big barrier is that you need more scale in order to improve on technologies surrounding the recycling of batteries. This simply does not exist now, yet.

"Battery recycling is very much still in its infancy. Can we reach a large enough scale in order to get a good business case?" – Regulatory C

And

"Iron phosphate batteries are relatively shorter on the market than NMC. These are harder to recycle because the supply of end-of-life is simply too small." – Manufacturer A

Stakeholders mention as well that there is no volume in terms of capacity for processing or recycling (EOL C, Manufacturer B, Customer B, Regulatory C). This can be linked to the fact that it does not get operational because there is not enough supply of end-of-life batteries. It is mutually dependent:

"There is just too little processing capacity for lithium batteries. They only get operational once there is volume… that is hard because there is too little capacity. It can be done in a network, that you make sure it is bundled on one location…" – EOL C

There were a total of 3 mentions of cultural barriers. This would mean internal barriers within organizations that mean this transition can be slowed down.

Manufacturers would say that the barrier is that a company looks for ways to adhere to laws and regulations, rather than it being an intrinsic motivation. It is more reactive than passive. This as a cultural barrier (Manufacturer A).

Suppliers mention from their experience how culture plays a big role. They mention the difference from their stakeholders when it comes to CBMs and their role as a supplier.

"When we interacted with (name of manufacturers) we noticed a big difference when we talked to a person that really stood for that sustainable idea. It has to live internally in order to be implemented" (Supplier B)

Within the industry, there is also the barrier of logistics. This was mentioned 3 times. Because (used) batteries can be seen as dangerous goods, they require certain handling during transport. Figuring out a proper supply chain for recycling or repurpose can be more expensive than throwing a battery away, especially in isolated parts of the world (Customer B).

In other parts of the world like the Netherlands, with a large density of people, it can be difficult to get a circular stream of goods in multiple directions. A linear stream is a one-way trip (Regulatory C). A respondent from EOL simply mentions that the infrastructure is missing in terms of central collection locations.

Guldmann and Huulgaard (2020) proposed that when it comes to CBM adoption for industries in general the most influential barriers relate to organizational level. This seems to not be the case for this industry as the most important barrier relates to technical limitations within the ecosystem. The barriers relating to organizational level are actually ranked relatively low in this study. Findings are thus very telling for this specific industry.

The stakeholders pointed out in general that the technical limitations play a big part for actors to not take a big part in adopting CBMs. Followed by barriers relating to costs and regulations there is some work to be done in order to pave the way towards easier and better adoption of CBMs. Theory suggested that stakeholder coordination is needed to solve these barriers by collecting resources and capabilities (Schulz et al., 2021). The proposed barriers would be the best starting points.

The barriers touch upon several important CBMs proposed by Olsson (2018). Within the volume barrier, some stakeholders indicated that there are simply not enough used batteries to operationalize a proper system for sorting and collecting for second life applications. This is a big problem for the proposed circular business model of 'refurbishing' and 'second using before recycling', as proposed by that research. Furthermore, the research of Benedikte Wrålsen (2021) indicated that a business model with remanufacturing + reuse + recycle + waste management to be the most suitable. The research at hand found that technological barriers for proper waste management and recycling is not done due to the technical limitations that exist, or the volume that does not yet exist. Barriers relating to volume hinder proper remanufacturing as well as this cannot be operationalized. Knowing these barriers can help in solving pressing issues for the most promising CBMs that were proposed in past research by Benedikte Wrålsen (2021) and Olsson (2018).

4.3 Value co-creation

Within value co-creation, interactions between stakeholders help with creating value. It emphasizes collaboration among these stakeholders. Insights, resources and capabilities are shared to collectively obtain the value. (Busch et al., 2018; Schulz et al., 2021)

From the interviews, a lot of different examples can be drawn up on how this could look like within the industry for lithium-ion batteries. In total 25 inputs were given by the interviewees what should be added. Because many variations were proposed by the different stakeholders, it is hard to quantify which one works best. There is however a very clear distinction between the inputs in order to co-create value.

The first input for value co-creation refers to the flow of relevant information within the ecosystem. This can refer to what parties need to share knowledge, what parties need to actively collaborate to generate new ideas and what parties should get involved to initiate standardization.

The second inputs to co-create value refer to physical flows in the ecosystem. These are inputs that indicate where certain batteries have to go within the ecosystem, where finance streams should go in order to realize the value co-creation and to solve certain barriers. Other flows of materials refer more to raw materials and where these should end up in order to complete the cycle.

4.3.1 Value co-creation: information flows

Within the ecosystem of the lithium-ion battery, several collaborations can happen based on knowledge exchange to co-create value. This can be in two ways. The first method for co-creation is materializing where concepts and knowledge is shared for improving the offering and giving feedback. This relates to co-designing and co-testing. The second method is institutionalizing which refers to developing rules, norms and standards for the product. This is to retain and capture the value, in collaboration with multiple stakeholders (Marcos-Cuevas et al., 2016). According to several inputs from the interviewees, this is necessary and can resemble figure 2.

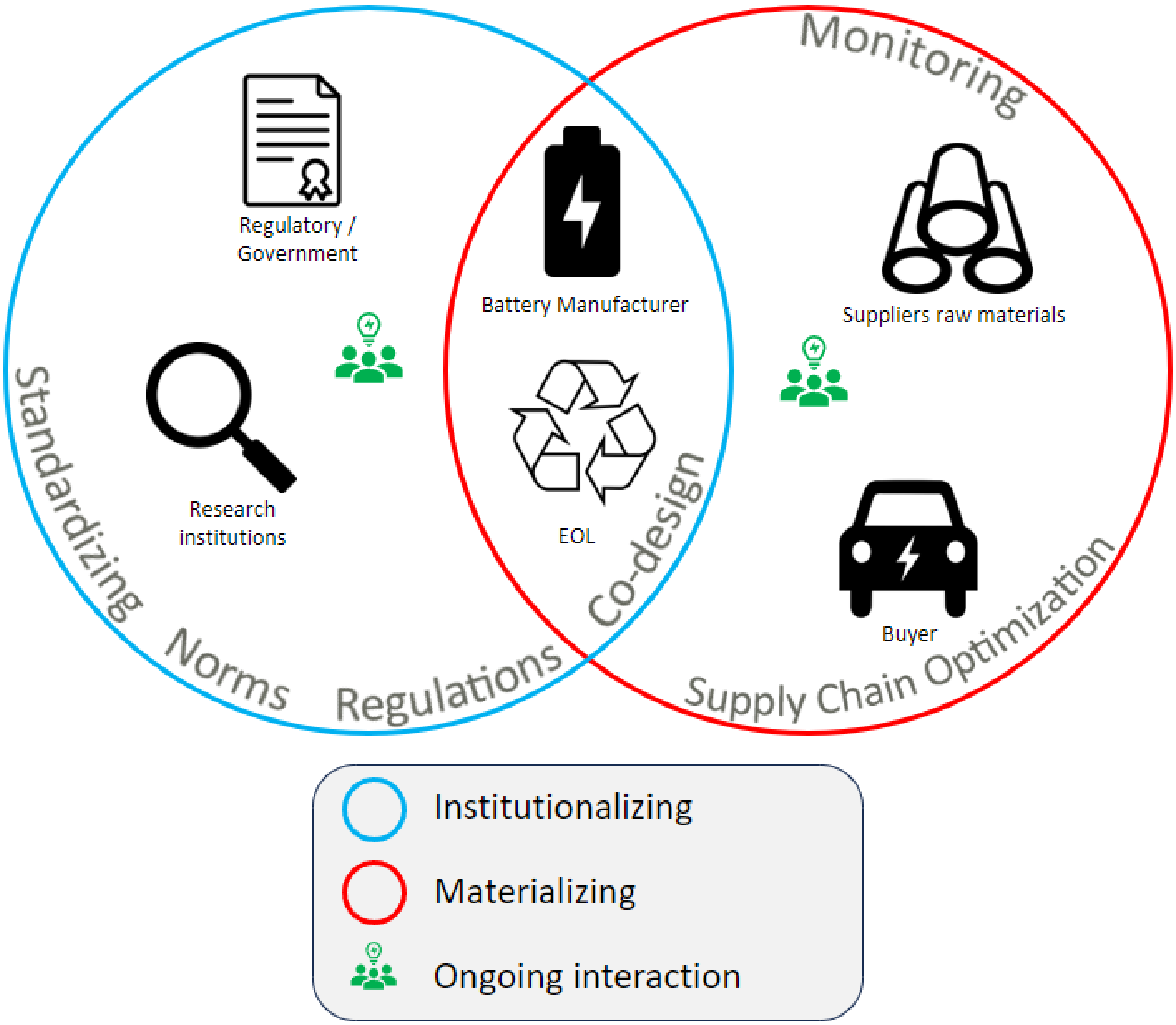

Figure 2: Value co-creation information exchange

The figure is divided into two types of information exchanges: institutionalizing and materializing. EOL parties, like recyclers, and battery manufacturers should involve themselves in both. The reason why battery manufacturers should have active ongoing exchange with the EOL is because they both can work on operationalizing a better battery design which improves the recycling:

"What is important is that the parties who do the recycling have spot at the table with the parties that make the batteries. You would hope that gives a good information exchange, that they bring up points they do not know from each other. They should together find out how that develops and based on that take a step towards circularity, which increases the recycling in the future." - Regulatory C

And

“We want to talk with companies that specialize in the recycling of the battery cells. We really want to work together with a party like (recycler) because they can retrieve more back when looking at the cells.” – Manufacturer A

EOL A strengthened this claim by stating how this is already carefully done with the car recycling within the Netherlands. Together with recycling parties, the car manufacturers try to co-create a product that more easily dismantled and thus easier recycled. This should be more common practice (EOL A).

The information exchange between the EOL, and manufacturing parties should extend their interaction within the institutionalizing sector of the model to set standards and to generate certificates for proper guidelines. The certifications and proper guidelines are now missing and a regulatory party should co-create these with the EOL and manufacturing parties:

“We should sit down together and discuss what good conditions are. And how can we come to working agreements? Or requirements for certifications. A standard can be set with (name of manufacturer). This standard allows for a structure of certified end-of life parties that can take these batteries back to highly-qualified raw materials.” – EOL C

Stakeholder EOL C further emphasizes that there should be a party involved that manufactures the product themselves. They can properly understand what needs to be done when it comes to safety, for example within the repurposing phase:

“When you can interact in such a triangle to discuss how to safely work with these batteries in the repurpose phase… that way we can get a lot done” – EOL C

Further role of the government is that they should look at possibilities in solving information asymmetries and finance shortages:

“The role of governments in this should be to look at where frictions still exist. Where can we get rid of asymmetries? Is it purely financial and can we compensate in this?... We can certainly play some kind of kickstarting role.” – Regulatory C

EOL A did mention that in order to be more successful in terms of circularity, the government should play an active role in promoting responsibility towards manufacturers for the entire life-cycle of the product. This improves on circular design.

“The only way to get this done properly is when the government interferes with this. Their input should be that the manufacturing party remains responsible for the product during the entire life-cycle” – EOL A.

EOL C added to this that end-of-life batteries should not be allowed to be exported outside of Europe. This should be pushed by regulatory parties in these conversations:

“Regulatory has a gigantic influence in this. They should say that batteries are not allowed to be exported outside Europe, inside of Europe is fine for hyper plus points, but not outside of Europe. It remains here and we force high-quality processing in Europe. That means we can build good

recycling facilities… the batteries are only allowed to be processed at these certified facilities” - EOL C

The reason research institutions are involved in the institutionalizing ring is because of an input from Regulatory A. Research institutions can contribute in this because research topics on circularity of batteries has lately gained more traction. However, this does not reach governments as there seems to be distant contact between government and research institutions:

“Maybe a reason the government cannot play a good facilitating role is because there is insecurity between the government and startups and universities on these subjects.” -Regulatory A

A good foundation for standards can assist in the lack of proper guidelines when it comes to repurposing. The co-creation of product standards set by the battery manufacturer together with the recycler can help in developing a better recycling process. The government and its regulatory parties can actively co-create with these stakeholder to systematize proposed standards. As an added benefit, this creates more feasible regulations. Manufacturer A mentioned in chapter 4.2 that regulatory is currently pushing for recycling regulations, while the current technological position makes this hardly possible (Manufacturer A). A model like this helps towards synergizing.

When we look at the materializing ring, the collaboration exists mostly between the battery manufacturer, the EOL, the suppliers of raw materials and the customer. There was no mention from these 13 interviews that the customer and supplier of raw material should be in the institutionalizing ring. The interaction remained limited as presented in the figure above.

The battery manufacturer and the EOL parties exist in both the materializing ring and the institutionalizing ring. The reason for this is because the above quotes by Regulatory C and Manufacturer A indicate not only the need to set standards for the product, they indicate the need to co-design the battery as well.

Next, there are instances where the supplier of raw materials has input in the operations of the battery manufacturer and the customer:

“We often sit around the table with our customers to discuss topics together with their end-customers. The whole supply chain can be at one table to discuss pros and cons. So the manufacturer, their end-customer and we as a supplier.” - Supplier B

And

“We (the battery manufacturer and supplier) can test it here together at (city name). When a new, more sustainable (packaging) material is implemented, we should test that together. Like a physical test, we drop it on a few angles for example, to assure safety” – Supplier B

Supplier A added to the collaboration between suppliers and battery manufacturers that the active monitoring of the batteries installed at the customer’s application is important. The stakeholder mentioned this should be done with a product manager from the battery manufacturer that gains insights from online live monitoring reports relating to the installed battery. When it is end-of-life, the take-back system should do the rest of the work (Supplier A).

This takeback system between a customer and battery manufacturer was proposed again by EOL A. This stakeholder mentioned the need of a service interaction in this new circular business model to make it work properly:

"Don't sell a battery, sell usage. Pay-per-use. You get the possibility to do the monitoring… The customer benefits because when you can do live-monitoring, you can advise the customer on proper usage of the battery. Make sure preventive maintenance happens at the right moment to make it last. The usage gets cheaper because it is used better and more efficiently." – EOL A

This stakeholder added to this point that this improves the responsibility of the battery manufacturer has for its product, because in this business model they remain responsible for end-of-life. It provides an incentive to construct the battery in such a way that it can be cost-efficiently dismantled and preferably reused (EOL A).

Additionally EOL A mentioned that as a EOL party, there should be collaboration with the supplier of the raw materials. This ensures that the materials get back into the loop from the EOL party towards the supplier of raw materials (EOL A). Customer A mentioned that there should be collaboration with them and a EOL party to properly lay down agreements to send used batteries to them (Customer A).

Taking the inputs from all the different stakeholders in this model ensures that the model (partly) captures value as envisioned by the stakeholders. Creation of mutual value through service-exchange is essential (Schulz et al., 2021; Sedoglavich & Dabić, 2016). In this model the mutual value is created within the institutionalizing ring for regulatory stakeholders by garnering knowledge on pressing issues within the ecosystem because of their interaction with research, manufacturers and recyclers. The recyclers and manufacturers benefit in the institutionalizing ring by exchanging knowledge necessary for standardizations and norms which lead to optimized recycling for the recyclers and leads to a better end-of-life process for the manufacturer. In extension, having the regulatory party involved here means that fitting solutions for the adoption of CBMs can be standardized and regulated based on relevant inputs from the manufacturers and recyclers. All-in-all this leads to a network of actors connected through shared institutional logics, as was proposed by (Sedoglavich & Dabić, 2016).

Further mutual value can be found within the materializing ring from the exchange between the manufacturer and the recycler by co-designing a product. First of all it is easier for the recycler to recycle a co-designed battery. Second, the battery manufacturer gets insight in how to optimize the end-of-life process of their product by involving the EOL party in the co-design process. The customer gains value by partaking in the materializing ring by sharing knowledge with the battery manufacturer on how they use the battery. This can be a live monitoring feature as proposed by EOL A. The benefit for the customer is the advice they get on how to use the battery properly. The value creation for the battery manufacturer in this cooperation is the close monitoring of their product within the customer's application. It allows for better understanding of the product and can assist the manufacturer in developing a take-back system for giving the battery a second life.

4.3.2 Value co-creation: physical flows

Within the ecosystem, several flows have to be implemented to make the co-creation work on a physical level according to the stakeholders. The inputs from the stakeholders are collected in figure 3.

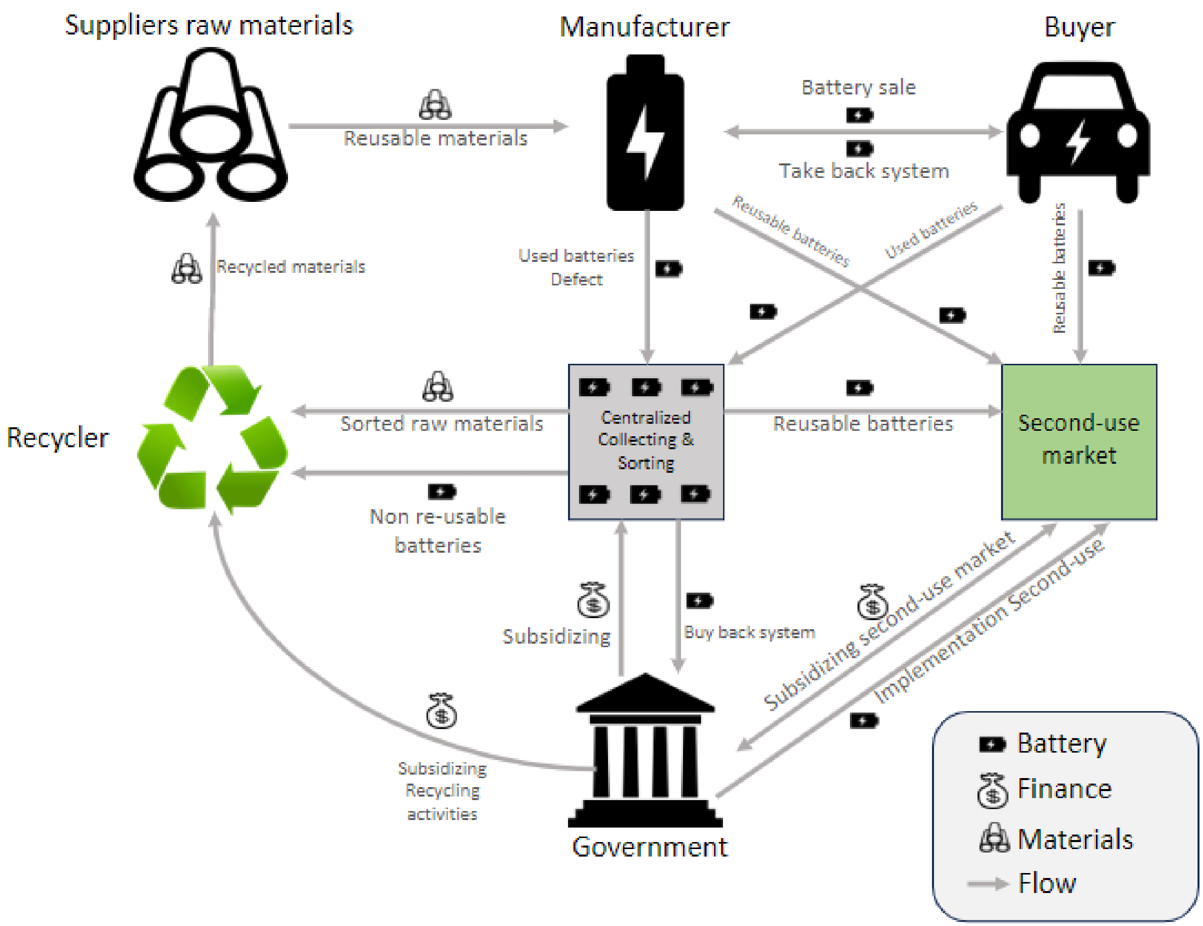

Figure 3: Value co-creation physical flows

When looking at the barriers, the problems of low volume is repeatedly mentioned (Customer A & B, Regulatory B & C, Manufacturer A & B and EOL C). This meant that it would be hard to operationalize proper recycling facilities, the low volume limited a growing second use market and it is a bad business case to apply intensive testing to this low volume (see 4.2). During discussions, several stakeholders gave input how this should be handled. Customer B and Manufacturer C mentioned that there should be a collaboration between manufacturers to bring together multiple streams. This should go to a central location, as indicated in figure 3. The EOL party should be involved within this stream:

"Maybe it should be brought together with other battery manufacturers. There is some kind of homogeneity you can reach. It is very intensive to put together for us alone, but why won't you bring it together with (name of EOL stakeholder)? Start with centralizing here." -Manufacturer C

As it happens, this same input came from the EOL party:

"We should organize a network for collection and sorting. In Germany this is done properly already because they collect proper volume. When we apply it here, we can kind of upgrade our market. Eventually this paves a way for high-quality refurbish activities for batteries and companies that think this is profitable. This also allows for a structure of high-quality processors." – EOL C

Customer B mentioned as well that governments can play a role in this where they purchase these working used batteries to put them in the second-use market, in for example infrastructure. This government buy-back system promotes this second-use market (Customer B). Manufacturer C mentioned that they should play a subsidizing role to promote proper recycling facilities or to promote the second-use market by incentivizing parties that apply the second-use of batteries (Manufacturer C).

The stream in figure 3 between the recycler, the supplier of raw materials and the battery manufacturer is constructed of the input of EOL A and EOL B:

"EOL should prove they have connections with suppliers to close the loop… otherwise there is the often-made false claim of circularity when actually materials are just used for lesser purposes." – EOL A

And

"You need collection and processing. These stakeholders should collaborate. Materials are processed, they go back to that factory to make new products to be bought again by that stakeholder." – EOL B

The usage of the central point seems to be a necessary input in the value co-creation process in the ecosystem. This fits closely to the theory of Haki et al. (2019) which indicated that the exchange of services can often be facilitated. This may be tangible or intangible. The research provides a clear direction for the need of a tangible point of collection which enables, facilitates and distributes the service provisioning in this ecosystem.

This tackles the volume barrier which gained a lot of traction during the stakeholder discussions. This scaled up volume can make way to solve other problems. Examples of solutions can be properly operationalizing recycling facilities and allowing for better sorting, better research towards repurposing activities and can create a more positive business case through economy of scale. These are closely connected to the barriers for costs and technical. When enough batteries are collected and sorted in the centralized connection point, the qualified batteries can make their way towards the second-use market, as indicated in figure 3.

4.4 Value co-destruction

When one of the system's well-being is declined, we speak of value (co-)destruction (Smith, 2013). The ecosystem of this research consists of suppliers, Customers, Manufacturers, Regulatory institutions and End-of-Life organizations as important stakeholders derived from the research by Benedikte Wrålsen. The system looks beyond these stakeholders, taking into consideration all affected parties within the system. Table 4 shows the types of destruction that were mentioned by the interviewed stakeholders.

Table 4

Value co-destruction for circular business models according to stakeholders in the lithium-ion battery industry.

Type of co-destruction	Mentioned by stakeholder	Frequency
Environment	**All stakeholders**	**8**
	EOL	5
	Manufacturers	2
	Regulatory	1
Safety	**All stakeholders**	**3**
	EOL	1
	Manufacturers	1
	Regulatory	1
Costs	**All stakeholders**	**2**
	Regulatory	1
	Suppliers	1
Income decline	**All stakeholders**	**4**
	EOL	2
	Suppliers	1
	Manufacturers	1
Total		**17**

The most often mentioned type of value co-destruction according to the stakeholders have to do with destruction to the environment. This can be very diverse, and the examples really depend on the stakeholder. For regulatory, an environmental co-destruction example is that promoting circular business models can make way for new recycling plants having to be built and different processes having to be implemented both of which cause co2 emissions.

"When we will go into that direction, the co2 peaks will first skyrocket. We will only earn that back during the usage phase, for example in a car." – Regulatory A

The next example is harmful due to current regulations and certifications not being set up properly to fully benefit the environment. Transitioning towards a CBM only benefit the actors because regulations are followed and certifications are obtained, not because the environment is supported. Greenwashing was a word used to describe this (Manufacturer B, EOL A).

An additional example of how the transition to a CBM can negatively benefit the ecosystem is when the actors transition to a CBM that focuses on repurposing. In chapter 4.2 there was mention of the barrier that indicated that there is no good market for second use, or repurposed batteries. This can create an abundance of second-use batteries that cannot find a new purpose. Several stakeholders think due to this, that in a transition to a repurposing CBM certain end-of-life batteries can be dumped to markets in third-world countries with no clear control (Manufacturer C, EOL C).

"That (repurposing) is of course a very good cloak for illegal export. There is no good prevention for that now (...) In the third world there are already lots of energy problems. If we do not do it properly, we will get a waste leakage stream into that direction" – EOL C

EOL A mentioned that the transition to a CBM with recycling is good in one way; however it causes damage in another way. Recycling is improving and will get so good and cheap that it can become the norm, however it faces attention away from something better:

"What we are doing is, we are building a suboptimal system. We are recycling batteries, that are in fact not recyclable (...) It could have been so much better, if the product was designed better. The priority should be on that." – EOL A

Safety is the next category of value co-destruction. Three different stakeholders mention safety to be negatively affected in this transition. A manufacturing stakeholder mentioned that switching to regenerated plastic in the product, can lead to a product that is less robust. This can have negative effects on the safety (Manufacturer B). A regulatory stakeholder mentioned safety concerns within the product as well, saying that safety margins are challenged in new designs. This is a problem with products as dangerous as batteries. – Regulatory B

EOL stakeholder B mentioned that with the current demand low demand of second use batteries, means that some second use batteries are stored in one location a long time. This means a repurposing CBM is affected by this dangerous negative aspect:

"The capacity for processing of batteries is very small. We see that as well with one company in (city in the Netherlands) where they have so many batteries stored that simply cannot go anywhere. They have a literal fire hazard on their grounds." – EOL B

Costs is the next type of value co-destruction. A regulatory stakeholder mentioned that promoting batteries and circularity practices and subsidizing this can become a large cost problem, as they have seen with solar panels in the Netherlands:

"It (subsides) was meant to sponsor solar panels. They are now so cheap that it benefits to put one on your roof. (...) Actually you should get rid of this and promote batteries, to accommodate peak hours. They did this in Belgium. This was however so successful, too successful that they got rid of it within 1,5 years… with solar panels we also created an abundance, and now there is no recycling capacity and it is costly to get find ways fast to get rid of them." – Regulatory A

Supplier A mentioned the rise of a non-profitable flow of goods. It can result in procuring goods that have a higher buy-in price than selling price due to wrong valuation estimations (Supplier A).

When looking at income decline in value co-destruction, one supplier, two EOL and one manufacturer came up with an example. The supplier mentioned that with a CBM and having repurposed items within the offerings can lead to obtaining a b-store predicate. This can negatively affect the image of the company when it transitions to a repurposing CBM, if not communicated properly. This change of image can affect sales (Supplier A).

The manufacture stakeholder mentioned that transitioning to a CBM with repurposing and implementing this within the ecosystem that involves potential customers can lead to cannibalizing of the product. When the CBM for repurposing is well developed and potential customer opt for a cheaper reused/repurposed product instead of a more expensive new product, it can eat into revenues. – Manufacturer C

The recycler is negatively affected within a collaboration between a manufacturer and a recycler. The idea of this collaboration is that a manufacturer makes the product, and the recycling party advises on how this product can be made in order to be recycled easier. This eats into the revenue of the recycling party (EOL A & C).

"The recycler needs to dare to talk about making himself neglectable. (...) The product has to be so easily recyclable that the recycler earns as little money of off it as possible. We have to make ourselves no longer necessary" – EOL A

In summary there seems to be some potential value co-destruction when transitioning to a CBM. This can be for the individual actor within the ecosystem, like the recycler becoming neglectable. Becoming neglectable can in this case lead to a financial loss of resources which is a clear example of value co-destruction (Sthapit & Björk, 2019). Moreover, this can be for the ecosystem as a whole, like the illegal exports of repurposed batteries mentioned by EOL C. This indicates negative feelings or a decline in well-being of a party involved in the ecosystem (Sthapit & Björk, 2019). Lastly, there is the abundance of repurposed batteries when this gets too heavily subsidized as mentioned by Regulatory A. The value co-creation process should take these into consideration.

5. Conclusions, implications and limitations

The direct stakeholder interviews were used to identify the drivers, barriers, value co-destruction aspects and value co-creation aspects of a transition to a CBM within a lithium-ion battery industry. The interviewed stakeholders provided valuable inputs and knowledge from their unique perspectives. The inputs can be used to face the complexity of the transition towards a circular economy and to assist in the adoption of CBMs. The topic requires insights from all stakeholders to construct the right policies, the proper design features and the correct waste management.

5.1 Theoretical contributions

The adoption of a circular business model is essential in the creation of the circular economy. The circular business models were discussed during the stakeholder conversations in the research at hand. During the conversations, several drivers and barriers were found which add more context to the adoption of circular business models. For example, business model of refurbishing and second use before recycling gained more context through this research by discussing that volume barriers and direct technological barriers should be solved before adoption becomes easier. Elaborating on the challenges for these CBMs pave way for research that should focus on solving these. This adds to the discussion in existing theory surrounding these circular business models as can be found in articles by Albertsen (2021) and Olsson (2018) that came up with these CBMs. With this paper, these CBMs become more palpable and easier to grasp as they have been examined by stakeholders that may or may not use these.

The drivers and barriers for adopting circular practices to build towards a circular economy are now better conceptualized. Both are more deeply explored using the insights of direct stakeholders. This not only assists in better understanding circular economy adoption, it also provides current theory with more examples of drivers and barriers to further explore. Studies by Govindan (2018), Babatunde (2020) and Karanja (2020) explored these drivers and barriers for CE in other industries and this paper adds to the overarching theme of that discussion.

Additionally, this research gives multiple insights on how the CBMs specifically for lithium-ion batteries should be embraced and approached when it comes to co-creating the value. It provides a clear blueprint that can serve as a steppingstone for further examination. It takes these insights and puts it against real world scenarios to better understand how these operate in the specific context of this industry. This contributes to both theory of Olsson (2018) that provided specific CBMs and to the theory of Wrålsen (2021) that provided the most important stakeholders in this transition within this industry. It connects these discussions by paving a more direct path towards a CBM that works best according to the relevant stakeholders. Secondly the business models and stakeholders have gained more context with the help of this study, by taking a fresh view of drivers, barriers and value co-creation using direct stakeholders' perspectives.

The study at hand applies the point of view of direct stakeholders and discusses how value co-creation and co-destruction can present itself for their ecosystem. It gives a unique view from within an underexplored industry by letting the direct stakeholders shape the value co-creation process. The research at hand can serve as a source of inspiration for discussions on how value co-creation may manifest. The research provides possible instances of value co-destruction on top of that. Additionally, it attempts to better understand stakeholder interactions, the responsibilities and the important power dynamics which are topic points within stakeholder theory. Furthermore, these abovementioned points fit constructively to the discussion in the literature by Schulz et. al. (2021) or by Busch (2018) about value co-creation and value co-destruction and how this may present itself within an ecosystem.

5.2 Managerial implications

Managers that operate within this industry or a similar industry can look at the drivers and barriers found in this paper to get a good understanding of their stakeholders when going through a transition that embraces circularity. This understanding can be found in why certain stakeholders can or want to take certain steps in the transition. This helps managers in either capitalizing on drivers, or by correctly identifying pressing barriers early in the process.

Another insight is that the driver is mostly present from a regulatory standpoint. This stresses the importance that regulation should play a leading role in facilitating this transition. Policymakers can take this research as inspiration when forming new policies and regulations. Policymakers should actively work together with the parties in the proposed institutionalizing ring to come to better guiding regulations and good technical guidelines in order to drive the adoption of CBMs.

Furthermore, the results in the chapters discussing the value co-creation give all actors in the ecosystem their required contribution. For example, the visualization of the information exchanges clearly presents the need for end-of-life parties, regulatory, research institutions and battery manufacturers to develop clear and feasible standards. When any actor within the ecosystem wishes to transition to a CBM, they can use this research as inspiration on what their role should be in the value creation chain and what parties they should reach out to for collaboration. Distinct boundaries are stated within this collaboration as well. The roles of other actors within the value creation are now clearly stated, which helps in making collaboration agreements and setting accountability. For example, a battery manufacturer knows that they have to actively be involved in institutionalizing as well as materializing. The chapter on value co-destruction gives clear insights into what the actors should be aware of in terms of value destruction during the realization of this transition. These should not come as surprises. Moreover, actions should be taken, if possible, to avoid these. An example is to come to good working agreements between policy makers and EOL parties that reusable batteries cannot be exported to third world countries to prevent the value destruction regarding dumping.

At last, while the paper shows the need for the actors to work together, it proves the willingness of the actors in the system to work together as well. In some instances, this willingness exists, but simply not carried out. Stakeholders in the ecosystem should take the lead to facilitate the implementation of value co-creation. The paper proved that there exist several benefits and big roles for battery manufacturers and EOL-parties when making value co-creation happen. They should actively try to find each other to set up a business case that attracts involvement of other parties like regulatory institutions. Managers involved within these collaborations may use the results in this paper for designing the co-creation process.

5.3 Limitations and future research

While the paper gives an in-depth analysis of multiple stakeholders' point of view, it is still a baseline for value co-creation within the lithium-ion battery industry. Future research can focus on further assessment of the value co-creation and value co-destruction aspects that are provided in this paper. Some of the mentioned co-creation practices might be operationalized within certain districts and those should be investigated.

Additionally, the value co-creation aspects can be further explored with more contextualization to give clearer insights. Further research should focus on best practices to optimize communication and collaboration within the ecosystem. This can be both qualitative and quantitative. More information on this can support the transition even further.

Moreover, the different stakeholder interviews proved that the actors are operating on separate islands. This indicates that there is a need to strengthen the collaboration in terms of information exchange. Research should be done on how to centralize data flows in terms of the battery supply chain. More information on these streams can help in solving the volume barrier.

Another limitation is that for this research 30+ potential interviewees were approached. Unfortunately, the research could only include the insights of 14 interviewees. Other interviews did not take place due to scheduling conflicts or lack of time, to name a few.

Lastly, a limitation is that the research focuses mostly on a limited ecosystem. Most respondents operate from the Netherlands, except for the customer group that operate outside of Europe.

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Appendix

Appendix I: Building blocks for value co-creation. Made with stakeholder inputs

Value co-creation inputs by stakeholders

Interviewee notation	**Regulatory**	**Manufacturer**	**Customer**	**EOL**	**Suppliers**	**Second use market**	**Research institutions**
EOL A (1)							
EOL A (2)							
EOL A (3)							
EOL A (4)							
EOL B							
EOL C (1)							
EOL C (2)							
Cust A (1)							
Cust A (2)							
Cust B (1)							
Cust B (2)							
Supplier A							
Supplier B (1)							
Supplier B (2)							
Regulatory A (1)							
Regulatory A (2)							
Regulatory B							
Regulatory C (1)							
Regulatory C (2)							
Manufacturer A							
Manufacturer B							
Manufacturer C							