DEPARTMENT OF POLITICAL SCIENCE CENTRE FOR EUROPEAN STUDIES (CES)

EU's Action Plan for a Circular Economy in Practice

Stakeholders response to adopting circular economy initiative for electric vehicles batteries in Sweden

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Abstract

Despite EU and national climate goals, transportation-related emissions are on the rise, accounting for almost a quarter of EU GHG emissions. Policymakers, particularly in the European Union, are beginning to question the future of mobility as a result of these unfavourable implications and tendencies. The European Commission has responded by introducing a number of strategies and tightening policies and regulations focused on reducing CO2 emissions significantly by 2025. In line with this, electrifying roads and public transportation is widely believed to be an effective way to cut carbon emissions. As a result, electric cars (EVs) are becoming increasingly popular in the EU. The aim of the research is to examine the implementation of the circular business model for electric vehicle batteries in Swedish industries using the Circular economy theory. More specifically, the research elaborates on stakeholders' perspectives on the industry's current CE strategies for lithium-ion batteries, which is critical for the future battery manufacturing process. Semi-structured interviews with thirteen industry experts involved in the Lithium-ion battery (LIB) life cycle in Sweden were conducted to identify current CE strategies across stakeholders, their operationalization, and underlying influencing factors. Although the concept of circular economy (CE) is relatively new to businesses, this study found that CE strategies are already being implemented and that efforts are already being made toward a circular business model transition. The study also discovered that one of today's greatest challenges is the lack of a well-functioning recycling industry, particularly in the recycling of batteries. This makes closing resource loops difficult, and another issue that is often overlooked is the urgent need for new critical raw materials, without which the transition to a low-carbon economy will be difficult. Finally, this study provides new knowledge crucial to the future adoption of circular business models in the manufacturing industry, as well as significant insights into present problems and enablers of the circular economy in the automobile industry.

Key Words: Circular economy (CE), Circular Business Models (CBM), Swedish manufacturers, Electric Vehicle Batteries (EVB), Critical Raw materials (CRM).

Acknowledgement

I would like to dedicate this thesis to my daughter, partner and my mother. Thank you for your love and support. I would also like to thank my supervisor Roman Martin for his continuous support and feedback. And a special thanks to all participating respondents, without whom this study would not have been possible. I would also like to thank all my friends in the Master's program in European Studies for making the last two years under the pandemic special and fun. And lastly would like to express my gratitude to the University of Gothenburg for providing the opportunity, it has been an honour to be a GU student.

EU Legislations Referred in this Study

Regulation (EC) No 595/2009 of the European Parliament and of the Council of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy-duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/EC. OJ L 188 18.7.2009, p. 1-17.

Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 (Text with EEA relevance.)

Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC PE/60/2019/REV/1. OJ L 198, 25.7.2019, p. 202-240.

The Directive on End-of Life Vehicle 2000/53/EC is the first EU waste directive with which the EU Commission has introduced the concept of Extended producer responsibility. The directive aims at reduction of waste arising from end-of-life vehicles.

The Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC, commonly known as the Battery Directive, regulates the manufacture and disposal of batteries in the European Union with the aim of "improving the environmental performance of batteries and accumulators".

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A new Circular Economy Action Plan For a cleaner and more competitive Europe
COM/2020/98 final

Content

Abbreviations

CRM	Critical Raw Materials
CE	Circular Economy
CBM	Circular Business Model
CEAP	Circular Economy Action Plan
EV	Electric Vehicle
EVB	Electric Vehicle Battery
BMS	Battery Management System
EMF	Ellen MacArthur Foundation
GHG	Greenhouse Gas
OEM	Original Equipment Manufacturer
PSS	Product-Service Systems
UP-PSS	Upgradable Product Service System
LIB	Lithium-ion Batteries
Li	Lithium

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1. Introduction- *Electrification of road transport in Europe.*

> *"With this innovative EU proposal on sustainable batteries we are giving the first big push to the circular economy under our new Circular Economy Action Plan. Batteries are essential for crucial sectors of our economy and society such as mobility, energy and communications. This future-oriented legislative toolbox will upgrade the sustainability of batteries in each phase of their lifecycle. Batteries are full of valuable materials and we want to ensure that no battery is lost to waste. The sustainability of batteries has to grow hand in hand with their increasing numbers on the EU market."* Virginijus Sinkevičius, Commissioner for Environment, Oceans and Fisheries (European Commission, 2020)

European road transport accounts for 75 per cent of its transportation-related GHG emissions and is a significant source of harmful air pollution (European Environment Agency, 2016; European Environment Agency, 2019). Despite EU and national climate goals, emissions from transportation continue to rise, accounting for about a quarter of EU GHG emissions (European Environment Agency, 2019). Because of these unfavourable consequences and patterns, policymakers have begun to wonder about the future of mobility, particularly inside the European Union. As a response, under *Article. 1 Regulation (EU) 2019/1242 and Article. 1 (4) Regulation (EU) 2019/631*, the European Commission introduced tighter CO2 emission performance criteria in 2019, intending to reduce the EU's fleet of new cars, vans, and heavy-duty vehicles' average annual CO2 emissions by 2025 (European commission, 2019).

Thus, electrifying roads and public transportation is widely believed to be an effective way to cut carbon emissions (Alonso Raposo et al., 2019). As a result, electric vehicles (EVs) have gained widespread acceptability in the EU (European Environment Agency, 2019b). The International Energy Agency (IEA) anticipates this tendency to continue as more countries implement new carbon laws and targets. Additionally, the number of new hybrid and all-electric vehicles is rising (Paulo G. Pereirinha et al., 2018). Despite the EU's End-of-Life Vehicle Directive, the rising popularity of electric vehicles raises new environmental and technological problems. Such as lack of access to sustainable energy and transportation technologies and, most notably, high consumption of critical raw materials (Rajaeifar et al. 2022, Lewicka E et al. 2021). Consequently, the demand for lithium, cobalt, and graphite (***See figure 1***) will grow by roughly 25 times in 2030, while the demand for rare-earth elements will increase by around ten times (Szymanski et al. 2021: 6-7).

Demand forecast in the EU for selected critical raw materials

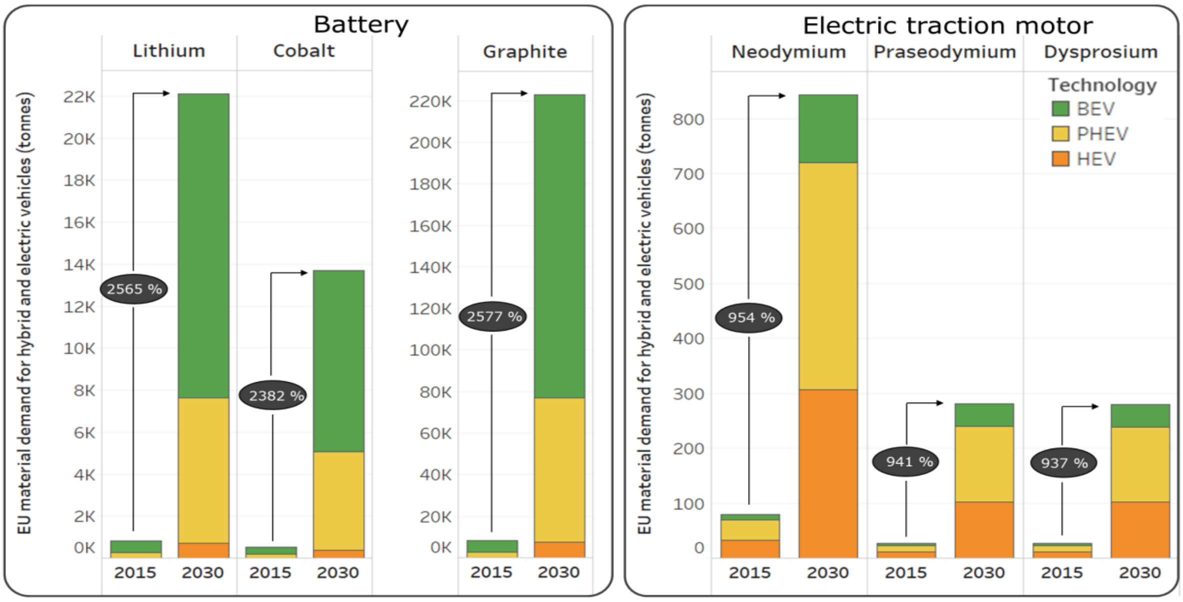


Figure 1: Source [EC, Raw materials scoreboard 2018]

Moreover, these growth rates might be much higher if the most recent and ambitious EV adoption predictions for 2030 and beyond are adopted (Szymanski et al. 2021: 6-7). Given that Chinese enterprises own the majority of lithium mines, this raises concerns about European businesses' competitiveness, which could jeopardise their green transition (Szymanski et al. 2021: 6-7 and European Commission, 2009). Similarly. Cobalt, a key component of batteries, is also manufactured in a limited number of nations (***Also see: Figure 2***). Although it's possible that the situation could change soon, cobalt mining now takes place mainly in the Democratic Republic of Congo (Alves Dias et al. 2018; Szymanski et al. 2021: 6-7).

As a result, policymakers are working to ensure that raw materials important for energy and transportation solutions are readily available (Klimenko et al., 2021:1). For future mobility, the EU's raw materials policy and sustainability aspirations require a long-term supply of raw materials. Thus, maintaining a long-term supply chain that serves market demands while not jeopardising social or environmental systems is crucial (Giorgi et al., 2022). Furthermore, proper material access will be required to avoid materials becoming a significant barrier to technological advancement and ambitious future transportation scenarios in the EU (Blagoeva et al. 2016; Szymanski et al. 2021: 6-7).

Therefore, scholars argue that implementing circular economy strategies like conserving a product's material value (*closing resource loops)* and extending the usable life of a product's parts (*slowing resource loops)* may aid in the preservation of such critical raw materials while also benefiting the environment (Bocken et al. 2016; Geissdoerfer et al. 2017). Additionally, the European Commission's latest CE Action Plan highlighted lithium-ion batteries (LIBs) as a critical product value chain, hence creating a new regulatory framework for batteries was recommended, considering the principles of reuse, repurposing, and recycling (European Commission, 2020). Thus, on a political level in the EU, LIBs have been recognised as a critical product for the CE, and their waste management is currently managed by the Battery Directive (Zhao, 2021), which legally requires manufacturers to recycle and dispose of batteries with a 50% weight-based recycling obligation (Chen et al. 2019).

Since batteries and magnets are required for electric vehicles and other high-efficiency engines. The European Union has recently identified several minerals and rare-earth elements as "critical" due to access barriers and rising demand for these materials in cutting-edge technology which poses a threat to future mobility (Szymanski et al. 2021: 6-7). Experts argue that, it will be difficult to meet future transportation needs if we can't ensure a steady supply of raw materials and a high level of reuse, remanufacturing, and recycling (Szymanski et al 2021) Additionally, several environmental and economic concerns discourage dumping EV batteries directly into landfills, including the possibility that they could be used for stationary energy storage for a few more years after they reach their end-of-life. Furthermore, even if the battery isn't fully functional, it still has important components that can be recycled. To put it another way, as Pereirinha et al. (2018) point out, this reduces demand for raw materials like cobalt and other rare earths while also opening up new industries like second-life manufacturing.

Since LIBs (lithium-ion batteries), which is the most common form of battery used in electric vehicles, also happens to be the most expensive component in the electric car, they make up a significant amount of an EV's total cost (International Energy Agency, 2019; Reinhardt et al., 2020). As a result, corporate players have a strong incentive to profit from the battery's intrinsic worth after it has been used in a vehicle. Currently, there are few discarded LIBs, but this number will rapidly rise, reaching six million packs by 2030 and a capacity of 277GWh per year in the coming years (Jiao, 2019). This volume advocates for new technologies and techniques to ensure that LIBs in electric vehicles continue to perform environmentally responsible after their initial use (Olsson et al., 2018). LIBs, unlike other consumable electric items like old computers and electronics, can be repaired, remanufactured, or repurposed and can be utilised in second life applications (Pagliaro & Meneguzzo, 2019), because they still have a capacity of 70-80% by the end of their first life in automobiles (Mathieux et al., 2018; Olsson et al., 2018). Thereby reducing waste and environmental implications, as well as mitigating supply security concerns for critical raw materials (Idjis and da Costa, 2017). Furthermore, this has resulted in a greater emphasis on LIB life cycle strategy and management among scholars who consider both social and environmental factors, which is typically associated with the circular economy notion (Olsson et al., 2018; Geissdoerfer, Savaget, Bocken, et al., 2017).

Additionally, due to the commercial importance of LIB recycling, EU regulations such as the circular economy action plan and the recently proposed battery directive have aided the implementation of the CE method (European Commission n.d.). Consequently, there is a need to fill in the gaps in knowledge on Lithium-ion battery strategies in Sweden, so this thesis aims to investigate the implementation of the circular business model in Swedish enterprises given the existing challenges in the supply security of critical raw materials.

2. Research aim and scope

In light of the European Commission's recently proposed revisions to the battery directive in response to the global supply security of critical raw materials, the overarching study aim is to investigate the implementation of the circular business model in Swedish enterprises given the existing challenges in the supply security of critical raw materials. This research highlights the stakeholders' standpoint on the circulation of lithium-ion battery materials, which is fundamental to the future battery production process. Due to the rapid electrification of road transport in the EU, the supply security of critical raw materials is a severe problem that may hamper the EU industry's green transition. Therefore, the circular economy concept is seen as a viable option to reduce dependency on imported raw materials and help narrow, close, and slow down the resource loops for complicated products like batteries (Baars et al., 2021).

Furthermore, the EU has various political measures, such as the Circular Economy Action Plan and the Battery Directive (2006/66/EC) in place (Fraint et al. 2021), which are there to assist governments and businesses in the transition towards a circular economy from the traditional linear economy model. In addition to such existing policies and measures, new political developments in the EU further push the implementation of the CE concept. For example, during the current six-month French EU Council presidency (January to June 2022), Paris exclusively plans to expand on the European Commission's efforts in this sector, especially in the supply of raw materials, the generation of decarbonised energy, and the development of green technologies (Moussou, 2022).

As a result, there is a strong need for studies examining the perspectives of stakeholders in the member states who are directly impacted by such measures and EU policies. This study examines the implementation of a circular economy by Swedish stakeholders and illustrates the industries' transition to a low-carbon economy through the implementation of circular business models for products such as lithium-ion batteries, which play a crucial role in reducing the carbon footprint of the automobile industry. Moreover, since the same EU policies and directives regulate the European vehicle sector, the researcher's perspective on Swedish industries may be generalised to the rest of EU's automobile and battery industries. Therefore, in this research datas are gathered by conducting semi-structured informant interviews with industry experts to understand how they cope with regulated policies and assess from a bottom-up perspective when implementing the circular economy. As a result, the knowledge gap for this study is generated from the recent development of EU policy involving batteries, which was proposed by the European Commission on December 10, 2020, as part of the Circular Economy Action Plan, to modernise EU legislation on batteries. In contrast to the existing guidelines, which only required 50% recycling, this new plan (***See: Section 4.2.2 & Figure 3***) aspires to make EU-produced batteries environmentally friendly, high-performing, and safe over their whole life cycle. This implies that batteries must be made with a minor environmental effect, using materials that have been sourced according to human rights and ecological and social norms (European Commission, 2019).

Since this study addresses these gaps in knowledge, it intends to investigate the implementation of the circular business model in Swedish enterprises given the existing challenges in the supply security of critical raw materials. Furthermore, the study believes that focusing on stakeholders in an individual member state will resolve the puzzle at the European level. Moreover, this research will offer some insight into how the new battery regulations will influence companies and stakeholders' views along the European EVB value chain and the second-life EVB market. The green transition is a shared EU commitment that necessitates involvement from actors at state levels for two main reasons: first, members of the EU have similar characteristics. Second, social or technical innovations diffuse quickly in similar economies (Rabadjieva et al., 2020). Additionally, the same directive that governs European industries and supply chain security also impacts EU industries and the single market (European commission). Thus, by answering the research question presented below, this thesis attempts to fill research gaps and, as a result, to draw conclusions for EU policies that have a significant influence on the green transition of the European automobile industry by focusing on the implementation of circular economy initiatives for Lithium-ion batteries in Sweden.

What Circular Business Models (CBM) for Electric Vehicle (EV) batteries have been implemented by companies in Sweden given the existing challenges in the supply security of critical raw materials?

1. *Which strategies have been implemented by the stakeholders to address the resource optimization challenges of lithium-ion batteries?*
2. *Which strategies have been taken by the stakeholders to address the product-life extension of Lithium-ion batteries?*
3. *Which strategies have been taken by the stakeholders to address the end-of-life challenges of Lithium-ion batteries?*

3. Thesis outline

The thesis is structured as follows. Following the previous presentation of the introduction, thesis aim and scope, chapter four will present a general background of this thesis. This contains a brief overview of the critical raw materials required for battery manufacturing, as well as relevant EU policy and regulatory frameworks. A literature review on circular business models is done in chapter five. The study's theoretical framework is presented in chapter six. The methodological aspects and considerations of this thesis are discussed in chapter seven. Between chapter eight to eleven the operalization, validity, reliability, ethical considerations and limitations of this thesis are outlined. Following this the gathered data from the expert interview will be analysed in detail in chapter twelve. Finally, in the last chapter, the findings of the research questions will be summarised, followed by concluding discussions and recommendations for policymakers.

4. Background

4.1 Critical raw materials required for battery manufacturing.

> "*Today, the data shows a looming mismatch between the world's strengthened climate ambitions and the availability of critical minerals that are essential to realising those ambitions.*" Dr Fatih Birol, IEA Executive Director

The global economy relies heavily on the availability and efficient use of raw materials (***See Figure 2***). Raw materials having a high risk of supply are referred to as Critical Raw Materials (CRMs) by the European Commission (Careddu et al. 2018; Popov et al. 2021; Hofmann et al. 2018; European Commission). They have a solid industrial basis, generating various items and applications for everyday usage and sophisticated technology (Hofmann et al., 2018). The European Union and the rest of the world are increasingly concerned about the availability of raw materials (IEA, 2017). The European economy relies heavily on these commodities, which are 'essential' to a variety of industries such as; '*environmental technology, consumer electronics, health, steel industry, defence, space exploration, and aviation*' (Ferro & Bonollo, 2019). To meet this issue, EC has created a list of EU CRMs that includes raw materials that are both important to the EU economy and associated with a high level of risk and which are reviewed and updated on an ongoing basis (European Commission, 2017).

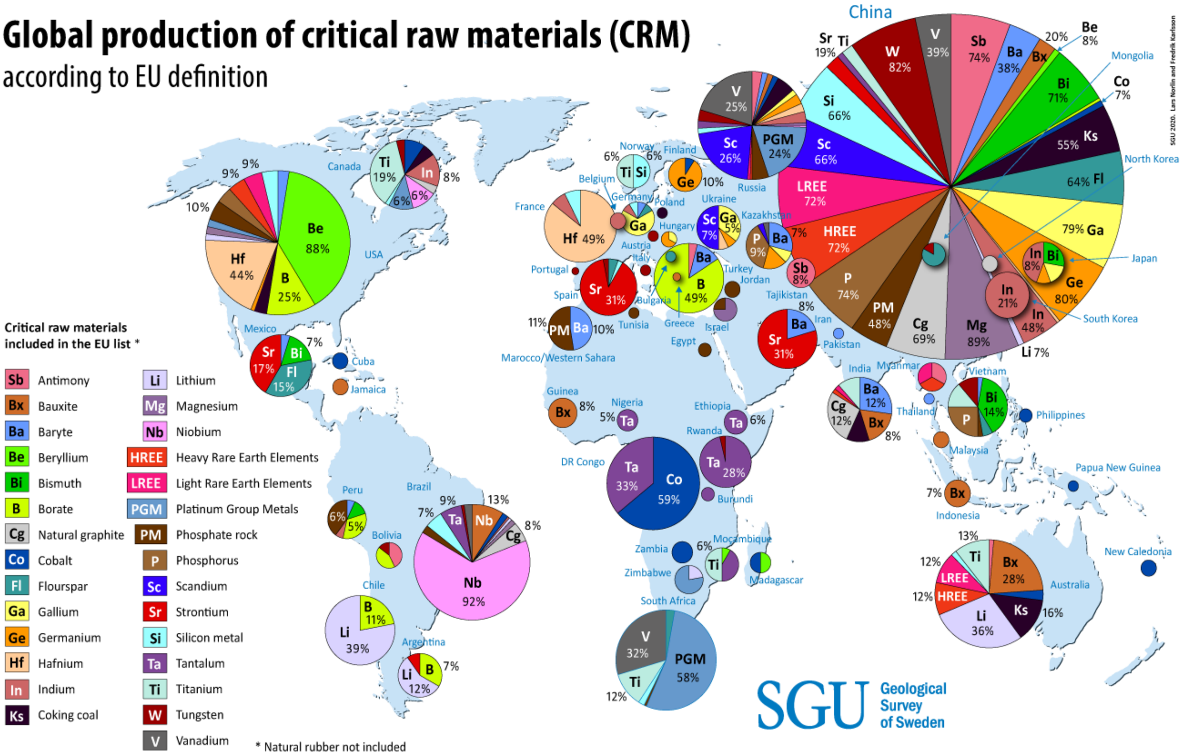


Figure 2 Source: Geological Survey of Sweden (nd)

However, it is crucial to emphasise that these materials are classed as critical not because they are rare; instead, they are designated as critical because they have a large economic value for key sectors of the European economy. Second, they have a significant supply risk because of the high import dependency and a large concentration of critical raw materials in certain nations as shown in the figure above, which increases the danger of supply shortages. Third, due to the extremely distinctive and dependable qualities for present and future applications, (viable) alternatives are scarce (Ferro & Bonollo, 2019: 1-2; European Commission, 2017). Therefore, CRMs play a vital role in the supply chain due to their links with several industries (Olivetti et al., 2017)**.** Solar panels, wind turbines, electric automobiles, and energy-efficient lighting are just a few sustainable technologies that rely on these components. Therefore, access to growing quantities of these so-called critical raw minerals is required for technological innovation, a better quality of life, and industry's shift to a low carbon economy (Ferro & Bonollo, 2019).

4.2 Relevant EU policies and regulations concerning batteries.

The most relevant EU policies, initiatives, and regulations affecting European vehicle and battery manufacturers and their consortium-companies will be described in this part in a simple and concise manner. This is to ensure a thorough understanding of the conditions and context in which these companies function.

4.2.1 EU's Circular Economy Action Plan

The European Commission endorsed the new circular economy action plan (CEAP) in March 2020. It's a key component of the European Green Deal, the EU's new plan for promoting sustainable economic growth and development. The EU's move to a circular economy will minimise natural resource pressure while also generating long-term growth and jobs. Additionally, it is a necessity for meeting the EU's 2050 climate neutrality goal and halting biodiversity loss (EC, 2020). The new action plan emphasises activities encompassing the product's life cycle, from conception through destruction or recycling. The EU has emphasised the importance of batteries as a value chain component in transitioning to a carbon-free transportation industry (European Commission, 2019). As part of its "Strategic Action Plan on Batteries", released in May 2018, the European Commission emphasised the need to establish a European battery value chain. In the action plan for a circular economy, the management of end of life products such as Lithium batteries is critical (Alamerew and Brissaud, 2020). Moreover, recycling and reusing existing LIBs is argued as a practical way to reduce dependency on imported raw materials and preserve resources in the EU economy while encouraging sustainable consumption (Mathieux et al., 2017; European Commission, 2017, 2019b).

Therefore the implementation of a circular economy not only provides significant advantages in waste volume reduction and raw material consumption but also aids in economic growth (Alamerew and Brissaud 2020; Fellner et al., 2017). The Circular Economy (CE) aims to keep products, components, materials, and resources useful in the economy for as long as possible. Finally, one way to implement CE is via circular business model which can be divided into two categories: those that extend product life periods through *reuse, repair, repurpose, refurbish, recondition, upgrade, and redesign,* and those that conclude resource cycles through *recycling strategies* (Bocken et al., 2017, Stahel, 2016).

4.2.2 The Battery Directive (2006/66/EC)

Member States are required under the Batteries Directive 2006/66/EC to guarantee that all collected batteries are cleaned and recycled according to established practices. It also establishes collecting objectives and targets for recycling efficiency to reduce costs while maximizing resource utilisation (Mathieux et al., 2017: 38-39; Mayyas et al., 2019 and Albertsen et al. 2021). As a result of the Batteries Directive, EV batteries (e.g LIBs) are now subject to Extended Producer Responsibility (EPR). This implies that industrial batteries must now be collected and recycled by the producer/manufacturer, who is also liable for all associated costs (Kunz et al., 2018; Lifset, 1993).

As a result, automotive manufacturers and importers in the relevant countries are directly impacted by this legislation. Therefore, it will be the responsibility of manufacturers rather than municipalities to reduce trash and increase recycling by revamping their goods and packaging to make them more environmentally friendly (Kunz et al., 2018; Lifset, 1993; OECD, 2016; Albertsen et al. 2021). Thus, extended producer responsibility (EPR) is seen as a strategy for encouraging firms to participate in CBM projects. In addition to this, the recent development ***(See: figure 3)*** on the existing battery directive further encourages businesses to implement CBMs. As a part of the Circular Economy Action Plan the European Commission has recently released a legislative proposal on December 10, 2020 to modernise EU legislation on batteries which aims to create a legal framework on the sustainability, traceability and circularity of batteries production throughout a product's life cycle. The new proposal is an integral part of the Green Deal, the EU's new growth strategy (European Commission).

Thus, companies are not only burdened by the extended producer responsibility (EPR), but the new proposal now also mandates that the batteries placed on the EU market in the future should also be sustainable, high-performing, and safe throughout their full life cycle (Beaudet et al, 2020; January 2020, Battery Directive 2006/66/EC). This refers to batteries that are made with the least amount of environmental effect as possible, utilising materials sourced in complete compliance with human rights, social, and environmental norms (Beaudet et al, 2020). Due to the circular business model's popularity as an effective strategy for complying with the battery directive, it is critical to look at how businesses and other stakeholders affected by the new regulations are responding on the ground. Lastly, this is an extremely significant part of the research because the aim of this study is to investigate the implementation of the circular business model in Swedish enterprises given the existing challenges in the supply security of critical raw materials.

Changes in the New Battery Directive Proposal

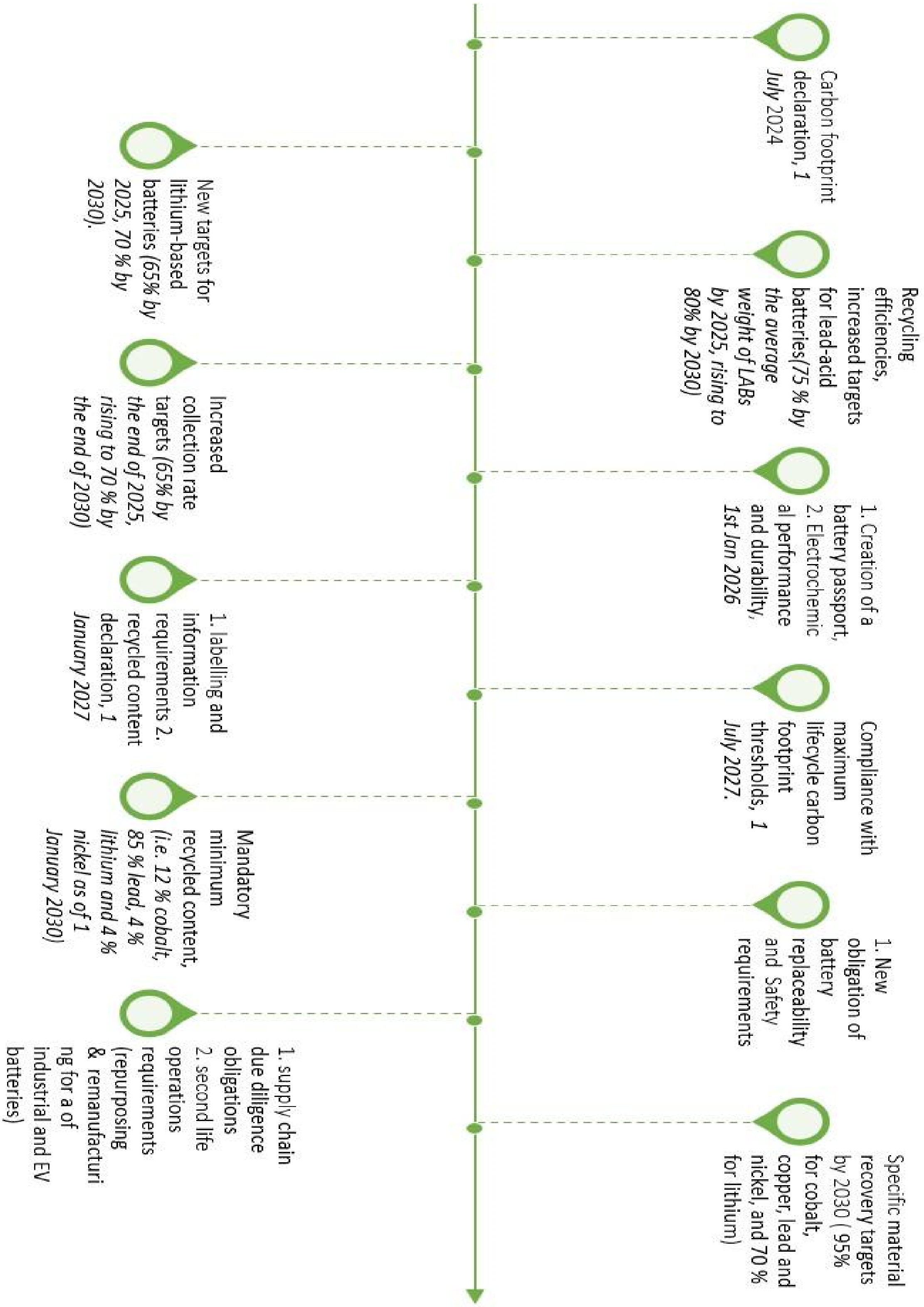


Figure 3: Self modification by author, Data gathered from European Commission (2020)

5. Literature Review on Circular Business Models

This chapter provides insights into previous literature on implementation of Circular business models in manufacturing industries. The number of published Circular economy (CE) literature increased significantly in 2015 (Bjrnbet, Skaar, and Fet, 2021). However, recent research has provided additional case studies studying how to close loops, slow them down, and narrow them through post-consumer recycling. However, several case studies only covered a few organisations, and the hurdles noted by researchers are severe (Bjrnbet, Skaar, and Fet 2021). Studies revealed a wide range of context and business model (BM) specific barriers (Guldmann and Huulgaard, 2020; Vermunt et al., 2019). CBM was found to be a potential facilitator for the circular economy. Nonetheless, case study results revealed that business model (BM) modifications require time and effort and should be considered a gradual, step-by-step method rather than an on-switch strategy (Bjrnbe, Skaar, Fet and others 2021).

Nonetheless, Bjrnbet et al. (2021) imply that circular business models (CBM) can help manufacturing companies achieve CE advances (Frishammar and Parida, 2019; Guldmann et al, 2020; Lieder et al, 2016; Sousa-Zomer et al., 2018) by prioritising and coordinating efforts to realise CE objectives. A CBM ensures an equal allocation of the benefits and costs of CE activities (Braun et al., 2018). A model for mapping scalable CBM value propositions was presented by Kristensen and Remmen (2019). This framework for sustainable value propositions in product-service systems (*which simply means when a company provides a mix of both products and services i.e PSS, instead of just focusing on products as they have in the past*) aims to map and analyse potential sustainable value propositions based on the three crucial PSS components: product, service, and system, and the type of interaction required for each dimension. The paradigm reveals how value rises when the focus switches from product to service to the system, allowing more stakeholders to identify value, ultimately shifting the interaction from transactional to partnership (Kristensen and Remmen, 2019). Similarly, a study by Moreno et al. (2019) looked at the role of digitalization in supporting CBMs, tracking assets for reuse and take-back plans, understanding damages, selecting the proper recycling technology, and communicating with the end user.. Additionally, one of the CBMs widely addressed in a study conducted by Bjrnbet et al. (2021) was the product-service system.

Yang et al. (2018) discussed how product-service systems can help to make the supply chain more circular (Yang et al., 2018). Using PSS business models, Yang argues that long and cascading use circles can be effectively innovated for circular supply chains by utilising value creation in inner circles. Yang’s study used an exploratory case study in a big Chinese manufacturing company to look at three possible business models for product-service systems (Yang et al., 2018). Kaddoura et al. (2019), outlined that making a PSS last longer through repair and refurbishment can be an economically beneficial path for manufacturing businesses to approach CE.

Similarly, Vermunt et al. (2019) discovered that the product-service system faces the same organisational and financial constraints as the other CBMs studied. Vermunt et al. (2019) believe that neglecting how barriers change amongst business models could lead to incorrect generalisations about the difficulties of implementing circular business models. Their research looked into the challenges of circular supply, resource recovery, product life extension, and product-as-a-service. Aside from that, two types of barriers were identified: internal concerns impacting the firm and external barriers affecting the environment. There was a significant external environment aspect, and the difficulties varied among the four company concepts assessed. Compared to the product-as-a-service approach, other alternatives showed fewer organisational barriers (e.g., *leasing models*). Due to the heavy reliance on third parties for the input of rejected products and waste materials, issues with the external supply chain occurred in the resource recovery, product life extension, and circular supply models. In their research, Vermunt et al. (2019) examined how organisations may overcome these obstacles and concluded that firms and governments should focus on customised solutions and strategies for various CBMs to encourage the development of circular enterprises.

However, Sousa-Zomer et al. (2018) suggested internal and external partnerships and collaboration to reduce risks and overcome hurdles (Sousa-Zomer et al., 2018). As a result, to successfully implement the circular business model, diverse organisational functions must collaborate to create mutually beneficial outcomes. Additionally, such models should consider the context of the business at hand, i.e., external conditions should be compatible with the business model (Sousa-Zomer et al., 2018).

Nonetheless, Garza-Reyes et al. (2018) found that many manufacturing firms feared losing product ownership (Garza-Reyes et al., 2018). Due to product ownership concerns, Yang et al. (2018) indicated that user-oriented and result-oriented product-service systems (PSS) are the most ideal for developing circular supply chains. In this PSS, the manufacturer retains ownership and control of the products, creating incentives to avoid environmental impacts throughout the product life cycle. To reduce product ownership loss, Pialot et al. (2017) presented a hybrid system called "Upgradable Product Service System " (Up-PSS) that incorporates upgradability, optimised maintenance, and repurposing of old parts. Compared to established manufacturing/consumption models such as manufacturable products, readily recyclable products, PSS, optimal maintenance products, or basic upgrade items, this new concept offers improved customer appeal and new revenue opportunities for producers and various environmental benefits. Furthermore, an upgradable product service system introduces a new way to move between offerings without transferring ownership, making the circular economy model more accessible (Pialot et al., 2017).

Some authors, on the other hand, recommended frameworks to steer organisations through the "CE journey," defined as activities carried out as part of the development and analysis of potentials and barriers to the circular economy through slowing, narrowing, and closing resource flows in a specific business and its value chains (Jørgensen and Remmen, 2018). Similarly, Frishammar and Parida (2019) suggested a framework to guide organisations through the transformation process (Frishammar and Parida, 2019). Many well-established enterprises are attempting to incorporate circular economy concepts in achieving positive economic, environmental, and social outcomes. However, these enterprises frequently fail due to a lack of information about the steps required for a successful transition. Frishammar and Parida (2019) suggested the circular business model transformation approach based on eight case studies. In addition to meeting '*environmental, social, and financial goals'*, their roadmap allows organisations to approach sustainability proactively (Frishammar and Parida, 2019).

However, Bjornbet et al. (2021) found that the process typical of organisations transitioning to a circular business model is *"more iterative than sequential, and more emergent than planned"*. Furthermore, the shift in the business model (BM) appears to be driven by imitating rather than creativity (Frishammar and Parida, 2019). Thus, resource efficiency strategies that take a life cycle approach necessitate a mix of business model (BM) adjustments (Diaz Lopez et al. 2019). Others have determined that handling multiple BMs, one circular and one traditional, is risky (Frishammar and Parida, 2019). Parida et al. (2019) highly advised manufacturing firms to analyse their internal and external readiness for a CBM shift. Finally, the study by Sousa-Zomermer et al. (2018) underscored the significance of a link between the modifications to become more circular and the factors that impact these changes.

Wang et al. (2018) claim that product design and development impact the entire lifecycle of a product, from conception through disposal. Customers are affected and influenced by manufacturing organisations' efforts to embrace more circular processes (Wang et al., 2018). Corporations may be reluctant to take risks to develop a circular economy (CE) product since consumers may reject refurbished or recycled products. So, CE-focused manufacturers must be adept at addressing this conflict (Bjornbet et al., 2021). Regardless, many academics believe that resource conservation is at the core of a circular economy and that no particular product or actor is the starting point. This means that a circular economy cannot be applied in a single department or even a single facility in a manufacturing organisation. It requires the commitment of the entire organisation and strategic stakeholder management (Bjornbet et al., 2021). Finally, numerous CE approaches for LIBs have been investigated in terms of wide enablers and barriers (Olsson et al., 2018; Albertsen et al. 2021). However, LIB life cycle management is rarely researched from a qualitative social science perspective, such as how automobile manufacturers design and implement circular economy strategies for LIBs from a business model perspective.

6. Theoretical background

6.1 Studying sustainability and socio-technical changes via transition theory.

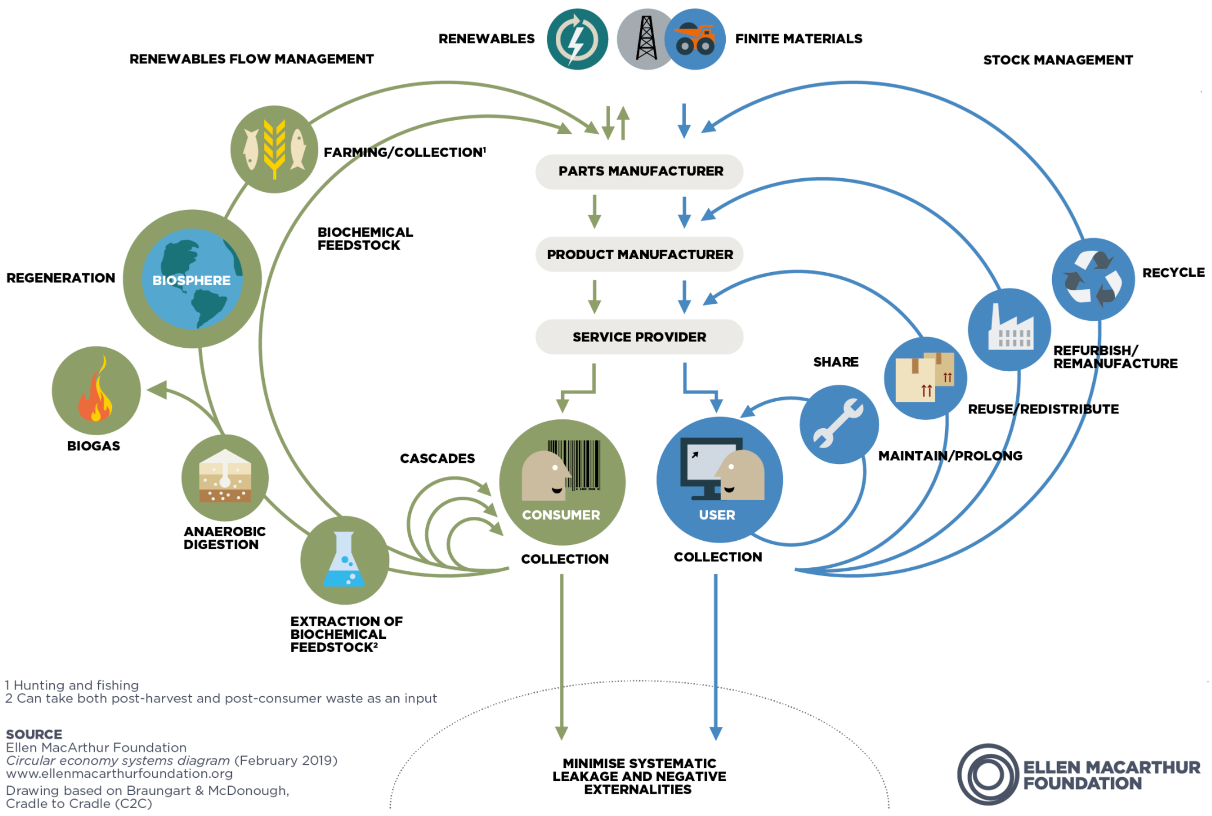
Transition theory presents notions for a complete assessment of *"processes that lead to a fundamental shift in socio-technical systems,"* emphasising how social and technological improvements must co-evolve. (Truffer and Coenen, 2012; Markard et al., 2012: 956, Boschman et al., 2017). Transition theory is founded on the idea that socio-technical systems are organised around regimes, which is the most typical method for a socio-technical system to function (Jedelhauser et al., 2018). The existing state of institutionalised and socially imprinted system structures is determined by incoherent principles that regulate actors' behaviour (Geels, 2011). While they typically stick to established developed paths, they frequently preserve the pre-existing system structure (Geels, 2002). As a result, transitioning to a circular economy necessitates fundamental adjustments to the social system and the technical-technological subsystem, which are split into three components: economic, cultural, and political (Ghisellini and Ulgiati, 2020).

Thus, adopting a circular economy on a theoretical and practical level demonstrates that moving to a circular economy requires rethinking how the economy analyses welfare beyond income-flow concepts to emphasise the necessity of preserving and increasing natural capital (Ghisellini and Ulgiati, 2020). As a result, sustainability has emerged as a socio-technical change (Geels, 2011) in response to long-standing environmental concerns and the need to enhance the overall performance of the traditional linear ways of production and consumption (Geels, 2011). Such transformations entail reforms to social and technological assets (Ghisellini and Ulgiati, 2020), which can be viewed as interacting systems of actors, institutions, material artefacts, and knowledge (Markard et al., 2012; Markard, 2011; Geels, 2004; Weber, 2003) that aims to progress toward more environmentally sustainable ways of production, consumption, and living (Pearson 2016).

Consequently, making a more sustainable production system requires both changes in how firms work and changes in how they design, like improving product design, equipment, and manufacturing processes, adopting new technologies, making changes to products (like making them last longer), managing waste both inside and outside the company, and using recycled materials (Bressanelli et al., 2017; Masi et al., 2016; Hens et al. 2018). As a consequence of the latter actions, societies may necessitate additional infrastructure and organisations for waste collection and treatment (Geng and Cotè 2002), while new environmentally friendly items may necessitate changes in consumer behaviour (Mugge 2018). However, sustainability transitions are challenging processes due to the nature of socio-technical transitions (Ghisellini and Ulgiati, 2020), and the journey towards the objective of sustainable development as a new state of '*dynamic equilibrium*' (Bosman and Rotmans, 2016) may be lengthy (Geels, 2011). Many governments around the world are formulating policy objectives to facilitate the transition to a circular economy (CE) while also reaching the global sustainable development agenda's 2030 targets (European Commission, 2018; UN Sustainable Development Goals, 2018).

A circular economy eliminates waste and pollution by recirculating products and materials and restoring nature. The circular economy system diagram by Ellen MacArthur Foundation, illustrated below also known as the butterfly diagram, shows the economy's continual flow of materials through two main cycles (***See: figure 4***).

The Circular Economy System Diagram



1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input

SOURCE
Ellen MacArthur Foundation
Circular economy systems diagram (February 2019)
www.ellenmacarthurfoundation.org
Drawing based on Braungart & McDonough,
Cradle to Cradle (C2C)

Figure 4: Source, Ellen MacArthur Foundation

The circular economy, the bioeconomy, and the energy transition are thus all examples of sustainability transitions (Van den Bergh and Bruinsma, 2008; Ellen MacArthur Foundation, 2017; Bosmans and Rotmans, 2016). The energy transition implies an increased dependence on renewable energy sources and a decline in fossil fuel consumption in the energy mix (Van den Bergh and Bruinsma, 2008). Because the energy transformation is required for the circular economy and bioeconomy to flourish (D'Amato et al., 2017), it might be considered a subsystem of both (Ghisellini and Ulgiati, 2020). Finally, Bosman and Rotmans (2016) argue that the transition to renewable energy and the bioeconomy is fundamentally related to the transition to the CE take-off phase (Ghisellini and Ulgiati, 2020). According to the Ellen MacArthur Foundation (2017), the "cradle to cradle" theory of CE (described chapter 6.2), there is a strong connection between these two ideas (Braungart and McDonough, 2009). This approach sees products and materials meant to be recycled and reused as biological or technical nutrients, (***See Figure 4***) emphasising the importance of increasing renewable energy consumption while simultaneously protecting the integrity of human and environmental systems (Ghisellini and Ulgiati, 2020). Lastly, implementing CE could ,directly and indirectly, contribute to these goals (Schroeder et al., 2018). The circular economy (CE) is an appropriate framework for all of society to achieve a more sustainable future because it is founded on a solid theoretical foundation that spans multiple disciplines (Korhonen et al., 2018), contains clear rules connected to the use of natural resources (both nonrenewable and renewable), optimises resource utilisation, and introduces a new concept of waste (Ellen MacArthur Foundation, 2017; Geng et al., 2016).

6.2 Circular Economy as a driver of sustainable transitions.

The notion of a circular economy (CE) was first proposed by Pearce and Turner in 1990, but it has only lately gained popularity and has received widespread recognition from researchers, governments, and businesses (Kirchherr, Reike & Hekkert, 2017). CE has evolved and been absorbed by numerous schools of thought over time (Ellen MacArthur Foundation, 2013, Geissdoerfer, Savaget, Bocken, et al., 2017; Lüdeke-Freund et al., 2019, "*including industrial symbiosis, cradle-to-cradle, and eco-efficiency*" (Geissdoerfer, Morioka, et al., 2018; Korhonen et al., 2018; Lewandowski, 2016; Albertsen, 2020; Pahm, 2021). Despite this, there is no universally accepted definition of CE; it has been perceived differently by various scholars using different perspectives. (Kirchherr et. al., 2017; Zucchella & Previtali, 2019).

Korhonen et al. (2018) define the circular economy as economies generated by social production-consumption systems that optimise the service provided by a linear nature-society–nature materials and energy consumption cycle. The three pillars of sustainable development are strengthened even further with the help of renewable energy sources. Circular economies also help to maintain the natural reproduction rates of both ecological and economic cycles (Korhonen et al. 2018:39; Albertsen et al. 2021). It's important to remember, however, that there isn't a straight link between CE and sustainability (Geissdoerfer, Savaget, Bocken, et al., 2017, Albertsen et al. 2021). CE's impact can be measured using material flow accounting or a life cycle evaluation. The environmental benefits of circular products or services, on the other hand, may be harmed by rebound effects (Geissdoerfer, Savaget, Bocken, et al., 2017; Kalmykova et al., 2018; Albertsen et al. 2021). As a result, selecting a CE technique should be based on the total value generated rather than just the financial advantage.

The most common definition of a "circular economy" today comes from the Ellen MacArthur Foundation (EMF). It says that "*a circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems*" (Ellen MacArthur Foundation, n.d.). In addition, Bocken et al. (2016) developed three CE framework strategies outlined below (***See also: Figure 4 & 5***) that are consistent with Ellen MacArthur Foundation’s circular economy explanation, which is further elaborated in the upcoming chapter 6.3.

1. ***Narrowing the loop****; Focusing on resource optimization per unit of product.*
2. ***Slowing the loop****; Focusing on product-life extension or product-utilisation intensification.*
3. ***Closing the loop****; Focusing on material recycling when products reach their end of life.*

Circular life cycle of Electric Vehicle Batteries

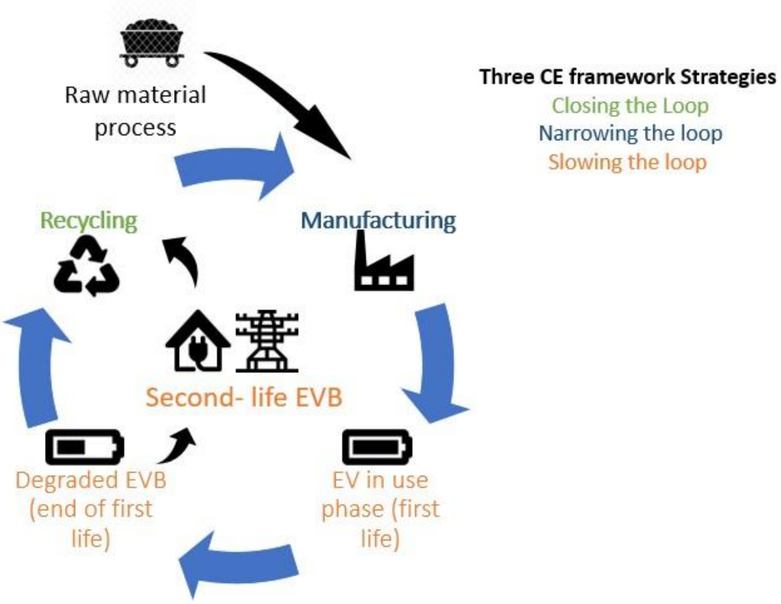


Figure 5: Source- Created by the author after Bocken et. al. (2016) and Ellen MacArthur Foundation’s butterfly diagram (figure 4) .

Bocken et al., (2017), argues resources and waste should be kept to a minimum by making sure that "*products, components, and materials are used to their utmost usefulness and value at all times*" (Bocken et al., 2017, p. 476). Furthermore, in order to contribute positively to sustainable development, the CE's value should be exclusively economic, environmental, and social (Bocken et al., 2013). Figure 4 above illustrates an overview of CE for EVBs from the manufacturing stage, which includes EVB innovation and design, to the usage phase, when EVBs are installed in EVs, and when EVBs reach the end of their initial life. EVBs can subsequently be processed to a second life use, such as serving as a building energy storage system or be recycled, allowing the materials to be retrieved and used in a new production cycle.

Therefore, the CE concept's technology cycles emphasise resource efficiency enhancement beyond original manufacturing through inner loop procedures, with only recycling as a final step (Ellen MacArthur Foundation, 2013; Korhonen et al., 2018). This helps to aid the economy by lowering volatility in resource prices and supply chain risks, as well as cost savings and job creation, but also help the environment by reducing waste, pollution, and emissions of greenhouse gases (Ellen MacArthur Foundation, 2015; Lewandowski, 2016; Ness & Xing, 2017; Albertsen et al. 2021).

6.3 Circular business model (CBM) as a key enabler of CE transitions

The circular economy is a new economic framework that strives to detach from wasteful and damaging industry methods that are based on large sales volumes and rapid consumption (Bocken and Ritala, 2021). In order to help companies integrate the circular economy, the concept of circular business models (CBMs) has been developed (Nußholz, 2017). Circular business models have been established in response to the growing need for circularity, and these models deliver stronger consumer value propositions while resolving resource constraints and combatting the conventional linear "take-make-dispose" business model (Bocken et al., 2016). Aside from the environmental and community benefits, these are also profitable. Bocken and Ritala, (2021) argue that moving forward this will be a huge challenge for both startups and established businesses alike to come up with new circular business models that are both financially and ecologically viable in the future (Bocken and Ritala, 2021).

> *"A circular business model is how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending the useful life of products and parts (e.g., through long-life design, repair, and remanufacturing) and closing material loops"* (Nußholz, 2017:8; Den Hollander and Bakker 2016:2)

On the other hand, To incorporate CE activities, it is vital to reimagine supply chains and the ways in which value is produced and transferred across the business model (Lüdeke-Freund et al., 2019; Schenkel et al., 2015; Wells and Seitz, 2005; Albertsen et al. 2021). Holgado and Aminoff (2019), argues that with the development of the circular economy (CE) approach into business models, there is a need for a greater knowledge of resource loop activities and how present supply chains might assist the development of emerging CE business models. They suggest a closed-loop typology independent of product type and recommend that two distinct closed-loop supply chain models be used in circular business models.. The first type focuses on the original product's closed-loop and includes several actions such as direct reuse, renovation, remanufacturing, and recycling into the same material. (*i.e* ***See figure 6***, *under EV battery*). The second category is concerned with the product's closed-loop transformation. Initial transformation involves recycling and upcycling, but the converted product's closed-loop also known as its "new product" (*i.e shown in* ***figure 6*** *as stationary* *battery*) involves recovery operations such as direct reuse, refurbishment, remanufacturing, and recycling into the same transformed product. (Holgado and Aminoff, 2019).

Circular Economy Strategies for Lithium-ion Batteries

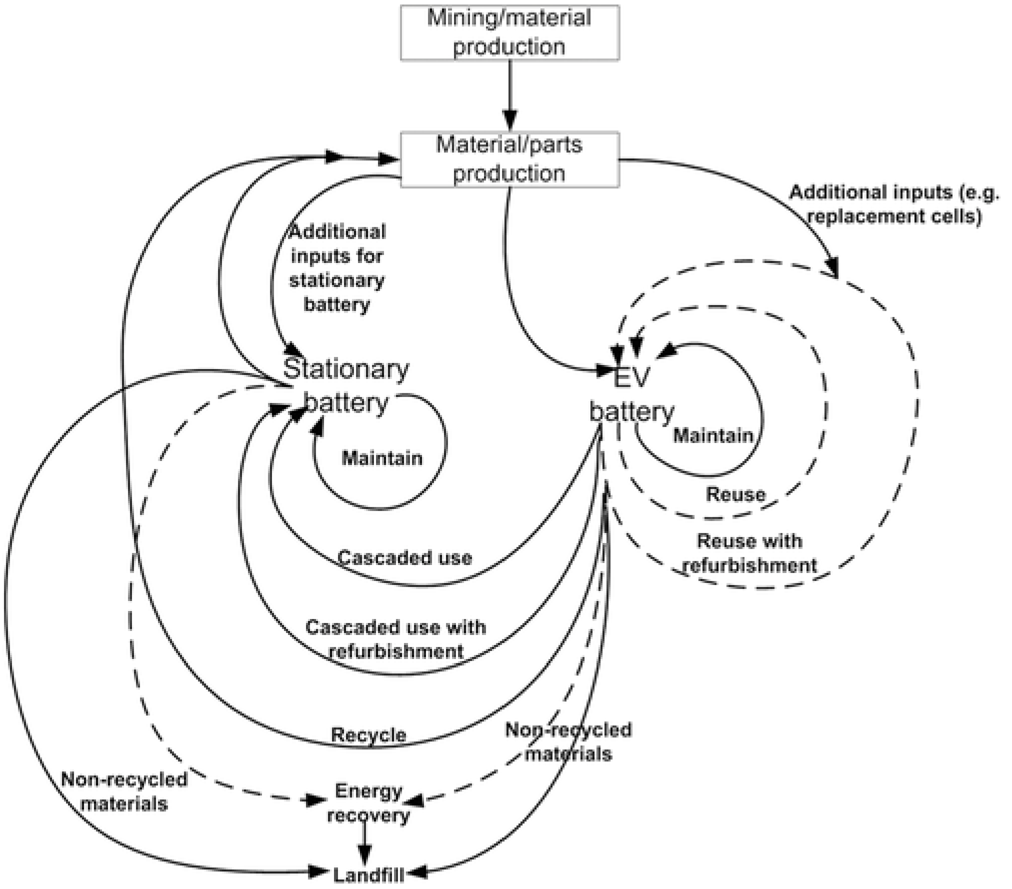


Figure 6: Source- Richa et al., (2017)

Consequently, it is critical to the design and effectiveness of CBMs in closed supply chains to collect and reintegrate products, parts, or materials. In comparison to traditional business models, the establishment of closed-loop supply chains and efficient reverse logistics systems (*Supply chain management system that moves goods from customers back to sellers or manufacturers*) is critical since it is increasingly viewed as tools for attaining regulatory compliance, such as the EU's Batteries Directive 2006/66/EC (Lewandowski, 2016; Schenkel et al., 2015; Wells & Seitz, 2005). Supply chains are strongly dependent on customer willingness to return products, and it is difficult to anticipate the quality or when they will be returned. Thus, Vermunt et al. (2019) advocate creating close ties with supply chain stakeholders or preserving ownership of the product in order to improve the quality of a product that is returned. In many cases, it requires establishing a long-term supply chain network that includes existing suppliers and manufacturers and additional service providers.

Moreover, in order to work together on a network level, parties must first agree on common environmental goals and other principles (Winkler, 2011).

As a result, CBM's for EV's Lithium-Ion batteries must then be translated by the different enterprises into their own strategic and operational decisions such as purchasing. Furthermore, there must be a need for a shared vision with existing partners and prospective future partners to achieve a common goal (Kraaijenhagen et al., 2016). CBMs and closed-loop supply chains, according to Wells & Seitz (2005), need new value-generating frameworks to compete with traditional linear supply chains. Many times, this necessitates the creation of new alliances, distribution channels, and client relationships. Schenkel et al. (2015), argues modular architecture (i.e *dividing into smaller parts*) is the ideal answer for closed-loop supply chains and highlights six clusters of value creation in reverse supply chains: *partnerships and cooperation, product design, service concepts, IT solutions, supply chain procedures, and organisational characteristics* (Schenkel et al., 2015).

Additionally, "*Long-lasting designs, maintenance, repair, reuse, remanufacturing, refurbishing, and the recycling of resources"* are all ways to create closed-loop systems (Geissdoerfer, Savaget, & Bocken and Hultink, 2017). One of the main goals of the CE strategy is to encourage an industrial and economic system based on greater cooperation among its actors. According to these authors, externalities can be used as long-term resources by stakeholders. They could reduce the number of virgin materials and energy they used in production this way. When discarded commodities and materials are no longer useful, they can be repurposed as resources for others through closed-loop industrial ecosystems (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Murray et al.,2017; Stahel, 2016). CBMs today are widely cited as a necessary step in achieving a circular economy (Ellen MacArthur Foundation, 2015; Urbinati et al., 2017; Vence and Pereira, 2018; Albertsen et al. 2021). Circular business models are not only good for society and the environment but are also profitable. Moreover, due to increasing environmental concerns people today are becoming more ecologically sensitive, which is reflected in their purchasing habits (Bocken and Ritala, 2021).

Additionally, regulators are working on circular economies, with varying degrees of success depending on the institutional framework, progressively offering incentives and enforcing circularity. For example, the EU has developed a new "EU Circular Economy Action Plan" aimed at making Europe greener and more competitive (European Commission, 2020). Hopkinson et al., (2018) point out that there is potential for new revenue generation and innovation through circular economies, especially if an appropriate business model is developed (Hopkinson et al., 2018).

According to Bocken et al 2021, clear strategic guidelines on how existing and new businesses can launch circular business model initiatives are required, and they have proposed a strategic decision-making framework based on two critical strategic choices: *the innovation strategy and the resource strategy*, which can be applied to develop or update business models based on three circular economy principles (explained below) that helps to reduce natural resource usage and environmental impact (Pal and Gander, 2018, Bocken and Ritala, 2021).

6.3.1 Narrowing the loop

Focusing on resource optimization per unit of product:

Narrowing loops minimises the number of resources used in the product and manufacturing process. The resource efficiency principle underpins this technique, which has already been effectively applied in a linear business model. According to Bocken et al. (2016), existing resource efficiency methods can be used with product life extension and recycling to create a circular system. In general, it refers to developing products and services that offer consumers (at least) the same level of performance while posing a lower environmental footprint (Jensen, 2018). Unlike efforts to slow resource loops, the "narrowing loops" strategy does not affect product flow speed and does not require any service loops (*e.g. repair*). Efficiency in product design and production, such as utilising less energy, water, and materials, emphasises this procedure, aided by more efficient manufacturing methods and better product design (*e.g., reducing packaging*). Due to its ability to reduce costs while also conserving resources, this approach is widely used in today's "linear" economy. Bocken et al. (2016) highlight that the goal of resource efficiency is to use fewer resources per product. This technique focuses on lowering resource usage associated with the product and manufacturing process, as visualised by Braungart et al. (2008) as an eco-efficient cradle-to-grave material flow (Bocken et al. 2016).

Additionally, the European Commission (2011) and scientific organisations like the European Roundtable on Sustainable Consumption and Production (ERSCP) advocate the shift to more resource-efficient production and consumption (Jensen, 2018). To achieve a 4-10 fold improvement in resource efficiency, the 'Roadmap to a Resource Efficient Europe' describes a fundamental restructuring of production and consumption (European Commission). It also emphasises resource efficiency as a driver of increased competitiveness and profitability (Jensen, 2018; European Commission, 2011). Furthermore, as technology and procedures advance, companies can achieve more with less. Hence, this strategy should be pursued regardless of their general business model. However, these advantages in efficiency should not come at the expense of quality or the value customers receive from the product (Bocken et al., 2016; Bocken and Ritala, 2021).

6.3.2 Slowing the loop

Focusing on product-life extension or product-utilisation intensification.

As defined by Bocken et al. (2016), slowing the loop refers to service loops used to extend the life of a product, such as repairs and refurbs, which cause a delay in the flow of resources due to the increasing use of long-life commodities and the extension of product life. This strategy focuses on extending the usage and reuse of items and materials over time by incorporating long-life and lifetime-extension activities into the design. This approach considers factors such as product durability and quality and strategies for routine maintenance and repair (Jensen, 2018). Furthermore, it may be viable to include product life extension features into service models (Bocken et al., 2016; Bocken and Ritala, 2021). Extending the life of products is thought to have a lower environmental impact than buying new products since manufacture and distribution can be delayed, and waste can be decreased (van Nes & Cramer, 2006). However, according to Jensen (2018), a life-cycle assessment perspective may, in some situations, particularly for energy-consuming products, allow for the substitution of older products for newer ones if the newer products offer significant energy savings (Bakker et al., 2014). Furthermore, extending a product's life and recirculating the materials might generate new revenues (Pocock et al., 2011).

Consequently, securing the best technological alternatives for maintenance, upgrade, or reuse, such as through the principles of eco-design or design for sustainability, can stimulate the development of circular opportunities. (Ardente et al., 2012). Bocken et al. (2016) argue that 'narrowing' and 'slowing' could be comparable (few resources moving through the system) but underline that slowing, "*invokes a different relationship with time*", whereas narrowing, "*accepts the speed of resource flows*". (Bocken et al., 2016). However, it's important to keep in mind that the method of narrowing eliminates the time dimension. As a result, if total flows outrun the overall resource efficiency, the overall savings from a system perspective are non-existent (Jensen, 2018). Fast fashion's use of organic fibres is one such example.

6.3.3 Closing the loop

Focusing on material recycling when products reach their end-of-life.

According to Bocken et al. (2016), "closing loops" is the practice of repurposing and recycling waste. This is frequently referred to as "recycling," and it relates to the method of reusing materials after consumers have consumed them. For example, precious metals recovered from electronic waste could be repurposed to create a new set of products. Poor-quality waste materials can be recycled for lower-value purposes (e.g., insulation material). In the worst-case situation, they might be burned to generate energy, which is referred to as "downcycling." Similarly, "upcycling" refers to making a high-quality product out of recycled materials, such as a piece of furniture (McDonough and Braungart, 2013). As a result, the quality of the acquired material and the end-product for which it is employed determine the viability of the business case. Recycling closes the resource flow loop between post-use and the creation of new products. This results in a resource flow that is circular (Bocken et al., 2016; Bocken and Ritala, 2021).

Nevertheless, these three approaches are not mutually exclusive but rather complementary. For example, a product could be made with cleaner manufacturing procedures (narrowing the loop) and recycled materials (closing the loop) and in such a way that the product is durable and the services allow for a long product lifespan (slowing the loop). Furthermore, a slowing loop may be combined with a business model that allows for loop closure, such as when the material from a high-quality product that is eventually abandoned is used to create new value elsewhere (Bocken et al., 2016; Bocken and Ritala, 2021). As a result, the circular economy can generate new revenue and innovation, especially if a viable business model can be created (Hopkinson et al., 2018). However, clear strategic guidelines on how existing and new businesses might undertake circular business model activities are needed (Bocken and Ritala, 2021). As a result, there is an intriguing research gap.

Hence, by using Bocken et al.'s (2016) three framework methods for a circular economy, I will be able to answer the research question and analyse the data gathered from this study's expert interview. Moreover, this research will add new knowledge by presenting the Swedish industry's perspective by showing the implementation of a circular business model as the automotive industry transitions toward a circular economy.

7. Methodology

7.1 Qualitative method and abductive approach

This is a qualitative study that entails interviewing informants in order to acquire the necessary data. Data for this study was gathered through expert interviews. In order to better understand and analyse stakeholder knowledge on the implementation of circular business models and strategies for lithium-ion batteries in the Swedish automobile industry, qualitative research is best suited. In the gathering and analysis of data, qualitative research (Bryman 2016: 374-5) allows researchers to examine, describe, and explain a real-world occurrence using words rather than quantitative analysis (See also Naderifar et al., 2017: 1). This method helps researchers to convey real-world occurrences to the rest of the world in a clear and simple manner, such as those recorded in an interview, presented in images, or what lies beyond the surface of a text (Halperin & Heath, 2017: 41-4). As a result, for this study, an expert interview was considered to be the most effective approach to answering the research question. Due to their expertise in their field, respondents will be able to explain the subject matter in greater detail. They were chosen based on their organisational position because only their knowledge matters, as well as a snowball selection process in which I was pointed to by others in certain positions. The interviews were semi-structured and divided into themes. When conducting interviews in this manner, I was able to gain insights into the deeper knowledge of the study's respondents on the subject matter at hand (Bryman, 2016). Because not every interview will yield the same results, this technique was chosen. This allows the interviewer to ask more relevant questions about the themes according to their expertise in respective themes instead of asking the exact same questions to everyone. While certain interview questions were the same for all interviewers, the follow-up questions were tailored to the respondent's knowledge and expertise. Finally, following the qualitative research method, the study is using an abductive research approach.

Abductive inference serves as the foundation of scientific inquiry and one of the three essential techniques of logical thinking, together with induction and deduction (Meyer and

Lunnay 2013). According to Habermas (1978), abduction is a technique of inference employed to widen knowledge and drive the research process. New concepts are introduced through abduction. The key distinction between abduction and deduction is that abduction demonstrates how something might be, whereas deduction establishes that something must be that way (Habermas 1978). This research strategy combines inductive and deductive reasoning. The inductive technique forms and develops new knowledge based on observations of reality that can be used as future theoretical frameworks. The deductive research approach investigates actual phenomena to develop existing theories and build new ones (Kovács and Spens, 2005; Bryman & Bell, 2007).

For instance, the findings may not fit the theoretical framework when theory-driven research is conducted. The deductive inference is used to establish or disprove a theory. On the other hand, unrelated findings to the fundamental theoretical premise may go overlooked. At its most fundamental level, abduction is a technique for establishing associations that enables the researcher to identify linkages and connections that would have gone unnoticed otherwise (Meyer and Lunnay 2013). This enables the researcher to produce new ideas, reframe an issue, and see something else' (Danermark et al. 1997). The goal is to find data beyond the initial theoretical premise (Meyer and Lunnay, 2013).

The abductive approach fosters more dynamic research where researchers are permitted to use a theoretical foundation when collecting empirical data while also utilising this empirical data to tailor existing theoretical literature to conduct profound research. Dubois & Gadde, (2002) argues using an abductive approach is a good option for researchers who need additional support in analysing theoretical and empirical data. It is appropriate to use an abductive technique because the present literature on CE adoption in the manufacturing industry is scarce. Prior research has revealed that CE applied by the manufacturing industry varies significantly. When creating their study viewpoint, researchers might use an abductive strategy to combine a constrained theoretical framework with objective empirical evidence, giving their conclusions more significant substance (Philipsen, 2018; Dubois & Gadde, 2002; Meyer and Lunnay, 2013).

Thus, It is important that these suggestions are well-founded because the purpose of this research is to advance fundamental concepts in the automotive sector and provide practical direction to stakeholders working on CE projects. This can only be achieved by combining two views and applying a dynamic abductive method. An abductive research approach typically requires extra analytical effort since researchers incorporate empirical and theoretical facts in an ever-changing research strategy. Meanwhile, there is a risk that critical elements will be neglected. To avoid this, the interview guide was revised in parallel with the theoretical framework, and respondents were asked additional questions as needed.

7.2 Research Design

The automobile sector in Sweden is primarily focused in west Sweden with expertise in organisational support structures, research, and innovation. Gothenburg region is home to some of the country's most well-known companies, including Volvo Cars, Volvo AB (trucks), Polestar (EV producers), HCL Technologies Sweden, Gheely group, China Euro Vehicle Technology (CEVT), Autoliv, and Northvolt. It employs around 35,000 people, accounting for 40% of the overall workforce in the Swedish automotive industry (Miörner and Trippl, 2019). Additionally, higher education institutions in the region, notably the Chalmers University of Technology, are important hubs for knowledge development and experimentation in the automotive business, particularly in electromobility. There are also a variety of independent research institutes, science parks, innovation areas, and cluster organisations that focus on encouraging innovation, technological, and societal concerns within the automotive sector. In other words, system functions have been created regionally and are closely aligned with the automotive industry's needs. As a result, the automotive industry has strong regional support structures in western Sweden. The region also has a significant ICT industry that works closely with various automobile businesses, indicating favourable inter-path links within electromobility (Miörner and Trippl, 2019).

The study therefore employs a case study design (Bryman 2012) to analyse the implementation of circular economy initiatives by automobile companies and their stakeholders in Sweden. A case study *"investigates a contemporary phenomenon within its real-life context, particularly when the boundaries between phenomenon and context are not readily visible,"* according to Yin (1994, p. 13). A case study design is excellent for investigating and describing a "real-world" phenomenon related to a current event. When the phenomena and context have multiple explanations, this method allows researchers to analyse a case empirically and perform an in-depth study by obtaining detailed information and analysing the phenomena carefully. A qualitative case study is a thorough, detailed, and reliable methodological framework that creates more information and allows researchers to examine phenomena and contexts in more depth. (Halperin & Heath, 2017: 92,156,214; Bryman, 2016: 60-1; Creswell, 2013: 97) Furthermore, given the nature of the study, a descriptive objective is appropriate because it allows the reader to grasp the principles of the case company when placed in the context of circular economies.

7.3 Sampling

Experts from the Swedish automobile industry who are currently employed, serve as consultants, or work for government bodies dealing with electromobility make up the study's target group. The reasons for selecting electromobility experts as the study's target group for measuring their expertise in implementing a circular business model for electric vehicle batteries were already discussed in previous sections. Due to their expertise, those selected to participate in the study will be better able to explain the topic at hand. Their position in the organisation was considered because only their knowledge is essential. After the initial few interviews, a snowball selection process was hinted at, which led me to being referred to further candidates in relevant roles. As a result, it is vital to adopt this technique, as randomly selecting participants from among the many top officials will be challenging (Bryman, 2016: 415; Naderifar et al., 2017: 2). Welch et al. (2002) found that accessing expert settings and persons involves specific problems not experienced when researching non-expert subjects.

Experts are deemed more difficult to reach than non-experts because they "establish barriers that set their members apart from the rest of society" by their nature (Hertz & Imber, 1993, p. 3). As a result, reaching out to experts was a time-consuming and challenging process.

7.4 Method of data collection

I conducted semi structured interviews as a data collection method. Qualitative researchers typically use this technique. In addition to helping researchers better understand the complexity of real-world problems, this technique will allow them to produce new knowledge by conducting interviews with individuals or groups (Brinkmann & Kvale, 2015, 3-5, 149; Halperin & Heath, 2017, 285-6; Bryman, 2016: 466). For this project, researchers employed an in-depth informant interview method to interview several experts in the field and gather a large amount of data for analysis. Semi-structured interviews were preferred since they allowed me to ask questions that required more than a "Yes" or "No" answer. Additionally, more information was gathered by using open-ended questions. This allowed me to address the research question in its completeness and provide more thorough answers to the study (Bryman, 2016: 468-9; Halperin & Heath, 2017: 289). Most importantly, this approach allows researchers to access the respondents' extensive understanding of the research problem based on their knowledge (Brinkmann & Kvale, 2015). Finally, because of Covid-19, 10 out of 13 interviews were conducted online (through Zoom and teams) and over the phone while three were conducted on site.

7.5 Semi-structured Expert Interviews

In-depth expert interviews with central government officials, industry experts, and senior researchers (PhD holders) in public and private sectors were used to gather data. ‘Experts’ are here defined as: *“an informant who occupies a senior or middle management position; has functional responsibility in an area which enjoys a high status in accordance with corporate values; has the considerable industry experience and frequently also long tenure with the company; possesses a broad network of personal relationships; and has considerable international exposure”* (Welch et al., 2002: 613). Interviews are helpful because they reveal previously undisclosed details about specific occurrences, such as processes and acts behind closed doors (Lilleker, 2003). To get into greater depth, I used semi-structured interviewing techniques. Semi-structured interviews require the preparation of a script. However, they allow the investigator and interviewees greater freedom to probe or answer a given question (Marshall & Rossman, 2016).

Given the goal of this thesis, which is to learn about the circular business models used by companies in Sweden for lithium-ion batteries, conducting expert interviews is a valuable method. The method can untangle relationships between powerful actors and provide insight into how certain events were perceived and responded to within the political establishment (Lilleker, 2003). Thus, in order to comprehend the complexities of strategies and the implementation of circular business models for lithium-ion batteries, interviews with key players in the field are required. In-depth interviews with centrally located sources at this point provide unique and crucial information about the historical event, i.e., *how the industry is transitioning to a circular business model from the traditional linear business model*.

I conducted 13 interviews with public officials, entrepreneurs, and professionals involved in the electrification of the transportation industry (see figure below). The interviewees play the role of informants because their job is to give information and insights from their work and field experience (Given, 2008). Considering that the subject matter is so wide-ranging, I decided to speak with a variety of experts in order to get a complete picture of the subject. I interviewed seven people from the manufacturing industry, three from government organisations, and three independent senior researchers who work in some capacity with both the industry and the government. In the beginning, the majority of the people were approached by email and LinkedIn messages without prior acquaintance. However, after a few initial contacts, I was directed to others who held comparable positions in similar organisations, allowing for a snowball sample of interviews (Given, 2008). Most of the interviews were conducted through video conference (Zoom, teams), except three interviews were held in person at the respondents' workplace. I recorded and transcribed the interviews with each informant's permission. Seven of the thirteen voluntarily agreed to have their names written down (which can be found in the reference list), while the remaining six are kept anonymous and are shown in general terms i.e: *senior strategists.*

7.6 Respondents' background and their professional relevance.

Respondent	Company	Title	Workplace Description
Interviewee 1 *Lars Bern*	Business Region Gothenburg	Group Manager Automotive & Transport	Business Region Gothenburg is responsible for business development in the City of Gothenburg and represents 13 municipalities in the region.
Interviewee 2 *Peter Kasche*	Energimyndigheten	Senior Programme Manager	Government offices of Sweden, the Swedish Energy Agency works with energy-related topics
Interviewee 3 *Sanders Jahilo*	Polestar	Head of Circular Economy/circular lead	Swedish Electric Vehicle Manufacturing company
Interviewee 4 *Andre Giminangiro*	Polestar	Senior Manager/Business development-Electromobility	Swedish Electric Vehicle Manufacturing company
Interviewee5 *Nicolas Gerende*	Volvo Energy	Head of battery industrialization and logistics	Volvo Energy is Volvo Group's newest business area, dedicated to accelerating the Group's

			electrification and sustainability journey
Interviewee 6 *Anonymous*	Volvo Cars	Senior strategist & researcher	Volvo Cars is a Swedish multinational manufacturer of luxury vehicles headquartered in Gothenburg. The company manufactures SUVs, station wagons, and sedans but has aimed to go fully electric by 2030.
Interviewee 7 *Anonymous*	Volvo Cars	Senior Strategist	Volvo Cars is a Swedish multinational manufacturer of luxury vehicles headquartered in Gothenburg. The company manufactures SUVs, station wagons, and sedans but has aimed to go fully electric by 2030.
Interviewee 8 *Anonymous*	Volvo AB	Purchasing Manager	The Volvo Group is a Swedish multinational manufacturing corporation headquartered in Gothenburg. While its core activity is the production, distribution and sale of trucks, buses and construction equipment, Volvo also supplies marine and industrial drive systems and financial services.
Interviewee 9 *Anonymous*	Northvolt	Purchasing Manager	Northvolt AB is a Swedish battery developer and manufacturer, specialising in lithium-ion technology for electric vehicles
Interviewee 10 *Anonymous*	Battery manufacturing company	Senior business director Service and Aftermarket	This company (anonymous) is an energy storage and control company that offers high-performance batteries for optimised products. Their main business is to define, develop, and deliver tailor-made batteries and power electronics to all kinds of demanding products that benefit from the new battery technology. Today, company

			focuses on LithiumIon cells that are viewed to be the best on the market with an exceptional number of cycles and safe behaviour. Company and its partners take full responsibility for the whole battery subsystem so its customers can focus on their products and applications instead.
Interviewee 11 *Dr. Lars Fast*	RISE. Research Institute of Sweden	(PhD). Senior researcher Energy conversion/ Energiomvandling	RISE Research Institutes of Sweden AB (RISE) is a Swedish state-owned research institute, collaborating with universities, industry and the public sector. RISE perform industry research and innovation as well as testing and certification.
Interviewee 12 *Anonymous*	Chalmers University of Technology	Anonymous: (PhD). Senior Researcher Electromobility/battery technology	Chalmers University of Technology is a Swedish university located in Gothenburg that focuses on research and education in technology, natural sciences, architecture, mathematics, maritime and other management areas
Interviewee 13 *Dr. Umar Hamid*	CEVT, China Euro Veichle Technology	(PhD). Lead Strategic Planning- Electromobility/future technology	CEVT is a development and innovation centre for the Geely Group focused on finding smarter ways to build cars – through modular development, by pushing the boundaries of virtual engineering, and by taking on new customer desires to create all-new cars.

Table 1 Source: Created by author

A total of thirteen interviews with experts (*namely; industry experts, experts from the research community and experts from the government*) in the Swedish transportation industry were conducted for this study. The names of the responders, their field of expertise (*job title*), and the names of the companies for which they work can be found on ***Table 1*** which is listed under ***Appendix 4*** at the end of this thesis. The table illustrates the selected expert's qualifications and significance to this study's data collection process.

Firstly, the senior PhD scholars provided an academic perspective on how the availability of CRMs, battery chemistry, existing policies, and present technological structure can affect the adoption of LIB circular business models. All three researchers are experts in the fields of electromobility and battery chemistry and strategists who have worked with the automotive industry in the past or present. As a result, they presented their extensive knowledge of battery circularity and a researcher's perspective on the feasibility of adopting circular business models for closed-loop items such as batteries.

Similarly, within the issue of energy governance, public officials linked with governmental institutions provided a practical and unique insight into the inner workings of the government *(i.e. circular economy for batteries)*. In this category, I spoke with one senior professional from the Swedish energy agency who oversees the circularity and electrification processes in Sweden and one from the Business Region of Gothenburg whose department works directly with stakeholders in Gothenburg to implement sustainable transportation solutions *(such as electrification and the establishment of a battery factory in Gothenburg).* As a result, the two senior public officials at these state agencies could provide information on practical issues such as everyday engagement, various projects, policy practices, and what the Swedish government and industry are doing to promote a circular economy in the automobile industry, particularly batteries. They could also provide a better understanding of the traditions that have shaped present policy culture and future considerations regarding battery circularity.

Finally, industry experts discussed the industry's perspective on the implementation of circular business practices for batteries, as well as how they are complying with the EU's Battery Directive, revealing how such measures are assisting their business practices as well as the challenges they pose to the industry, which is currently attempting to transition from traditional linear to circular business models. For example, two senior officers at Volvo cars and Polestar, both of whom serve as the head of the circular economy, have extensive experience in the challenges and benefits of implementing CBMs, as well as in-depth knowledge of legal issues related to complicated closed-loop products like lithium batteries, and thus contributed to the discussion. Other battery-related specialists also shared their thoughts on the present trends, existing measures, obstacles, and future practices for applying CBMs for LIB batteries.

A more detailed picture of Swedish lithium-ion battery company procedures and processes was obtained through interviews with various stakeholders, including representatives from government agencies, the manufacturing industry, and specialist researchers. Furthermore, Senior Experts interviewed (*e.g., from RISE and Chalmers*) are currently working, have previously worked, or have participated in battery technology research directly with industry experts (*e.g., Volvo and Northolt*), who is widely regarded as the industry's pioneers when it comes to electromobility (*Volvo was the first firm to proclaim that it will go fully electric*) and implementation of the circular economy (*Northvolt was the first company in Europe to create* *recycled batteries*). Similarly, experts from public sector organisations, such as the Swedish Energy Agency (SEA), have also been active in creating and implementing circular economy policies at the governmental and EU level. All of this contributed to a comprehensive data set that is critical to answering the study's research question.

Lastly, all interviews were conducted using a semi-structured interview guide (***See: appendix 2 & 3***). It is divided into four themes: ten main questions and several follow-up questions. In this manner, I began with a broad question that allowed the interviewee to respond to the subject freely. I continued with in-depth follow-up questions. Given the various roles of the professionals, I tailored the questions to each individual while attempting to maintain consistency. The questions stemmed from the thesis's central theoretical themes: Bocken et al.'s (2016)'s three circular economy principles of narrowing , slowing, and closing loops. I began by asking them about their overall views on electric vehicles and the circular economy and then their perspectives on the recently proposed battery directive. Using the three themes, I then posed questions. As outlined in this section, I wanted to learn about the current state of lithium battery narrowing and slowing and closing loops and the difficulties encountered in doing so.

8. Operationalization

Following significant theoretical research, an operationalisation chart (see: ***Chart below***) was used to construct an interview guide (*see: **Appendix 2 & 3***) for this research. All qualitative interviews were based on this guide. Using the Bocken et al., 2016's theoretical framework as a reference, the interview guide has been developed to guarantee that all study aspects are covered. Because the questions were grouped into three topics (*narrowing, slowing, and closing loops*) derived from the theoretical framework, the findings were more easily analysed. For example, to determine what Circular business model has been implemented in company **X,** questions such as; *What strategies are implemented by stakeholders in Sweden to narrow, slow, and close loops were created*. In order to accurately develop an interview guide, it is critical to collect the relevant data, according to Hennink, Hutter and Bailey (2020). Thus, according to Patel and Davidson, 2011; Hennink, Hutter, and Bailey (2020), the interview guide and operationalisation table should be based on central concepts identified in the study, from which the interview questions are created (ibid.).

Themes	Description	Sources	Question number (from interview guide)
Narrowing the loop	*How companies/stakeholders focuses on resource optimization per unit of product*	*Bocken et.al (2016)* *Bocken and Ritala, (2021)*	Appendix 2- (Q. 3,4,5) Appendix 3- (Q. 4,5,6)
Slowing the loop	*How companies/stakeholders focuses on product-life extension or product-utilisation intensification*	*Bocken et.al, 2016* *Bocken and Ritala, (2021)*	Appendix 2- (Q. 6,7,8,9) Appendix 3- (7,8,9)
Closing the loop	*How companies/stakeholders focus on material recycling when products reach their end-of-life.*	*Bocken et.al, 2016* *Bocken and Ritala, (2021)*	Appendix 2- (Q. 10, 11) Appendix 3- (Q. 10,11,12)

Table 2: Operalization chart

9. Validity

Researchers (e.g., Bryman, 2008; Yin, 2014; Leung, 2015) have described research validity as an evaluation of whether one analyses what is methodologically supposed to be researched. The validity of this thesis's research was ensured by ensuring that the findings from semi-structured interviews were in line with the stated goals and research objectives of the study. Moreover, this thesis maintained a high level of validity due to the fact that the interview guides and questions were developed and constrained to be consistent with the thesis goal and research objectives, which included the operationalization (***See Appendix 1***) of the theoretical framework of the three principles of Circular Economy by Bocken et al. 2016.

10. Reliability

Scholars commonly represent a study's reliability as being met if the study and its findings can be replicated by other researchers (e.g., Bryman, 2008; Silverman, 2014). Nevertheless, as argued by Bryman (2008), it is difficult and subjective to get at the same analytical interpretations and outcomes in a qualitative study, especially with the methodological option of conducting semi-structured interviews, like the structure of this thesis. It was possible to acquire dynamic information from the interviews because they were done semi-structured in the time and space they were held. It was feasible to "return" to the findings in this study since the interviews were recorded and evaluated numerous times as well as transcribed to achieve objective and unbiased results, increasing the study's reliability. Last but not least, the theoretical framework in this thesis was founded on past Circular economy theoretical research, which laid the groundwork for the operationalization (***See: appendix 1***) of theoretical notions to address and complement the subject of this thesis. This further strengthened the study's reliability.

11. Ethical Considerations

Ethical problems must also be considered when doing research. Respondents must provide consent for their names and recordings to be included in the study, as interviews constitute a vital research component. The respondents were told of the study's purpose and how they may help. They were informed that they are free to remain anonymous and opt not to answer specific questions during the research process. Participation in the interviews was entirely voluntary. Permission to record the interviews was also requested. Six participants desired anonymity, thus as a researcher, I have taken all reasonable precautions to ensure the participant's confidentiality. I have given the anonymous responders a general title (i.e. *senior strategist*) rather than their name throughout the study. The interviewee was also informed why such a step was necessary and notified that the recording will be deleted after the research is over. It was critical to stress the importance of interview recording since it aided the researcher when transcribing the interview and made it easy to recall various remarks made by respondents. Therefore, recording the interview was essential to avoid misrepresentation.

12. Limitations

One initial limitation of this research is that it focuses on the automobile industry in only one regional setting (*i.e. west Sweden*). Furthermore, because this study exclusively focuses on larger corporations, it is limited in its ability to assess the circular business models used by smaller enterprises. Moreover, the study's findings are limited to the implementation of circular economy initiatives in Swedish companies, which further narrows the scope of the thesis. This therefore limits the ability to draw generalisations to some extent, however it does allow for in-depth study. Nevertheless, because the battery directive governs the entire European manufacturing industry, the development of circular economy initiatives for electric vehicle batteries in Sweden could be considered somewhat universal and applicable at the European level, potentially making the analytical findings and the topic of this thesis interesting in a broader sense. Finally, the length of the conducted investigation, which covered between January and May 2022, is an obvious limitation of this research.

12. Findings

12.1 Narrowing the loop

RQ.1. Which strategies have been taken by the stakeholders to address the resource optimization challenges of lithium-ion batteries?

According to the research of Bocken et al. (2016), a circular system can be established by combining existing resource efficiency technologies with product life extension and recycling. As a result, the narrowing loop technique has no effect on product flow speed and does not necessitate any service loops. Product design and manufacturing efficiency, such as using less energy, water, and materials, highlight this procedure, which is supported by more efficient manufacturing methods and better product design. Due to its ability to reduce costs while also conserving resources, this approach is widely used in today's "linear" economy. Based on an interview with, senior strategist at Business Region Gothenburg, recognised that, the emphasis of this approach is on efficiency in product design and production, such as using less energy, water, and material, which is supported by more efficient manufacturing methods and better product design. In the interview, he highlighted how a company within the municipality of Gothenburg will utilise the sewage water as cooling water for the battery plant in the new battery factory in Gothenburg which is the *"Northvolts joint venture with Volvo cars*".

> *"A company within …… reused as cooling water for the for the battery plant. The city itself is like looking towards all the resources or sort of circular assets that could be put into the needs of the industry.* Group manager automotive & transport, Business Region Gothenburg

Furthermore, he emphasised the necessity of collaboration in adopting specific CE, in line with Vermunt et al (2019)'s argument about how enterprises and policymakers should prioritise customised solutions and strategies for various types of CBMs in order to support the growth of circular businesses.

Additionally, the goal of resource efficiency is to use a smaller amount of resources per product (Bocken et al. 2016). This strategy is not focused on the cyclic use of products and materials, but rather on reducing resource usage connected with the product and manufacturing process, as portrayed by Braungart et al. (2008) as an eco-efficient cradle-to-grave material flow (Bocken et al. 2016). In addition to the stakeholders in the manufacturing industry, an interview with a senior program manager at the Swedish Energy Agency stressed the importance of partnership, collaboration, and knowledge sharing when it comes to successfully narrowing the resource loop in the long run. The ability to demonstrate a greater understanding of the subject matter, according to him, is important throughout the transition period. However, the most significant barrier now remains in the absence of detailed data on emissions from both the material manufacturer and the company that sells the battery parts, which is a problem that occurs today as well. To achieve this degree of competence, a collaboration between stakeholders is required, and this can only be accomplished through the creation of partnerships, he argued.

> *Narrowing the loop can be done by having more knowledge about it. Today we don't have the exact data…………, knowledge can be gained from fostering partnerships between stakeholders.*
> Senior Programme Manager, Swedish Energy Agency

In particular, when interviewing informants from manufacturing industries such as Volvo they often pointed out that reverse logistics which simply put is a Supply chain management system that moves goods from customers back to sellers or manufacturers, plays an important role to narrow the resource loop. Findings indicated that the transition to a circular economy is a lengthy and time-consuming process and business model modifications require time and effort and should be considered a gradual, step-by-step method rather than an on-switch strategy (Bjrnbe, Skaar, Fet and others 2021). However, findings revealed that measures for transitioning towards a circular economy are already there in the case of large manufacturing industries like Volvo who already have an existing remanufacturing system and a good reverse logistics network within the industry. Thereby making it easier to implement circular strategies.

> *"It's not the first time that we are in this kind of business…. we already have a certain number of solutions where we buy and manufacture products and equipment.* Head of battery industrialization and logistics, Volvo energy

> *"reverse logistics is fundamental. And we have already got a very good reverse logistics network… ………they come back to our local distribution centres and even central distribution centres".* Senior sustainability and circular economy strategist, Volvo Cars

Moreover, a large part of the design and effectiveness of CBMs, according to the literature, is reliant on the collecting and reintegration of various goods, parts, and materials (Lewandowski, 2016; Schenkel et al., 2015; Wells & Seitz, 2005). In comparison to traditional business methods, the development of effective reverse logistics systems and closed-loop supply chains is critical which was also confirmed in the interviews. Due to the rapidly rising quantity of hazardous substances in the waste stream and their unique composition, waste flow, for example, is a severe environmental concern in the case of end-of-life vehicles and should be adequately addressed. According to the conclusions of this study, a diverse variety of stakeholders place a high value on the recycling and reuse of ELV parts and components, as well as metal recovery. Furthermore, according to an interview with head of battery industrialization and logistics at Volvo Energy, and another Senior Sustainability and Circular Economy Strategist at Volvo Cars, revealed that the increased complexity of end-of-life vehicle systems in the future appears to present a greater challenge for manufacturers today in terms of how to valorize specific components or elements and then incorporate them back into their systems. Nonetheless, this research has shown that as technology advances, producers will face a bigger challenge in determining what other types of specialised approaches should be used to close the loop in the near future for complex products like batteries.

> *" The problem is when we get to a stage where it's even more complex, because of end of life vehicles, how we valorize those components and materials to centralise them afterwards. It's not clear yet".* Senior sustainability and circular economy strategist, Volvo Cars

> *"Batteries are a little bit special………… And it means that the reverse logistic approach is fundamental and it is already in our existing system and we are therefore leveraging all our existing systems globally to handle the logistics and get the batteries back into our system as good as new shape".* Head of battery industrialization and logistics, Volvo energy

Furthermore, studies have shown it is impossible to develop efficient and environmentally friendly circular production and consumption systems in the current centralised model, which separates manufacturers from customers (Moreno et al. 2019). It was found in interviews with smaller battery/cell manufacturing companies that they do not focus on reverse logistics systems but instead invest in digitalization, which supports the claim made by Moreno et al. (2019), which highlights the role of digitalization to help CBMs, track assets for reuse and take-back plans, assess damages, pick appropriate recycling technology, and interact with users. In an interview with a senior strategist at a battery manufacturing company, stated that SMEs are not at the level of detail to implement a reverse logistics system; instead, what can be done is to invest in data collection to enable further digitalization within the company, which will then help the company by allowing it to leverage important data's to foster partnerships with strategic actors (i.e *origional equipment manufacturers like Volvo*) for whom those data are critical.

> *We are not in that level of detail yet [........], we don't look into reverse logistics in detail. Honestly, speaking we don't have the maturity level.* Senior Business development director, Battery manufacturing company.

Similarly, in another interview with a senior researcher from Chalmers University, conformed to this assumption about SMEs .

> *"If you want to have reverse logistics, you need to have data [.......] it's too naive to think that data will be freely available. Lot of people want to have the data and not give it away. Not for free".* Senior Researcher PhD, Chalmers University of technology

To summarise, for the circular business model to be successful, many different components of an organisation must collaborate in order to generate mutually beneficial results for all parties involved. To successfully build and operate a circular business model, a collaborative effort amongst multiple stakeholders is required. These models should also be utilised to take into consideration the specific circumstances of the firm in issue. For example, external conditions should complement the business model, or the business model should complement the context (Sousa-Zomer et al., 2018).

In conclusion, based on the information acquired and analysed from the interviews, findings showed that strategic partnership, data availability, and access to data *(in other words access to the vehicles battery management system)* appear to be essential factors in the effective implementation and narrowing of the resource loops strategy for companies. In addition, the fact that all of the interviewees, regardless of their differing backgrounds and points of view, were more or less in agreement on this point confirms this idea. A well-functioning supply chain management system that moves goods from customers back to sellers or manufacturers which is often referred as *reverse logistics* in academia, seems to play an important role in this regard. However, All end-of-life CBMs rely on the return of the batteries, which is often ensured via the OEM's take-back or reverse logistic mechanism. Interviews highlighted that larger companies (*Volvo*) organise the take-back through their existing dealer network, which serves as the primary point of contact for customers (*Respondent 4, 5 and 7 from Volvo*). In comparison, external recyclers and, in the case of passenger vehicles, national producer responsibility organisations such as BilRetur in Sweden collect and potentially return LIBs from end-of-life vehicles (*Senior Researcher, RISE*). The majority of these take-back schemes rely on voluntary returns from customers, and findings showed that OEMs do not appear to make a deliberate effort to retain ownership of the LIBs. It became evident during the interviews that many OEMs are not so worried about reclaiming their LIBs. Polestar's head of circular lead, stated particularly that as long as LIBs are a cost of end-of-life, they will eventually wind up at OEMs.

As a result, the findings of this study indicate that, as a result of the already-existing reverse logistics system in place, larger corporations appear to have the resources and competitive advantage to transform their sectors to a circular business model. Those involved in other sectors, on the other hand, are more likely to have access to the extensive dataset, without which the shift to a circular economy for larger corporations will be a lengthy and time-consuming process. Furthermore, when the findings of this study are compared to the requirements outlined in the EU battery directive ***(See: section 4.2.2***), such as; *supply chain due diligence*, *carbon footprint declaration requirement, complemented by battery passport-labelling and information and a requirement to comply with maximum lifecycle carbon footprint thresholds*, it becomes clear that implementing three principles of circular economy strategies from Bocken et al. (2016), makes it possible for companies to comply with the battery directive as well as execute the circularity of sophisticated products such as batteries.

12.2 Slowing the loop

RQ.2. Which strategies have been taken by the stakeholders to address the product-life extension of Lithium-ion batteries?

A product's lifespan can be extended by including long-life and lifetime-extension activities into its design, such as repairs and refurbs, which focus on extending the consumption and reuse of items and resources over time (Bocken et al. 2016). When doing so, product’s quality and durability are taken into account, as are methods for routine maintenance and repair of the product in question (Jensen, 2018). Additionally, incorporating product life extension features into service models has been theorosied by some researchers as well (Bocken et al., 2016; Bocken and Ritala, 2021). Furthermore in an interview a senior researcher at CEVT also confirmed this argument, however interestingly he also outlined that in a circular business batteries suppliers play a crucial role. Their understanding of battery service design is critical, as is their understanding of OEM's specific product platforms and their demands for certain materials. Not only will this save money in the long run, but it will also reduce the amount of waste generated by batteries throughout the course of their lifespans. This was further validated in another interview conducted with a Senior sustainability and circular economy strategist at Volvo Cars

> *"Understanding the service design by suppliers is a key [........] suppliers can solve this by having really a new perspective of service design externally and also understanding various points in the market situation is crucial".* Lead Strategic Planning- Electromobility and future technology, CEVT

> *"Suppliers have a critical role to play [........] also the opportunity for them to participate in the end of life".* Senior sustainability and circular economy strategist, Volvo Cars

Furthermore, due to delays in manufacture and distribution, and reduced waste, it is projected that extending the life of products will have a lower environmental impact than purchasing new products (van Nes & Cramer, 2006). Findings from the expert interview revealed that, when it comes to slowing resource loops, most experts agreed that involving suppliers from the early stage is critical because it will act as a key enabler of various strategies such as reuse, repurpose, remanufacture, and redesign, all of which are essential to slowing the loops over time which was highlighted in the interview with senior business manager at Polestar.

> *"A key piece in this puzzle will be the supplier partnerships. From the supplier's perspective, it is more simple since some suppliers provide components for both the automotive and other renewable energy markets (solar & wind). Since they already have both types of clients it is easier for the suppliers to deal with both customers".* Senior Manager, Business development-Electromobility, Polestar

Furthermore, previous research has shown that CBMs for EV Lithium-Ion batteries must be translated by multiple organisations into their own strategic and operational decisions, (i.e purchasing), with the need for a shared vision with current and potential future partners to reach a common goal (Kraaijenhagen et al., 2016). To compete with typical linear supply chains, CBMs and closed-loop supply chains, according to Wells & Seitz (2005), require novel value-generating frameworks. This therefore frequently demands the formation of new partnerships, distribution channels, and client relationships. Which was also outlined in an interview with a Senior Business development director, Battery manufacturing company.

> *"Customer optimization and purchasing will be critical from the perspective of suppliers, as will other types of collaborations, and consultant companies thinking more broadly about who they need to bring in to pursue a key element or, let's say, a priority area".* Senior Business development director, Battery manufacturing company.

In line with Bocken et al. (2016), argument whare author highlights that slowing the loop refers to service loops used to extend the life of a product (e.g by repurposing), which cause a delay in the flow of resources due to the increasing use of long-life commodities and the extension of products life. However, compared to other CBMs *(reuse, repurpose),* remanufacturing received little attention in the interviews, mostly due to the fact that it is not practised by many car manufacturers.

However, interviews with the stakeholders showed that today only a few full-scale repurposing CBMs exist. According to the findings most projects are still in the piloting and experimentation phase. This was outlined by the group manager, automotive & transport at Business Region Gothenburg where he pointed out a test project carried out in the municipality of Gothenburg, where old Volvo bus batteries are being used as an energy storage for solar power in residential buildings.

In a separate interview with a Senior Business Development Director at a battery manufacturing company, the respondent described their technique for reusing/repurposing batteries taken from other heavy duty vehicles, which was an unusual departure yet very interesting strategy compared to larger OEMs or EV manufacturers.

> *"Specifically in Gothenburg as a part of a test project, second life reuse/repurposing of the bus batteries as energy storage of solar power has been done. Some of the batteries from old buses have been reused in one of the housing projects called Viva close to Chalmers which is built by Riskbyggan".* Group Manager, Automotive & transport. Business Region Gothenburg

> *"Reuse or repurposing as in a secondhand application is probably the simplest, the most close to heart useful solution. Because the difference between us and regular EV is that we use our applications in a three shift 24/7 application. So they 're very highly runned, it's very often two or three batteries in the same vehicle. Keeping that in mind when it's not useful for a triple shift 24/7 is probably good enough for double shift 24/7*" Senior Business development director, Battery manufacturing company.

Furthermore, the head of battery industrialization and logistics at Volvo Energy brought up an important point that is also worth noting. He explained how original equipment manufacturers (OEMs) might put the batteries to good use before recycling them. According to him, batteries with an 80 percent steady health status can be employed in a range of applications at a fair cost. Aside from that, there is a growing demand for such secure life applications in today's society.

> *"Recycling the battery is the very last stage because we can do more with batteries [........], I'm convinced that batteries with 80% stable health can be used in an economically valuable way, in some different kinds of applications. And I really believe it, because the demand for these applications are growing".* Head of battery industrialization and logistics, Volvo Energy

Nevertheless, scholars argue that short circles necessitate a move from incremental improvements to more radical solutions or systemic transformations, as well as incentives from stakeholders and policymakers (Reike et al., 2018). The interviews with several stakeholders indicated that they are ready to embrace transformation in their business model but there are several challenges. Among other internal organisational issues, interviewees revealed that the most pressing challenge most specialists deal with today is gaining access to critical data because the battery management system is regarded as intellectual property that provides a competitive advantage (Niese et. al., 2020). Furthermore, respondents expressed their dissatisfaction with current legislation, which can serve as an essential source of inspiration for policymakers. Regardless of the regulations aim to ensure batteries placed in the EU market are sustainable and safe throughout their entire life cycle. The existing legislation, according to the head of circular economy at Polestar and a senior researcher at Chalmers University, places a great deal of restrictions on mannufacturers' ability to innovate. The fact that this is an area that requires continuous improvement means that actors need a little more freedom in order to come up with innovative solutions in order to actually achieve a more resource-efficient economy and ultimately the production of more electric vehicles.

> *"If we implement legislation concerning the Second Life circular economy, it's possible that we put too much pressure on the battery market. So we will not get enough electric vehicles [........] that you should make legislation that makes innovation much more possible than having specific numbers, or percentages".* Senior Researcher, Chalmers University

> *"We want to slow the loops but if it doesn't make much economic sense we reduce the availability of recycled minerals for batteries thus making it harder to meet proposed EU battery legislation requirements. However, by prolonging the loop, this would be counter-productive"*., Head of circular economy, Polestar

Furthermore, besides the challenges posed by legislation, stakeholders also pointed out the lack of political incentives from policymakers as a major challenge for companies wanting to transition towards a circular economy. Interestingly this was validated by a senior program manager at the Swedish Energy Agency in an interview. He also pointed out that most certainly in the near future there will be some sort of incentives from the government to aid the purchase and sale of second life materials and highlighted that the government acknowledges the role of subsidies and its importance in facilitating the industries green transition.

> *"There are barriers when it comes to slowing the loop [........] unfortunately we don't exactly have any subsidies as of today. However, I think it will be in the future. Thereby, enabling external influence when it comes to buying circulated materials".* Senior Programme Manager, Swedish Energy Agency

Additionally, extending the usage and reuse of items and materials over time by incorporating long-life and lifetime-extension activities into the design is one of the characteristics of slowing the loop strategy (Jensen 2018). This approach thus takes into account factors such as product durability and quality, as well as strategies for routine maintenance and repair (Jensen, 2018). Group Manager of automotive & transport at Business region Gothenburg also emphasised in his interview.

"Designing for reuse and recycling from the very start is I think is one key thing".
Group Manager, Automotive & transport, *Business Region Gothenburg*

Studies and the findings from the interview have shown that many established manufacturing companies are seeking to incorporate circular economy principles into their operations to achieve favourable economic, environmental, and social effects (Frishammar and Parida, 2019). Furthermore, In some cases, it may be viable to include product life extension features into service models (Bocken et al. 2016; Bocken and Ritala, 2021). Extending the life of products is thought to have a lower environmental impact than buying new products since manufacture and distribution can be delayed and waste is decreased (van Nes & Cramer, 2006). Inline with this in an interview, respondent five from Volvo energy outlined that These batteries are an excellent fit because they can be reused and monitored effectively. Most likely in the next ten to twenty years, every home will have its own home battery solution that will last for about ten to fifteen years because it will only require one charge per day and one recharge. As a result, it's a cost-effective approach that also aids in delaying the loop and therefore postponing recycling. thereby giving the chance for technology to evolve.

"*With advanced technology the recycled products are less harmful and most importantly this will send back better recycled materials back into the production [........] the more we can repurpose the batteries, the more we will be able to slow the loop".* Head of battery industrialization and logistics,, Volvo Energy

Additionally, in line with Jensen, (2018) argument in some situations – particularly for energy-consuming products allow for the substitution of older products for the newer ones, if newer products offer significant energy savings if viewed from a life-cycle assessment perspective (Bakker et al., 2014). During an interview respondent five mentioned the necessity for innovative green solutions to address the growing demand for charging alternatives as energy consumption and technology progress.

"Repurposing the batteries in stationary applications will enable in restoring intermediate energy systems that are usable to manage the charging. Because as we move forward, the charging need will increase so we will need this kind of green solution". Head of battery industrialization and logistics, Volvo Energy

Furthermore, extending the life of a product and recirculating the materials might produce new revenues (Pocock et al., 2011). Consequently, by securing the best technological alternatives for maintenance, upgrade, or reuse, such as through the principles of Eco-design or Design for Sustainability, a sustainable product design can stimulate the development of circular opportunities. (Ardente et al., 2012). For example, an interview with a Senior sustainability and circular economy strategist at Volvo Cars revealed how OEMs are reusing different components via a well functioning internal exchange program.

"We have 40 components within a vehicle that go back and we manufacture those, put those back on the market, we reuse, we're looking at opportunities to reuse components, which would mean

> *that we can provide our customers with a range of different product offers"*. Senior sustainability and circular economy strategist, Volvo Cars

Nevertheless, interviews highlighted that even though the OEMs tend to have a good strategy in place and a quite well functioning internal exchange programme for reusing several components, there are challenges, Respondent four from polestar outlined this in his interview that actors in the second life market must have detailed knowledge regarding different parts and their components in order to have a minimum waste hierarchy. He outlined the importance of understanding such challenges in order to reuse certain minerals.

> *"The biggest barrier I see today is definitely the chemical compositions [.......] however you can reuse instead in different types of electrical machines or different types of the energy systems, i.e wind, solar etc and generate revenue"*. Senior Manager/Business development- Electromobility, Polestar

To conclude, findings from several interviews indicated that supplier partnerships from a very early stage seems to play a crucial role in implementing a flourishing circular business model for lithium- ion batteries. Furthermore, compared to traditional business practices where companies had power and freedom to choose who to work with, in a circular business model it seems to be the other way around. Since suppliers have a great deal of datas they can now leverage that and use it as their comparative advantage. Since the manufacturing firms are obliged by the law and they must incorporate and transition towards a circular business model there seems to be a great deal of economic and partnership opportunity for smaller actors along the battery value chain.

Interviewees highlighted that today there are a handful of incentives to slow the loop however this number is expected to grow rapidly as more and more batteries are entering the market. However the findings also showed that there are major challenges on the way towards the green transition. Particularly, most experts pointed out that the most pressing challenge most companies deal with today is gaining access to critical data because the battery management system (BMS) is regarded as intellectual property that provides a competitive advantage (Niese et. al., 2020). Additionally, lack of political incentives (i.e subsidies) from the government is also further delaying the process. Nevertheless, the interview with a senior consultant at the Swedish energy agency indicated that the companies must stay positive and in the near future there will most likely be some form of subsidies encouraging firms to purchase recycled materials which will further aid in slowing the loop.

Finally, the most striking findings from the interview indicated that the existing legislation (i.e the battery directive), pose a major challenge for companies that want to transition towards a circular economy. The experts' criticism of the updated battery directive proposal is perhaps one of the most important and interesting findings from this study. According to experts in this research, there is a lack of data and research in this sector thus, firms must innovate a great deal. Furthermore, from the interviews conducted with specialists in automobile manufacturing businesses (Polestar, Volvo cars) as well as a senior researcher at Chalmers university clearly shows that the legislation is on the way, which makes it difficult to pursue a circular initiative for lithium-ion batteries in a variety of ways. On one hand, a more resource-efficient economy and an increase in the number of electric vehicles and cars on the road are among top priorities, while on the other hand the current regulation appears to be impeding this transformation. As a result, stakeholders stressed that the legislators are placing too much pressure on the battery industry by introducing such regulations for a second life circular economy. Experts argued that this would instead lead to a shortfall of electric vehicles on the road thereby contradicting the European Commission's own ambition to have at least 30 million electric vehicles on the region's roads by 2030. Therefore, Rather than focusing solely on the numbers and percentages of materials recovered, it is necessary to consider the bigger goal of increasing the number of electric vehicles on the road. As a result, instead of focusing on restrictive regulations that are purely focused on numbers and percentages, as the newly proposed battery directive is, the focus should be instead on establishing legislation that encourages more innovation and not the ones that slows innovation.

12.3 Closing the loop

RQ.3. Which strategies have been taken by the stakeholders to address the end-of-life challenges of Lithium-ion batteries?

> *"Recycling is a compulsory part so that is considered as a final step naturally".* Head of Circular Economy, Polestar.

Closing loops according to Bocken et al, 2016 and 2021 is the practice of repurposing and recycling waste. This is frequently referred to as "recycling," and it refers to the practice of reusing materials after they have been consumed by consumers. In this section, I outline the expert interview findings for closing the loop strategies. When it comes to closing resource loops in a similar fashion as narrowing and slowing the a loop, most experts once again emphasised on becoming more engaged and collaborative, particularly with raw material, battery and electronics suppliers. Findings of the interview revealed that, moving forward larger manufacturing industries will be required to be more involved and collaborative in the future, according to a Senior sustainability and circular economy strategist at Volvo Cars. The method in which they interact with their material, electronics, and battery suppliers must change dramatically. The findings showed that currently large manufacturers are immature therefore it is crucial for them to understand that becoming a circular business must be a top priority. Furthermore, according to the findings of the study, most manufacturers now lack the necessary infrastructure to engage with suppliers or recyclers. Furthermore, they lack a thorough understanding of the economics of the particular circumstance concerning circular economy. This, however, should not be interpreted as a flaw or a disadvantage due to the fact that the vast majority of manufacturers did not have to consider this earlier because it was not considered a responsibility. Nonetheless, in light of the new battery proposal, the business model that has been in place for more than 100 years will have to take this into consideration, as it is now not only a responsibility, but also a legally binding standard of practice. Nevertheless, the interview also revealed that battery and car manufactures in Sweden are currently in the planning phase, and there is a great deal of internal communication and discussion within the car industry to figure out the best methods in which they might engage with people involved in battery recycling.

> *"At the moment, I would say that we are immature. We don't really have the infrastructure for engaging with suppliers, or recyclers. And we don't even have a really good grasp of the economics of that [........] ".* Senior sustainability and circular economy strategist, Volvo Cars

In the case of Volvo in the quote above, he explained that Volvo is actively putting up a different form of communication with the goal of developing more strategic relationships with the suppliers rather than taking a low-risk approach where they have a variety of suppliers, which is the situation in the current business model. Similarly another interview with a Procurement strategist at Northvolt also expressed similar argument he outlined;

> *"When it comes to battery recycling, we're doing some things for the first time [........] .finding a supplier or developing a mature solution is difficult".* Procurement Strategist, Northvolt

In line with the above findings from the large manufacturing company, another expert who is a senior researcher at CEVT confirmed the importance of supplier collaboration however he also elaborated on a scenario which can be beneficial for large corporations (*i.e Volvo*) as well as stakeholders in the value chain. He further outlined how cities and car manufactures must collaborate together to create a circularity of batteries. According to him there is a strong need to educate private customers, who are just like any other consumer. He outlined that this is one of the most challenging tasks before us today. According to him, the first and most important step is for all parties involved to become more aware of the need and necessity of recycling this type of technology, as well as understanding the battery's life-cycle. Additionally in a circular economy, cities must collaborate with suppliers and automobile manufacturers to develop battery switching hubs. Such collaboration will be required in the future in order to construct easily accessible recycling centres.

> *"cities must work together with suppliers and car manufacturers to build battery switching hubs'.*
> Lead Strategic Planning- Electromobility/future technology, CEVT

Nevertheless, findings show that there seems to be different initiatives and incentives to engage suppliers in the value chain. As highlighted by a procurement strategist at Northvolt, one of the key challenge today is to finding a supplier due to the fact that battery recycling for EVs has only taken off recently (in the EU) there hasn't been so much done in this sector as a result there is a lack of appropriate datas as well as major challenge in developing a mature solution while at the same time companies are worried that they will not be getting a good value for the money.

“ Getting things done in a young market while staying within budget is difficult, so we're concerned that we won't receive good value for our money in the end.”. Procurement Strategist, Northvolt

This concern raised by Northvolt and earlier also by strategists at volvo cars was acknowledged by a senior researcher at RISE who also argues that inorder to make recycling business successful you also have to make it profitable. Nevertheless researcher at RISE, provided an interesting approach which shows how companies can profit from the recycling business which can be seen as an important ***recommendation for companies*** aiming to close the loop by implementing a feasible circular business model. Findings from the interview with the researcher demonstrated how the business model has to be clear for all stakeholders who are involved. For example; when you put the battery on the market, it has a certain value which is unknown to external actors, but for manufacturers who put it on the market, it has a certain value. However by using the battery you obviously lower its value. Nevertheless, at the point where the battery is evaluated for Second Life, the company has to see the added value which is greater than zero. So, even if the value went down to zero or almost zero they have to find the business model to increase that. Thus, for every stage where you need this kind of assessment of battery, you have to see that the process that you do is not so costly and can actually put in a new value. Therefore to close the loop this kind of material quality zigzag pattern has to be created which will enable product circularity.

Additionally, findings from the majority of interviews indicated several factors such as transparency, battery architecture, design and chemistry also plays an important role for implementing successful recycling programs. The Head of Circular Economy at Polestar highlighted that the architecture of the battery determines the specific actions that can be taken. According to him, “*Some future model batteries are "locked in" since they have already been created and so have constraints*”, while others are still in the design phase and allow for a more circular design. Indicating that polestar is implementing CBM where it makes sense. Another interview with a senior business developer from a lithium- battery manufacturing company revealed the success strategy of their company's business model. The expert outlined that, If companies want to have a successful recycling program, they must design for recycling, which is the case in this specific company. Their service strategy easily enables them to repair any of their products. More importantly, their service concept showed that even their customers were capable of repairing themselves without the need of high voltage, because it is safe and pre-designed to make the consumers feel safe. However, experts stressed the bigger dilemma was to afterwards reviv clients' batteries when they have reached the end of their useful lives. Because due to lack of research in the field of second life li-ion batteries, no one exactly knows when exactly is the end of life.

“The challenge right now is to seal the deal with clients and reliving their battery when it actually reaches end of life. However, The question is, when is the end of life?” Senior Business director, Battery manufacturing company.

In addition to this two government officials from RISE and Swedish Energy Agency further added that along with the knowledge of batteries architecture and design, investing in data collection and transparency among stakeholders is critical to reduce the cost of recycling while also assisting in the closure of the loop as quickly as possible in the long term. Here for actors in the second life industry, One ***key recommendation*** from the interview with a Senior researcher at RISE was that companies can considerably save costs by performing things on a regular basis. As an example, as a second-use battery producer, if they choose to be cautious when collecting the batteries they intend to use in their second life. They must first collect a large amount of data, from which they will develop a database that will be extremely valuable, since the database will contain a wealth of knowledge that will help to cut the price of future recycled batteries. As a result, the more information a company understands and collects in their database, the better off they will be in the future recycling process, because the data will assist in every stage and serve as a critical point of reference. Additionally, Senior program manager at Swedish Energy confirmed this, stating that understanding the chemistry of the batteries could be one of the keys to its successful recycling. Another thing to think about is the battery's history and knowledge. It will be easier to receive batteries from all manufacturers if you are familiar with data (*for example, Northvolt's approach*). As a result, it will aid in the process of closing the loop.

"If you do things on a regular basis, you can lower your cost". Senior researcher, RISE.

Appropriate labelling and transparency is a key. Explaining the chemistry of the battery could be one of the keys to its successful recycling. Senior Program Manager, Swedish Energy Agency.

As battery recycling improves in terms of recovering and producing raw materials and high-quality secondary raw materials, including those currently wasted (Mathieux et al., 2017 and Szymanski et al. 2021: 6-7). Research has found that the full potential of new technology can only be realised by putting in place sufficient governance. In order for remanufacturing, recycling, and reusing to generate a system that is truly sustainable, policy support is essential (Szymanski et. al 2021: 6-7), which can act as a key enabler to close the resource loops as outlined below in the first quote by one of the respondents.

Key enablers of closing loop strategy could be here in the form of policymaking as well as infrastructure assistance, such as Northvolt's opening of a facility in Gothenburg. Lead Strategic Planning- Electromobility/future technology, CEVT

"We need to have a relevant ecosystem in place, which means that relevant policies by government public authorities have to promote the use of recycled batteries, this can be done by introducing subsidies for recycling batteries which is lacking today". Procurement Strategist, Northvolt

Nevertheless, from the recycling companies perspectives there isn't much being done as highlighted by the respondent from Northvolt in the interview which was later confirmed in another interview conducted with a senior government official at Swedish energy energy. However the findings from that particular interview suggested that due to the urgency of this issue, in the near future there might definitely be some form of subsidies in place in order to encourage manufacturers and consumers to buy more recycled products.

" There will be subsidies in the future to enable external influence when it comes to buying circulated materials". Senior Programme Manager, Swedish Energy Agency

Data above confirmed that a typical company transitioning to a CBM has shown that the process is more iterative than sequential and more emergent than planned (Frishammar and Parida, 2019). Closing resource loops, thus, poses some difficulties. The results of the interview revealed that today's major challenge is a lack of a well-functioning recycling industry, particularly in the area of battery recycling which has been highlighted above.

While this study's primary goal is to identify the best CBM strategies implemented by stakeholders in Sweden, the study also attempted to bring up a discussion regarding the supply security of critical raw materials with the stakeholders in Sweden and understand their take on this matter. Experts expressed concerns about the need for new CRMs, without which the goal of transitioning to a low-carbon economy will be difficult to achieve. This thesis and its findings showed that not only in the literature, but also inside the industry, this is a problem that isn't being addressed nearly enough. In the supply chain, CRMs play a critical role because of their connections to a wide range of industries (Olivetti et al., 2017). Sustainable technologies that rely on these components include solar panels, wind turbines, electric cars, and energy-efficient lighting. As a result, increasing access to these CRM is fundamental for technological innovation, improved quality of life, and industry's transition to a low-carbon economy (Ferro & Bonollo, 2019).

"In the future, CRMs will be more expensive and extremely scarce hence it is also economically viable to close the loop now". Senior Programme Manager, Swedish Energy Agency

"If you want to build up the recycling industry, availability of raw materials to manufacture batteries is one key challenge today". Senior Researcher, Chalmers University.

In an interview with Senior Programme Manager at the Swedish Energy Agency, it was revealed that the recycling of lithium-ion batteries is regarded as a relatively straightforward process among the stakeholders because the business is still in its infancy (technologically and scientifically). However, research indicates that it is more sophisticated than it sounds. He emphasised that in general *"Batteries can be recycled, although it isn't always clear how, Particularly for lithium-ion batteries, there isn't a lot of information".*

Findings from the interview also revealed that some CRMs, such as nickel, are very easy to recycle; lithium, on the other hand, is challenging. However, the cost is now exceedingly high, both economically and in terms of overall energy consumption. As a result, the energy required to circulate them exceeds the energy obtained in return. As a result, in order to accomplish it successfully, businesses must consider a variety of aspects. Because there are so few materials on the market today, it is usually more cost-effective to buy new materials. Since it is also quite simple to disseminate it must be perhaps circulated one material(CRM) at a time. However, such raw materials will become more expensive in the future, therefore it is in companies economic interest to close the loop. However, in practice, this is rather complicated, not only the availability of CRMs is a major challenge for the industry but in order to close the loop, there must be a well-functioning industry that can recycle the batteries with minimum wastage and maximum safety and durability. In an interview, a senior researcher at Chalmers university problematised this issue. He pointed out that the expected life cycle of electric vehicles is approximately 15 years. Taking into consideration that the first electric vehicle was sold around the year 2010, For the foreseeable future (at least until 2030-2035), we will not have as many batteries returning to the recycling industry. Consequently, before they can generate significant money, they must first establish a functional recycling industry. This is one issue when it comes to closing the loop that needs attention.

> *“It's my concern about the impurities of the waste per product”*Senior researcher, RISE

> *“You may need to obtain some “new” critical materials that are difficult to recycle, you can address this issue by investing more in research and innovation”.* Senior Programme Manager, Swedish Energy Agency

In addition to this the interview also revealed that scientists are concerned about the impurity in waste per product, necessitating the consumption of "new" necessary ingredients to add to recycled batteries (*i.e CRMs*). As a result, this is an issue that must be addressed, which can be accomplished by increasing investment in research and innovation. A senior scientist in energy conversion at RISE, explained that ***companies can reduce*** the cost by thoroughly understanding the product that you recycle. Rather than having a basic procedure where you toss all the rubbish, companies in a certain industry must adapt the decomposition process in detail, including not only the chemical process, but also the mechanical process. In the long run, this will improve the recycling process.

Lastly the findings of this study confirmed that, as a result of the EU's electrification process, the consumption and availability of critical raw materials is a major challenge (Rajaeifar et al. 2022, Lewicka E et al. 2021). Hence, to avoid materials becoming a significant barrier to technological innovation and ambitious future transportation scenarios in the EU, proper material access will be essential (Balgoeva et al. 2016 and Szymanski et al. 2021: 6-7). Multiple interviews with key stakeholders showed that managing LIBs at the end of their life i.e implementing a circular business model can help minimise waste costs and environmental impacts, while also mitigating supply security concerns for vital raw materials (Idjis and da Costa, 2017), without which closing the loop and transitioning to a low-carbon economy will be challenging.

13. Conclusion

13.1 Concluding the research question

The overarching study aim is to investigate the implementation of the circular business model in Swedish enterprises given the existing challenges in the supply security of critical raw materials. This was externalised by analysing how stakeholders in Sweden are addressing resource optimization, product life extension and end of life challenges for lithium-ion batteries, the most common form of battery used in electric vehicles. Therefore, an examination of the narrowing, slowing and closing loops strategy was conducted. The results reveal that while firms are relatively new to the execution of CE strategies, certain measures are already being taken toward transitioning to a circular business model.

To conclude, strategic partnership and the availability and access to data appeared to play an essential role in closing the resource loop. Similarly, it was found that repair, refurbishment, and repurposing are the primary methods used by manufacturers to slow the loop, but remanufacturing is rarely used. The analysis of the research revealed that the majority of experts showed concern over how enterprises are unable to innovate due to a lack of political incentives and strict limitations imposed by existing regulations (e.g., the EU's battery directive).

As a result, industry stakeholders pointed out that legislators are putting too much pressure on the battery industry by imposing regulations for a circular economy with a second life. Furthermore, according to the researchers interviewed for this study this in the long term may instead result in a shortage of electric vehicles on the road, contradicting the European Commission's own goal of having at least 30 million electric vehicles on the road by 2030. Finally, data revealed that today's most significant difficulty is a lack of a well-functioning recycling industry, especially in battery recycling, making closing resource loops challenging. Furthermore, a broader issue that is not being emphasised nearly enough is the need for new critical raw materials, without which the broader goal of transitioning to a truly low-carbon economy will be unfeasible.

Through expert interviews with senior government officials and senior industry leaders in decision-making roles and senior researchers in expert committees, the results show that in order to implement a function circular business model, stakeholders' engagement in strategic partnerships, investment in data collection, knowledge sharing particularly with smaller actors along and throughout the value chain is vital. This then leads to a well functioning reverse logistics system, which is a key enabler for narrowing the loop. Similarly, findings also showed that in order to slow and close the loop, designing for sustainability (Ardeente et. al. 2012) is crucial since a product's design and development affect not just its production but also its entire lifecycle (Wang et al. 2018), from conception to disposal as well as the battery's history and architecture. However, strategic partnerships and supplier integration throughout the value chain can further push transitioning from the traditional linear take-make-dispose paradigm to a successful circular business model, particularly when dealing with complex products like batteries. In addition, this research contributed new insights from the automotive industry's standpoint on the recently updated battery directive. The findings show that companies must innovate a lot owing to a lack of research and data, yet it is evident that there isn't much freedom to innovate due to the proposed legislation's strict requirements. Moreover, due to a lack of political incentives from the national governments (*i.e subsidies*) and very strict requirements in the EU regulations, it is difficult to pursue a circular initiative for companies in a variety of ways and a major challenge to both slowing and closing the loop. Therefore, according to experts in the industry, rather than increasing the number of electric vehicles on the road, the new battery directive will result in a shortfall of electric vehicles. Thereby, contradicting the European Commission's own goal of having at least 30 million electric vehicles on the roads of Europe by 2030.

Additionally, by building on the real-world experiences of industry experts, scientists, and government officials in Sweden who have been actively involved in implementing circular economy initiatives and strategies, this study shows that in the new business model strategic partnerships, data access and sharing, supplier integration in the value chain and, and, last but not least, progressive policies that encourage innovation are critical to a successful transition to the circular economy. Moreover, Since the same EU policies and directives regulate the European vehicle sector, this research findings on Swedish industries may be generalised to the other European automobile and batteries industries to some extent. As a result, the findings of this study are especially important for smaller stakeholders with valuable data (suppliers, recyclers, SMEs), where there appears to be huge growth potential, as the findings of this study have demonstrated. Furthermore, as a result of the strict rules in place, larger firms are realising that without collaborations across the value chain, their transition to a low-carbon economy will be slowed much more. It appears that, in order to adopt circular business models and successfully transition to a low-carbon economy, strategic relationships at all levels are required, and this research serves as a learning point for both companies and governments alike. Future research could examine how stakeholders in different leading manufacturing countries, such as Sweden and Germany, are implementing circular business models for lithium-ion batteries, as well as the challenges that the newly proposed battery directive would bring once it is fully adopted. Furthermore, it would also be interesting to investigate research that might also assess the economic and social value provided by various solutions in order to develop the ideal CE approach based on the three pillars of sustainability.

13.2 Recommendation for policymakers

The European Commission's proposal for a new battery regulation, released in 2008 as part of the Strategic Action Plan for Batteries, will repeal the Battery Directive 2006/66/EC and amend Regulation 2019/1020 (European Commission, 2020). The proposal includes significant provisions to delay the loop for EVBs and encourage recycling and repurposing. As indicated earlier (***See:*** S***ection 4.2.2),*** the proposal further intends to restructure battery waste by requiring access to the data (i.e., *Battery Management System*), information sharing, and introducing battery passports and an exchange platform (***See: figure 3***). These policies, however, greatly disfavour battery and electric car producers, according to stakeholders interviewed for this study. As a result, rather than focusing on restrictive policies based solely on numbers and percentages, as the new battery directive implies, the outcomes of this study reveal that policymakers should focus on drafting legislation that encourages more innovation.

Additionally, stakeholders are worried that sharing the data on electric vehicle batteries could jeopardise the company's ability to maintain a competitive advantage. In this case, the risk of disclosing firm secrets is significantly greater if third parties have access to their battery management system. As a result, legislators must consider the perspectives of a wide range of stakeholders to guarantee that implemented legislation facilitates the transition to a circular economy without being burdensome. Stakeholders revealed that in many cases, the information gathered by an EVB is either retained in the battery management system or sent straight to the vehicle management system. In another way, manufacturers can therefore extract data from the electric veichel's vehicle management system, which means they don't need to grant third parties access to their battery management system to share data they've retrieved from the electric vehicles battery.

Hence, one recommendation to policy makers could be to maintain the requirement for information exchange in battery regulation. Nevertheless, also consider allowing the stakeholders to manage their battery management system internally via a closed agreement between the manufacturers and their clients. Finally, the new proposal, which includes a '*battery passport, battery exchange platform, a battery label, and a QR code requirements'* ***(See: figure*** **3)** must clearly explain what sort of information is required to determine the health and quality of the used batteries. One immediate problem due to this could be the requirement of excessive quantity of paperwork and red tapes for second life manufactures. Therefore, one viable solution and feedback to policymakers would be to establish a centrally governed single point of entry where information could be classified and controlled in terms of who could access it and for what purpose thereby allowing a little bit of flexibility for companies. This recommendation was also validated by a senior sustainability and CE strategist at Volvo Cars in his interview.

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Appendix 1. Operalization of Theory

Themes	Description	Sources	Question number (from interview guide)
Narrowing the loop	*How companies/stakeholders focuses on resource optimization per unit of product*	*Bocken et.al (2016)* *Bocken and Ritala, (2021)*	Appendix 2- (Q. 3,4,5) Appendix 3- (Q. 4,5,6)
Slowing the loop	*How companies/stakeholders focuses on product-life extension or product-utilisation intensification*	*Bocken et.al, 2016* *Bocken and Ritala, (2021)*	Appendix 2- (Q. 6,7,8,9) Appendix 3- (7,8,9)
Closing the loop	*How companies/stakeholders focus on material recycling when products reach their end-of-life.*	*Bocken et.al, 2016* *Bocken and Ritala, (2021)*	Appendix 2- (Q. 10, 11) Appendix 3- (Q. 10,11,12)

Appendix 2. Interview Guide- *Government and other experts*

Themes	**Key questions and sub-questions**
Theme 1 – Introduction and research context	1. How does your organisation participate in business operations concerning circular economy and electromobility? What is your role/ involvement in them? 2. What is your knowledge on the implementation of the circular economy strategy for EV batteries (narrowing loop, extended life and closed-loop recycling)? *(SEE: theme 2,3 and 4)*
Theme 2 – Narrowing the loop through reverse logistics *focusing on resource optimization per unit of product*	3. What recommendations do you have for stakeholders to successfully implement CE in the near future? *(e.g Can you give some example)* 4. How can organisations effectively implement an EV's battery reverse coordination system & simultaneously deal with the threat of potential supply risks and price volatility of CRMs? 5. In your opinion what are the key limitations to successfully narrowing the resource loop? What is your advice to the stakeholders in the industry?
Theme 3 – Slowing the loop *focusing on product-life extension or product-utilisation intensification*	6. Could you briefly outline the operations carried out by your organisation to help stakeholders extend the life of their EV's Battery *(repair, refurbishment, remanufacturing, repurposing)*? Is there a government scheme in place? ***If applicable*** 7. In your opinion what are the aspects that contribute to the effectiveness of the organisation's actions to extend the life of the EV Battery? 8. What strengths does your organisation leverage in order to successfully help organisations to extend the life of the EV's battery; i.e implement circular business models? 9. In your opinion when it comes to extending the life of a battery, what are the most pressing challenges for organisations today? What is the role of the government? *Do you have any feedback?*

Theme 4 **– Closing the loop** *focusing on material recycling when products reach their end-of-life.*	10. What elements influence the effectiveness of successful battery recycling programs? Do you have an example? 11. What are the primary obstacles that exist today impacting any current or future recycling efforts? *Lastly, is there anything that you want to add or comment to this interview?*

Appendix 3. Interview Guide- Manufacturing *Industry Experts*

Themes	**Key questions and sub-questions**
Theme 1 **– Introduction and research context**	1. How does your organisation participate in business operations concerning circular economy and electromobility? What is your role/ involvement in them? 2. What is your knowledge on the implementation of the circular economy strategy for EV batteries (narrowing loop, extended life and closed-loop recycling)? *(SEE: theme 2,3 and 4)* 3. How does your company plan to implement a circular economy strategy for EV batteries (narrowing loop, extended life and closed-loop recycling)? And, if so, in what manner? Could you please elaborate? *(SEE: theme 4,5 and 6)*
Theme 2 **– Narrowing the loop through reverse logistics** *focusing on resource optimization per unit of product*	4. How does your company keep ownership of the batteries? 5. How does your company manage EV battery's reverse logistics? 6. Can you elaborate on the strengths and weaknesses of narrowing the loop?
Theme 3 **– Slowing the loop** *focusing on*	7. Could you briefly outline the operations carried out by your organisation to extend the life of EV's Battery *(repair, refurbishment, remanufacturing, repurposing)*?

product-life extension or product-utilisation intensification	**8. Supplier involvement *(if applicable)*** *a. What role do your battery suppliers play in battery repair, remanufacturing, and repurposing?* *b. Is your company's battery purchase influenced by battery design for repair, remanufacturing, or repurposing? And, if so, how (for example, by selection criteria or early design collaboration)?* 9. What are the aspects that contribute to the success and barriers to narrowing the loop?
Theme 4 – Closing the loop *focusing on material recycling when products reach their end-of-life.*	***10. Supplier involvement in recycling (If applicable)*** *a. When it comes to battery recycling, what is the role of your suppliers?* *b. Is your company working with cell/battery suppliers to create a closed-loop recycling system? If so, how?* *c. Do you consider design for recycling when purchasing batteries for your company? If yes, could you share your selection criteria or early design collaboration?* 11. Would you say recycling EV's battery is an expense to your organisation or a probable future revenue stream? 12. . What elements influence the effectiveness of your company's battery recycling programs? a. Can you elaborate on your company's core competencies and weaknesses for successfully recycling EV's batteries?

Appendix 4. Interview Informant Table

Respondent	Company	Title	Workplace Description
Interviewee 1 *Lars Bern*	Business Region Gothenburg	Group Manager Automotive & Transport	Business Region Gothenburg is responsible for business development in the City of Gothenburg and represents 13 municipalities in the region.
Interviewee 2 *Peter Kasche*	Energimyndigheten	Senior Programme Manager	Government offices of Sweden, the Swedish Energy Agency works with energy-related topics
Interviewee 3 *Sanders Jahilo*	Polestar	Head of Circular Economy/circular lead	Swedish Electric Vehicle Manufacturing company
Interviewee 4 *Andre Giminangiro*	Polestar	Senior Manager/Business development-Electromobility	Swedish Electric Vehicle Manufacturing company
Interviewee5 *Nicolas Gerende*	Volvo Energy	Head of battery industrialization and logistics	Volvo Energy is Volvo Group's newest business area, dedicated to accelerating the Group's electrification and sustainability journey
Interviewee 6 *Anonymous*	Volvo Cars	Senior strategist & researcher	Volvo Cars is a Swedish multinational manufacturer of luxury vehicles headquartered in Gothenburg. The company manufactures SUVs, station wagons, and sedans but has aimed to go fully electric by 2030.
Interviewee 7 *Anonymous*	Volvo Cars	Senior Strategist	Volvo Cars is a Swedish multinational manufacturer of luxury vehicles headquartered in Gothenburg. The company manufactures SUVs, station wagons, and sedans but has aimed to go fully electric by 2030.

Interviewee 8 *Anonymous*	Volvo AB	Purchasing Manager	The Volvo Group is a Swedish multinational manufacturing corporation headquartered in Gothenburg. While its core activity is the production, distribution and sale of trucks, buses and construction equipment, Volvo also supplies marine and industrial drive systems and financial services.
Interviewee 9 *Anonymous*	Northvolt	Purchasing Manager	Northvolt AB is a Swedish battery developer and manufacturer, specialising in lithium-ion technology for electric vehicles
Interviewee 10 *Anonymous*	Battery manufacturing company	Senior business director Service and Aftermarket	This company (anonymous) is an energy storage and control company that offers high-performance batteries for optimised products. Their main business is to define, develop, and deliver tailor-made batteries and power electronics to all kinds of demanding products that benefit from the new battery technology. Today, company focuses on LithiumIon cells that are viewed to be the best on the market with an exceptional number of cycles and safe behaviour. Company and its partners take full responsibility for the whole battery subsystem so its customers can focus on their products and applications instead.
Interviewee 11 *Dr. Lars Fast*	RISE. Research Institute of Sweden	(PhD). Senior researcher Energy conversion/ Energiomvandling	RISE Research Institutes of Sweden AB (RISE) is a Swedish state-owned research institute, collaborating with universities, industry and the public sector. RISE perform industry research and

			innovation as well as testing and certification.
Interviewee 12 *Anonymous*	Chalmers University of Technology	Anonymous: (PhD). Senior Researcher Electromobility/battery technology	Chalmers University of Technology is a Swedish university located in Gothenburg that focuses on research and education in technology, natural sciences, architecture, mathematics, maritime and other management areas
Interviewee 13 *Dr. Umar Hamid*	CEVT, China Euro Veichle Technology	(PhD). Lead Strategic Planning-Electromobility/future technology	CEVT is a development and innovation centre for the Geely Group focused on finding smarter ways to build cars – through modular development, by pushing the boundaries of virtual engineering, and by taking on new customer desires to create all-new cars.

Table 1 Source: Created by author