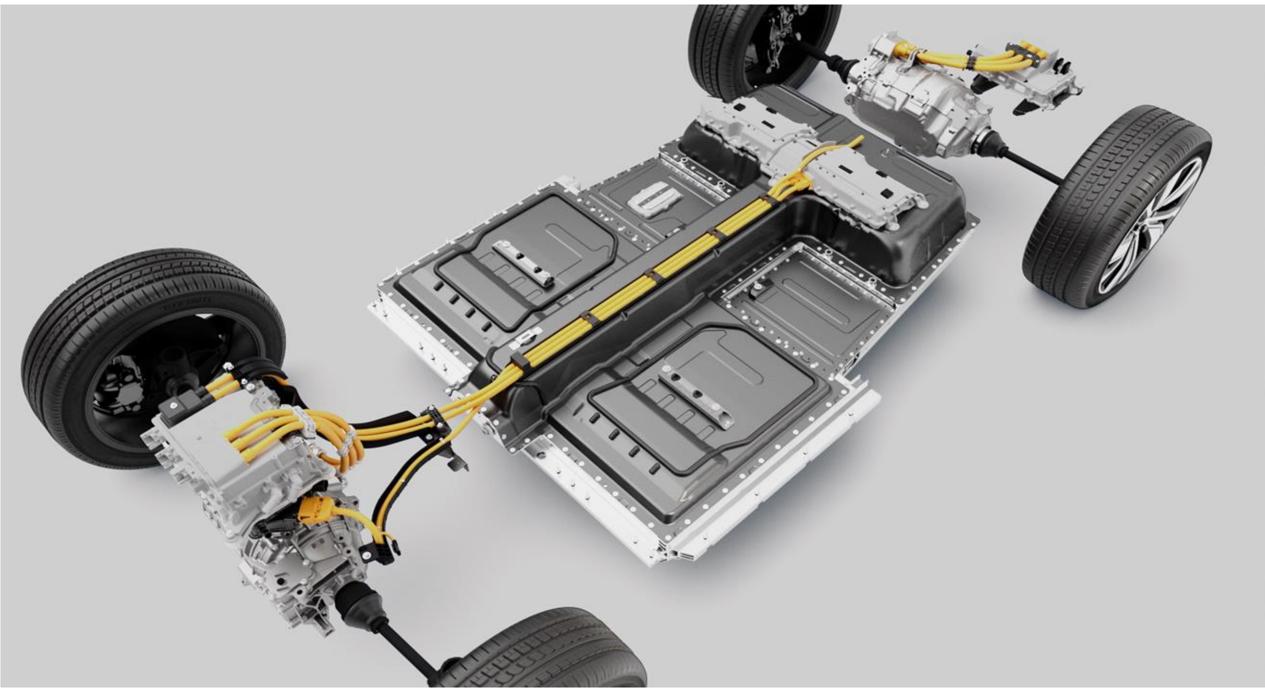

Life After Use: Circular Economy Business Models for the Second-Life of EV Batteries

Master's thesis in:
Management and Economics of Innovation
Supply Chain Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020
www.chalmers.se

Report No. E2020:023

Master's thesis 2020:023

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Cover: Electric Vehicle Battery:https://www.media.volvocars.com/image/low/259182/1/1/5

Typeset in LaTeX
Printed by Chalmers Reproservice
Gothenburg, Sweden 2020

ACKNOWLEDGEMENTS

This master's thesis has been conducted during the spring of 2020, at Chalmers University of Technology, within the Department of Technology Management, and the Division of Service Management and Logistics. The original idea behind the master thesis was initially crafted by a vehicle OEM, which later was further developed in collaboration with the researchers and Chalmers University of Technology.

Firstly, we would like to express our gratitude to our supervisor and examiner at Chalmers University of Technology, Ceren Altuntaş Vural. Without her dedication, constantly helping and challenging us, we would not have accomplished to deliver the results in this master thesis. Moreover, we would also like to thank Arni Halldórsson for his help during the early stages of this thesis.

Secondly, a big thank you to our supervisor at the OEM that has been very helpful and provided the resources and guidance needed in order to achieve this master thesis. Further, our supervisor has also helped us by providing relevant contacts to potential interviews, something that was crucial during the whole master thesis. Moreover, we would also like to express our gratitude towards the OEM for hosting and taking care of us during the spring, even though the situation was exceptional due to the Covid-19 situation altering what is perceived as normal.

Our next thank you, is directed to all the interviewees participating in this study. Without your dedication, time, and insights, this master thesis would not have been possible.

Finally, we would like to thank Matilda Törnqvist Hegg and Sandra Svenske-Kristensen for their commitment, time, and valuable feedback when opposing on our master thesis.

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May 25th, 2020

ABSTRACT

Introduction: As the majority of the vehicle original equipment manufacturers are transitioning towards manufacturing electric vehicles, the supply of used electric vehicle (EV) batteries is also deemed to increase during the coming decade. These so-called second-life EV batteries have a multitude of potential application areas, however, few earlier studies have explored how to properly design business models and the associated supply chains for these applications.

Purpose: The goal of this thesis have been to explore what types of business models and associated supply chain design that are suitable for OEMs to utilize when entering a future market for second-life EV battery applications.

Methodology: The data have been collected by conducting semi-structured interviews with stakeholders at one vehicle OEM. Further, additional semi-structured interviews were held with customers and external experts. Moreover, the researchers created a theoretical framework that guided the design of the proposed business models.

Findings and Implications: By exploring a future business model based on second-life EV batteries, a number of business model implications have been identified: seven suitable application areas, five potential customer segments, and four types of actors. Moreover, the exploration of the activities taking place in a future associated supply chain have also revealed nine key activities. This thesis has derived three potential circular economy business models identified as suitable for OEMs to utilize when entering a future market based on second-life EV batteries. When assessing the future market, it was found likely that a battery service provider will enter, however as the market currently barely exist the characteristics of this actors is not yet fully known. Further, it has been revealed that the business models utilized in the future market for second-life EV batteries will be affected by the both the high innovation rate of new EV batteries, and also by upcoming laws and policies currently being drafted.

Originality: This master thesis contributes to the research field by proposing three potential circular economy business models and their associated supply chains that OEMs may utilize when entering the future market for second-life EV battery market. Further, a contribution is made by comparing these three business models upon their different sub-components in relation to potential customer segments and application areas.

Keywords: Second-Life EV Batteries, Business Models, Supply Chain, Circular Economy Business Models, Value Proposition, Value Creation and Delivery, Value Capture, PSS

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1 INTRODUCTION

Currently, vehicle OEMs worldwide have initiated a transition from manufacturing vehicles with internal combustion engines (ICE) fueled by gasoline and diesel, to instead offering electric vehicles (EVs). This change is driven by a projected decline in the demand for ICE vehicles, currently accelerated by increasing environmental awareness of the customers and also by tighter regulations emerging. EV vehicles are not, compared to their ICE counterpart, driven by fossil fuels, i.e. gasoline or diesel. Rather, they are powered by an internal electric battery which provides electricity to an electric engine, which followingly moves the car. Hence, the EV battery will be a key component in the new electric car architecture.

The EV batteries pose both a substantial monetary investment due to its high upfront cost as well as a high environmental impact stemming from the manufacturing of the EV battery. The performance of a battery is declining through its life and it is mainly affected by time, mileage, temperature, and usage. When a battery's health has reached a certain limit of its initial condition, it's no longer viable to use in a vehicle as it cannot withstand the aggressive charging and discharging that is required. Hence, the EV battery is no longer suitable for usage within the vehicle, i.e. it is deemed to be removed from the vehicle. Lüdeke-Freund, Carroux, Joyce, Massa & Breuer (2018) state that many firms currently have begun changing their mindset of how to view a product life cycle. The traditional approach regards the life cycle of a product as a linear flow. The resources are transformed into a product, sold to a customer, and then ultimately scrapped. The new mindset instead depicts the life cycle as a circular resource flow, where companies consider used goods as potentially valuable assets (Lüdeke-Freund et al., 2018; Lüdeke-Freund, Gold, & Bocken, 2019). Hence, rather than scrapping these used goods, the OEMs may use these products in alternative applications. Thus, by giving the products a second-life the resource utilization may be improved while OEMs decrease their environmental impact and at the same time creates a new revenue stream. Further, due to the high upfront costs and the high environmental impact from manufacturing this is potentially suitable for EV batteries. However, in order to unleash the potential value from the circular life cycle, a firm needs to adjust its current business model in order to align with this new perspective. A business model that orbits around the circular economy is often recalled as a Circular Economy Business Model (CEBM) (Lüdeke-Freund et al., 2018; Lüdeke-Freund et al., 2019).

As the market for EVs is expected to grow radically during the coming decades, the vehicle OEMs will face a major challenge when huge amounts of used EV batteries are returned from their first life. Currently, the vehicle OEMs pay a fee when they send a used EV battery to a battery recycler. Hence, the coming supply of used EV batteries could be a challenge for the vehicle OEMs as it will pose a significant cost stemming from the recycling. However, swapping perspective to a circular economy mindset, these pile of used batteries could instead be regarded as potential assets that the OEMs may utilize. In order to do so, they could turn towards the practices advocated within the CEBMs. Currently, the theoretical area of CEBM is being explored by multiple scholars, outlining the general practices of a CEBM.

A review of earlier research shows that a couple of previous studies have been conducted within the overall field of second-life EV batteries. Neubauer, Wood & Pesaran (2015) have explored how the technical aspects of used EV batteries, such as battery degradation, affect the viability of utilizing them within second-life applications. Martinez-Laserna, Gandiaga, Sarasketa-Zabala, Badeda, Stroe, Swierczynski & Goikoetxea (2018) looked into current and relevant commercial products available on the market. Debnath, Ahmad & Habibi (2014) have studied how vehicle-to-grid batteries can be used within second-life applications, more specifically assessing the economic load dispatch and the associated revenues. Lacey, Putrus & Salim (2013) show that second-life EV batteries can be used within battery energy storage systems. Jiao & Evans (2016) have conducted a case study, exploring how the business models of four EV stakeholders are designed.Olsson, Fallahi, Schnurr, Diener & Van Loon (2018) have in their study looked into how CEBMs may be designed by stakeholders when establishing their business around second-life EV batteries. Moreover, Olsson et al. (2018) proposes four scenarios for how a circular economy business model may be designed according to the dimensions value network and customer value propositions.

As only a few earlier studies have approached the emerging field of second-life EV batteries from a business model and CEBM perspective, it is found that it is suitable to conduct further exploratory studies within this context. Hence, the researchers of this study regards this as an interesting research area which could benefit from an explorative study highlighting how the vehicle OEMs could design a CEBM within this emerging industry. Further, Lüdeke-Freund et al. (2018) state that when adopting a CEBM approach, the associated supply chain is key in order to enable the business model. Hence, this study will also incorporate the required supply chain design needed to establish a business model for OEMs within the market for second-life EV battery applications. In this study, the researchers will focus on the part of the supply chain taking place after the OEMs have regained the used EV batteries. Thus, the part of the supply chain encompassing the activities needed for the OEM to retrieve the EV batteries from its first life will not be a part of this study, hence considered outside the research scope.

This research study is a single source case study that has gathered data from one vehicle OEM in order to explore their views and perspectives regarding how a future business model could be designed. However, the study has also incorporated potential customers and field experts in order to retrieve their views and insights into the future industry as well. Hence, the study aims to provide general insights for future actors not only relevant to this single OEM.

1.1 Purpose

The purpose of this master thesis is to explore what types of business models and associated supply chain designs that are suitable for vehicle OEMs to adopt in order to enable second-life EV battery applications. In order to fulfill the purpose, this master thesis strives to answer two research questions, namely:

1. *What are the dimensions of a Circular Economy Business model for second-life EV batteries and what are the de-*

terminants for the associated supply chain?

2. *How may the identified CEBM dimensions be configured and how could the associated supply chain be structured for second-life EV battery applications?*

1.2 Delimitations

This master thesis will not consider specific geographic market conditions and characteristics when answering the purpose of the study. A risk with this delimitation is that the study may neglect specific, local market conditions that could affect the chosen business model within a certain geographic context. Further, when deriving customer segments for the second-life EV battery applications, this study has outlined rather broad segments with general characteristics. However, there may exist more narrow subsegments within these broader segments that differ in terms of their characteristics. Hence, by delimiting the study to these broad customer segments, a risk that possibly could arise is that the study fails to acknowledge some differences between customers within the same general segments. The scope of the study will also be limited to the time available of the researchers during the thesis work. Hence, due to the time constraints, certain scope delimitations have been made, such as only incorporating one OEM in the study and also to exclude the part of the EV battery supply chain, as depicted in figure 1.1.

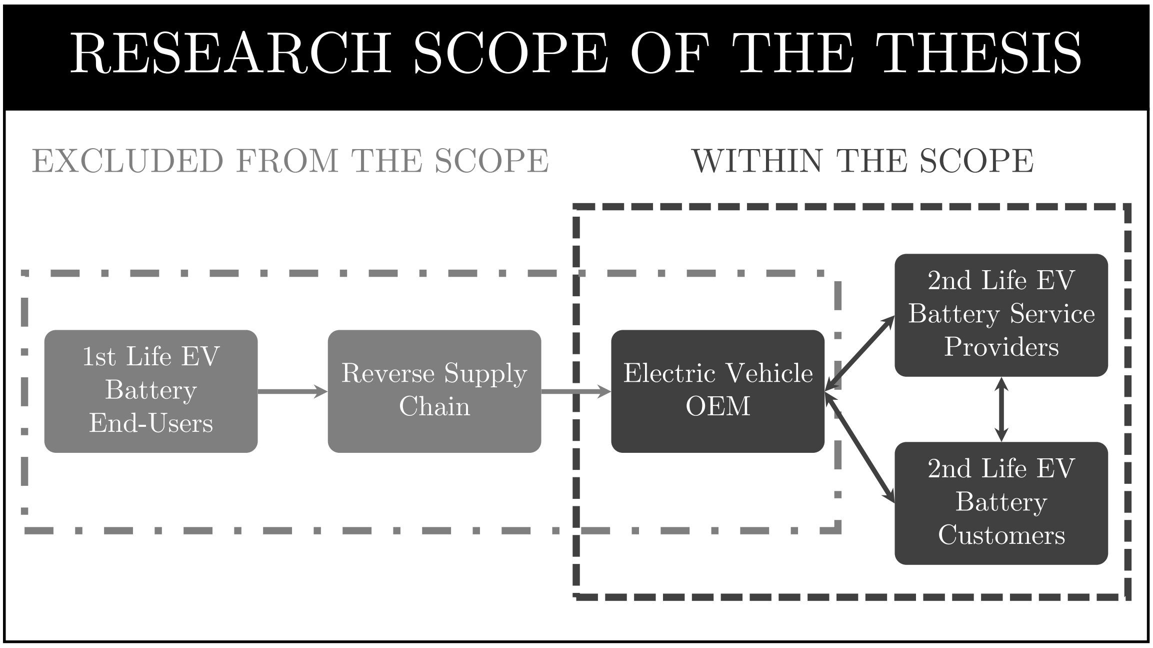

Figure 1.1: The figure depicts the potential future supply chain for second-life EV batteries. The scope of the thesis is limited to the part targeted in the black dotted box.

2
THEORETICAL FRAMEWORK

This chapter will serve as a theoretical framework, outlining and describing literature within business models, supply chain, and circular economy concepts. The theoretical framework will later be used in relation to the empirical findings of the study do derive potential circular economy business models that may be used for second-life EV battery applications. The chapter will start with a brief introduction of the fundamental concept of the business model, followed by an extensive review targeting the specific notion of the circular economy business model.

2.1 Business Models

The concept of business models gained momentum in management literature at the end of the last century as a response to the need of describing the emerging and diverse flora of businesses (Schaltegger, Hansen, & Lüdeke-Freund, 2016). One of the first definitions of the concept of the business model was derived from the works of Chesbrough & Rosenbloom (2002, p. 533) which linked it to the concept of business strategy. In their paper they define that the purpose of the business model is to *"i) articulate the value proposition, ii) identify the market segment, iii) define the structure of the value chain, iv) estimate the cost structure and profit potential, v) locate the position of the firm within the value network, vi) formulate a competitive strategy"*. Later, Shafer, Smith & Linder (2005, p. 202) defined the business model as *"a representation of a firm's underlying core logic and strategic choices for creating and capturing value within a value network"*. Teece (2010, p. 182), argues that in order to achieve a sustainable competitive advantage, the business model needs to determine *"targeted market segments, customer benefit of the product, embedded product features, design of revenue and cost structure and value capture mechanisms"*. According to one of the highly cited definitions of the concept; *"A business model describes the rationale of how an organization creates, delivers and captures value"* (Osterwalder & Pigneur, 2010, p. 14). This definition from Osterwalder et al. (2010) will be used further in this thesis.

How an organization establishes value may, according to Günzel & Holm (2013) and Lüdeke-Freund et al. (2019), be divided into four sub-elements, namely i) *Value propositions* ii) *Value creation* iii) *Value delivery*, and iv) *Value capture*. A value proposition is according to Osterwalder et al. (2010) a set of products and/or services that satisfies a customer need. From Chesbrough (2010) it can be read that a value proposition encompasses the potential value for the customers. Further, Osterwalder et al. (2010) highlight the importance of the value proposition as it increases the firm's competitiveness by convincing customers to choose their offering over the competitors. On the other hand, value creation describes the key activities, partnerships and resources that are necessary for the firm to create the value entailed in the value proposition (Lüdeke-Freund et al., 2019; Osterwalder et al., 2010). Value delivery describes how value propositions are delivered to the customers and which customers are targeted. Osterwalder et al. (2010) state that a firm should understand what the different customer segments are, what customer needs they have, and thereby understand which customers segment(s) to target. Based on that decision, the firm needs to determine how to deliver value to the selected customer segment(s) (Osterwalder et al., 2010). Bocken, Short, Rana & Evans (2014) argue that a part of the value delivery processes, is how the firm develops its channels. Osterwalder et al. (2010) states that the concept of channels encompasses three parts i) *Communication channels*, ii) *Distribution channels*, and iii) *Sales channel*, and are crucial to ensure a good customer experience. Finally, value capture refers to how a firm may capture a fraction of the created value. This includes the cost structure and the following revenue streams from value creation, hence the value capture ultimately describes how a firm makes a profit (Bocken et al., 2014). According to Amit & Zott (2012) a way to further enhance the value generated and captured by a business model is to develop and refine it, often called business model innovation.

Due to a certain structural ambiguity arising when trying to determine where to allocate the integrated subparts between the *value creation* and *value delivery dimensions*, this thesis will use the established notion of merging these two dimensions hence forming the dimension *value creation and delivery* (Bocken et al., 2014; Ranta, Aarikka-Stenroos, & Mäkinen, 2018; Richardson, 2005). Hence, as proposed by Ranta et al. (2018) , the rest of this thesis will describe the business model according to the following three dimensions: i) *Value proposition*, ii) *Value creation and delivery*, and iii) *Value capture*.

Recently, much effort has been put into adapting and developing business models to the concepts of sustainability and the circular economy. Due to the nature of the second-life EV battery and its conceptual proximity to the circular economy, the following section will assess this specific variant of the business model.

2.2 Circular Economy Business Models

Historically, most firms and businesses have had business models constituting a linear, non-closed flow of resources, i.e. linear business model. A linear business model usually encompasses a supply chain design with the purpose of refining raw materials into goods and products, which then are sold to a customer. After the products have reached their end-of-life, they are either scrapped or left for recycling by the customer (Urbinati, Chiaroni, & Chiesa, 2017). Due to the increasing environmental awareness and threat, this has shed light on a new type of non-linear thinking, namely the concept of *Circular Economy* (Urbinati et al., 2017). This revised perspective alters the linear approach of labeling end-of-life products as scrap, to instead see it as potentially valuable resources that may flow into the supply chain once again at various levels (Urbinati et al., 2017). From Lüdeke-Freund et al. (2019) it can be learned that closely related to the notion of Circular Economy, is the concept of *closed-loop supply chains*. Guide Jr & Van Wassenhove (2009) state that closed-loop supply chains aim to enhance value creation during the whole life cycle of the product. Hence, a closed-loop supply chain encompasses both the traditional forward supply chain but also the reverse supply chain of the used goods, thus it aims to create and capture additional value (Guide, Harrison, & Van Wassenhove, 2003). However, merely establishing a closed-loop supply chain is not sufficient to ensure value creation and capturing within a firm (Lüdeke-Freund et al., 2019). Hence, in order to understand how to actually create and capture value, firms need to align their business model with their supply chain design. Thus, in order to align with Circular Economy principles, firms can utilize the concept of *Circular Economy Business Models* (CEBMs) (Lüdeke-Freund et al., 2019).

2.3 CEBM Dimensions

In this section, the characteristics and key elements of a CEBM will be assessed accordingly to the three cornerstones of the business model identified above. Hence, from now on, the theory presented about business models will only focus on CEBMs.

2.3.1 Value Propositions

As identified earlier, the rationale behind the value proposition is to offer a pack of products and/ or services that aligns with customer preferences and demand, i.e. offer value. Chesbrough et al. (2002) state that value for the customer can come in multiple different forms, hence it is an ambiguous concept but ultimately it can be drilled down to what the customer is willing to pay for the product and/or service. Osterwalder et al. (2010) claim that a value proposition can be achieved by i) *having superior or new performance compared to competing solutions* ii) *offering customized solutions* iii) *brand impact* iv) *the attractiveness of the price*, and v) *its potential to reduce the cost for the user.* One of the reasons for firms to change to a CE perspective is to gain additional revenue streams (Lüdeke-Freund et al., 2019). However, when transitioning towards a CEBM approach, companies do not merely need to acknowledge what changes that needs to be done regarding the delivery, creation and capture of value, they also need to grasp how to adapt their value proposition to fit the new model as this will affect the other parts of the business model as well (Lüdeke-Freund et al., 2019).

When designing the value proposition of a CEBM, the firm needs to adapt it to the characteristics of the CE perspective. Urbinati et al. (2017) claim that one aspect of this is that firms need to rethink the classical notion of a transaction-based business. Hence, the idea of creating user value by selling products is maybe no longer viable, as the customer does not necessarily need to achieve value by owning the products. Rather, the value proposition should be based on the principle of establishing customer value by providing the use of the product and or service for the customer, who then pays for using the solution. Thus, the customer is charged for the number of functional units that have been consumed instead of taking ownership of the product (Urbinati et al., 2017). This fundamental change of the mindset of the value proposition, proposes that firms need to adjust their business logic to align with pay-per-use idea.

In order to establish a value proposition that is aligned with the core logic of the CEBM, Michelini, Moraes, Cunha, Costa & Ometto (2017) argue that the concept of a product service system (PSS) could be viable. Tukker (2015, p. 76) states that a *product service system* (PSS) can be defined as *"A mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs"*. Further, Tukker (2004) proposes that the usage of a PSS may be a suitable way for firms to improve their competitiveness and to achieve enhanced sustainability. These implications of the PSS mainly stem from the PSS ability to i) *Fulfill client needs and enabling the customers to focus on their core activities*, ii) *Improve customer relationships and customer loyalty*, and iii) *Improve innovation rate of the firm, due to better understanding of client needs.* Further on, Baines, Lightfoot, Evans, Neely, Greenough, Peppard, Roy, Shehab, Braganza, Tiwari, et al. (2007) state that PSS is an evolution of the logic of products and services, where products get accompanied with add-on services, and services are combined with a product. Moreover, the concept of PSS is closely related to the notion of servitization (Howard, Caldwell, Smith, Maull, & Ng, 2014). According to Howard et al. (2014), servitization can be defined as the extended value proposition from merely delivering products to instead offer products with one or multiple complimentary services.

There are typically three main categories useful for classifying different types of PSS (Tukker, 2004, 2015). Firstly, there are *product-oriented services* offering a value proposition similar to the transactional sales of products however with the selling firm offering complementary services such as installation, maintenance, and training programs. The customer buying logic for this type is to optimize the total cost of ownership (TCO) while the supplier may benefit from additional revenue streams and improved customer relations (Baines et al., 2007). Secondly, a firm may offer *use-oriented services* swapping the value proposition from a transactional offer to instead retaining the ownership of the product and instead leasing the product to the customer (Tukker, 2004). The rationale here is to increase the utilization rate of the produced product, thus extending the life of the product and to optimize the resource efficiency when the product has reached end of life (Baines et al., 2007). Thirdly, Tukker (2004) states that the last PSS category is the *result-oriented services*. Here, the firm does not merely offer the product as a leasing contract to the customer, rather it provides the customer with the outcome traditionally stemming from owning the product. The firm can be charged in two different ways; i) the customer pays per functional unit provided by the PSS or ii) the customer pays for a functional result, e.g. a specific indoor temperature (Baines et al., 2007; Tukker, 2004). Michelini et al. (2017) claim that in order to establish a CEBM and achieve the potential benefits of it, it is not sufficient to target the first two levels of the PSS as this may not clearly improve resource utilization. Further, in order for a firm to fully unlock the potential of CEBM, Michelini et al. (2017) claim that firms should focus on using the results-oriented PSS. Supporting this notion, Tukker (2015) claims that the result-oriented services have the strongest potential to facilitate this improvement in resource utilization and to unlock a circular economy approach As the firm retains ownership of the product, this will improve the possibilities to re-use, repurpose and optimize end-of-life activities in a more sophisticated manner (Michelini et al., 2017).

Hence, PSS encompasses a shift from purchasing products to instead purchase the product's function as a service. Earlier, merely the economic dimension of sustainability has been fulfilled, but by using a PSS logic, the sustainability of all three dimensions could potentially be secured, i.e. economic, environmental and social sustainability. According to Mont (2002) and Tukker (2015) the product-oriented business model encourages firms to accelerate the number of units sold, as this leads to higher revenues and profits. However, when companies adopt a service-oriented business model, this incentive changes. As the revenue stems from the services provided, the companies both have an incentive to decrease the costs related to the products and materials used, and also to extend the lifespan of the products as this leads to more revenues from the services provided (Tukker, 2015). Hence, the usage of service-oriented models may lead to simultaneously minimizing material flows and maximizing customer satisfaction (Tukker, 2015).

Mont (2002)states that the customer benefits stemming from the PSS model mainly come from altering the responsibilities that arise with the ownership of a product. By acquiring the value as a PSS, the customer may; eliminate or at least reduce the initial investment needed, reduce costs associated with ownership, reduce risks associated with ownership, For the firm providing the PSS, clear benefits also exist. Firstly, the competition in many industries is today fierce with multiple vendors offering similar products, here PSS can offer a way for established players to differentiate from low-cost actors and thereby secure a competitive advantage. Secondly, as the provider will retain ownership of the assets, they can refine the utilization rate of the product and enhance the usage, hence potentially unlocking new revenue streams stemming from added services, longer lifespan, and reuse (Baines et al., 2007; Mont, 2002). Furthermore, increased contact with the customers will result in a closer customer relationship which will lead to a bigger understanding of the customer's preferences and thus increase the flow of valuable feedback (Mont, 2002).

2.3.2 Value Creation and Delivery

The value proposition needs to be created and delivered to the customer in order to achieve the value proposed. Nussholz (2017) proposes that a firm aiming at establishing a CEBM needs to consider the following areas earlier established by Osterwalder et al. (2010) namely: i) *Key activities*, ii) *Key partners, and stakeholders*, iii) *Key resources*, iv) *Channels*. Thus, this section will assess how value is created and delivered divided upon these four dimensions.

Hence, these areas outline how value is established, which closely relates to the concept of Supply Chain Design (Lüdeke-Freund et al., 2019). Further, Lüdeke-Freund et al. (2019) and Olsson et al. (2018) state that when a firm aims to incorporate a CEBM, it will also need to address how to rethink their supply chain in order to enable this. Thus, this section will also assess certain supply chain aspects of a business model in more detail than usually done, as this is deemed as necessary in order to be able to fully answer the research questions.

2.3.2.1 Key Activities

A key activity in the CEBM is a process that is performed by the firm and or by its partners and stakeholders in order to create the actual value for the customer (Lüdeke-Freund et al., 2019; Osterwalder et al., 2010). The key activities is often regarded as a part of the concept of the supply chain of the firm (Lüdeke-Freund et al., 2019). Kranz (1996, p. 4) suggests that a supply chain may be defined as *"the effort involved in producing and delivering a final product from the supplier's supplier to the customer's customer"*. Later, Lambert, Stock & Ellram (1998, p. 2) defined the supply chain as *"The integration of business processes from end-user through original suppliers that provides products, services, and information that value for customers"*. A well-cited definition of the concept is: *"A supply chain in its classical form (forward supply chain) is a combination of processes to fulfill customers' requests and includes all possible entities like suppliers, manufacturers, transporters, warehouses, retailers and customers themselves"* (Govindan, Soleimani, & Kannan, 2015, p. 603). This definition by Govindan et al. (2015) will be used further on in this thesis.

As the fundamental idea of the CEBM concept is to bend the previously linear flow into a closed system Olsson et al. (2018). Therefore, it is necessary to establish a supply chain design that offers these abilities, i.e. a closed-loop supply chain (CLSC). According to Govindan & Soleimani (2017), early CLSC literature focused mainly on the operational and technical parts of the CLSC. However, the later literature has highlighted the business aspects and how value is created in the CLSC. Involving this perspective, CLSC is defined as *"the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of return over time"* (Guide Jr et al., 2009, p. 10).

The incentives to adopt a CLSC approach are two-fold (Govindan et al., 2015; Morana & Seuring, 2007). On the first hand, the adoption and research on CLSC has been driven by regulations imposed by governments and institutions, hence requiring firms to adjust their linear models. An example here is take-back regulations and producer responsibilities, such as the European Waste Electrical and Electronic Equipment Directive which requires producers to take responsibility for End of Life (EOL) goods (Govindan et al., 2015). On the other hand, CLSC has also lately been raised as a business concept that not only can lead to sustainability by enhancing resource utilization, but which also may provide economic value for the firms adopting it (Govindan, Noorul, & Kannan, 2009; Govindan et al., 2015; Guide Jr et al., 2009; Lüdeke-Freund et al., 2018; Olsson et al., 2018). Guide Jr et al. (2009) states that CLSC has great economic potential to offer new revenue streams for adopting firms stemming from value recovery processes.

According to Wells & Seitz (2005), the concept of CLSC incorporates two kinds of supply chains, namely i) *forward supply chain*, and ii) a *reverse supply chain*. As already defined by Govindan et al. (2015), the activities in the forward supply chain is set up to fulfill customer requests. Further, a reverse supply chain may be defined as *"The process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value"* (Govindan et al., 2015, p. 603). Urbinati et al. (2017) state that in order to create a reverse supply chain, a close cooperation in the supply chain is vital. Many of the activities needed in a reverse supply chain requires a good relationship with both customers and suppliers. This holds true, as much of the value-creating activities in a CEBM are done within the so-called value network, i.e. activities performed in collaboration between a firm and its suppliers and partners (Urbinati et al., 2017). The activities usually taking place within these two types of supply chain will be further assessed below.

Forward Supply Chain
This section will describe the activities likely to take place in the future, forward supply chain for second-life EV batteries. This will be done by first assessing and discussing traditional forward supply chain activities. Moreover, this section will later add on about specific activities deemed as reasonable to take place in the forward supply, due to the characteristics of the used goods that it is set up to handle.

According to Stevens (1989) a traditional supply chain usually consists of the following five activities, namely i) *Purchasing*, ii) *Material control*, iii) *Production*, iv) *Sales*, and v) *Distribution*. According to Dobler & Burt (1996, p. 35) purchasing may be defined as *"the essential activities associated with the acquisition of materials, services, and equipment used in the operation of an organization"*. Material control refers to the processes needed in order for a focal company to control the flow of material in all of the stages in the supply chain, with respect to e.g. quality and quantity (Jonsson & Mattsson, 2011). S. A. Kumar & Suresh (2009, p. 3) define production as *"The step-by-step conversion of one form of material into another form through chemical or mechanical process to create or enhance the utility of the product to the user. Thus, production* *is a value addition process. At each stage of processing there will be value addition.”* The activity sales refers to the processes a focal company engages in when selling a product and or a service to a customer (Jonsson et al., 2011). Hulthén & Mattsson (2010, p. 170) define *distribution* as *“The closing of the space, time and form gaps between production on the one hand and consumption on the other”*.

Moreover, according to the model proposed by Lambert & Cooper (2000) and later revised in Lambert & Enz (2017), a supply chain may involve the following processes, namely i) *Customer relationship management*, ii) *Supplier relationship management*, iii) *Customer service management*, iv) *Demand management*, v) *Order fulfillment*, vi) *Manufacturing flow management*, vii) *Product development and commercialization*, and viii) *Returns management*. According to Lambert et al. (2000, p. 76), a supply chain process is defined as *“a structured and measured set of activities designed to produce a specific output for a particular customer or market”*.

Guide et al. (2003) state that a CLSC contains both traditional forward supply chain activities, but also activities found in the reverse supply chain. Due to the scope of this thesis, delimiting the studied supply chain to activities taking place after the focal company has retrieved the used EV batteries from their initial use, the forward supply chain will, therefore, encompass parts usually described as taking place in a reverse supply chain. In the paper by V. Kumar, Amorim, Bhattacharya, Garza-Reyes, Beh, Ghobadian, He, Gallear & O’Regan (2016), one example of a forward supply chain for second-life clothes in the retailing industry is described. V. Kumar et al. (2016) state that the key activities encompassed in this supply chain are i) *Product disposition*, i.e. gatekeeping, collection, sorting, ii) *Refurbishing,* and iii) *Remarketing.* Hence combining the activities found in the empirical studies conducted by V. Kumar et al. (2016) with the insights of the activities taking place in a CLSC by Guide et al. (2003) the following activities will be further elaborated on, namely i) *Product disposition*, ii) *Refurbishing*, iii) *Remarketing.*

The idea behind the product disposition stage is to determine how the used goods should be utilized in the rest of the CLSC. Hence, activities here incorporate testing, sorting, and grading goods (Guide Jr et al., 2009). These activities strive to determine the state of health of the goods and thus serve as a guideline when deciding upon what reuse option that is most viable from an economic perspective (Guide et al., 2003). Moreover, Guide Jr et al. (2009) state that the outcome of the product disposition is to determine whether the used good should be sent to i) *Refurbishing*, ii) *Parts recovery*, iii) *Material Recycling*, and iv) *Disposal.* According to Lambert et al. (2017) the process of *manufacturing flow management*, encompasses activities that describe how the supply chain should ensure flexibility and how the good should flow into the chain. The process encompasses activities that need to be coordinated between the focal company and the members of the supply chain. Further, Lambert et al. (2017) argue that it might be necessary to adopt this process according to the requirements of the existing customer segments As the product disposition is conducted in order to choose which EV batteries that are suitable to enter a second-life application, manufacturing flow management will be part of this process as it coordinates how the batteries should flow in the rest of the supply chain. Further, Lambert et al. (2017) state that *returns management* describes the activities performed in order to enable returns management. Activities here are e.g. reverse logistics and avoidance management. The process is managed both by the focal firm, supplier and customers. Therefore, the product disposition could be seen as part of the returns management in this context as it facilitates the returned goods before it is deemed for its second-life.

When a used product has been deemed as healthy enough for a post first life use, but not good enough to be transitioned to a customer directly, i.e. remarketed, the health of the product may be improved again (Guide Jr et al., 2009). Lüdeke-Freund et al. (2019) claim that refurbishing enhances the health of a product by e.g. replacing parts and performing maintenance, however not such extent that it may be considered as “good as new”.

In order to facilitate and enhance effective and efficient refurbishing activities, Urbinati et al. (2017) argue that one must incorporate a design of the products and/or services that enable a circular flow, more specifically they mention the importance of having a product architecture that promotes disassembly. Further, Lüdeke-Freund et al. (2019) write that in order to promote CEBM value propositions, it is crucial to have products designs that promote disassembly and repairs. From Ghisellini, Cialani & Ulgiati (2016) it can be understood that designs promoting e.g. refurbishing, and recycling are often recalled to as eco-designs. Moreover, Lambert et al. (2017) claim that *product development and commercialization* is a process encompassing activities executed by the actors within the supply to develop and market a new product. Hence, the collaboration between the focal company, suppliers, and customers in order to produce innovation is included. The process must e.g. facilitate the flow of customer feedback and needs to R&D resources and coordinate manufacturing and purchasing activities (Lambert et al., 2017). Hence, the activity of refurbishing contains elements of the process of product development and commercialization as it encompasses how the second-life batteries should be prepared, i.e. refurbished, in order to meet the demand of the customers.

After a good has passed the previous stages in the forward supply chain, the product should once again enter the commercial market (Guide Jr et al., 2009). This can be done either by letting the product enter the previous market again or also enter secondary markets, i.e. second-life applications (Guide Jr et al., 2009). Lambert et al. (2017) state that *customer demand management* is the process that handles the administration of product and service agreements that are developed between the firm and its customers. As the remarketing activity states how a product should enter the market again, customer demand management can be seen as part of this as it will need to handle this customer administration. Moreover, remarketing will also encompass parts of the process by product development and commercialization (Lambert et al., 2017).

According to Abbey, Meloy, Blackburn & Guide Jr (2015), one risk that needs to be considered when marketing second-life products is the fear of cannibalization of the new products. Guide Jr et al. (2009) also mention that this fear of cannibalization exists at many focal companies. However, the authors argue that research has indicated that refurbished goods may not cannibalize on new products to the same extent as thought before, as it rather serves as a competitive product against alternatives sold by low-cost competitors. Also, when a refurbished product is sold on a secondary market, the risk for cannibalization on new products is deemed to be zero or at least very low (Guide Jr et al., 2009).

Reverse Supply Chain

In the following section, the activities traditionally found within a reverse supply chain will be highlighted and discussed. Due to the scope of the forward supply chain, mentioned above, this section will not assess the reverse supply chain activities already presented in the forward supply chain section. Hence, the section below will discuss the following activities identified in Guide Jr et al. (2009), i) *Used-product acquisition* and ii) *Reverse logistics*.

The first step of the reverse supply chain is to acquire the good from the customer, i.e. ensure access and ownership of the good in order to be able to retrieve it back into the closed-loop. Morana et al. (2007) argue that ensuring a good product acquisition stage is vital in order to establish a CLSC. Guide Jr et al. (2009), Guide et al. (2003) state that a product may enter the reverse supply chain mainly due to three reasons i) *Commercial returns* ii) *End-of-use returns* iii) *End-of-life returns*. A commercial return occurs in the case when a customer returns a good somewhere during the product life cycle (Guide Jr et al., 2009). Tibben-Lembke (2004) states that an example of a commercial return may be an e.g. guarantee issue, return within testing period etc. End-of-use returns on the other hand occur when a customer seeks to upgrade to a newer solution, hence the current product is returned. End-of-life returns occur when a product has either became functionally obsolete or if the product has stopped providing utility for the user, which could occur if the product is degraded (Guide Jr et al., 2009; Tibben-Lembke, 2004).

Lambert et al. (2017) state that *Customer relationship management* is the structure for how a firm should handle their relationships with their existing customers and develop new relationships with new customers. Thus, as the product acquisition will require the provider to have contact with the customer in order to acquire the products, this process from Lambert et al. (2017) relates here.

Morana et al. (2007) acknowledge that there are three product characteristics that affect the success of product acquisition. Firstly, they state that there is a connection between the length of the use period and the predictability of product returns. Hence, if a product has a long period of usage before it reaches end-of-life return, it is thereby harder to predict how and where to acquire the used product. A reason for this could be due to the complexity of locating the last owner, as this may shift depending on the contractual situation (Morana et al., 2007). Secondly, Morana et al. (2007) claim that the *marginal value of time (MVT)* affects the probability of successful product acquisition. Blackburn, Guide Jr, Souza & Van Wassenhove (2004) claims that the MVT describes the relation between time and the reduction of the initial value of the good, hence a product with a high MVT will see its residual value decrease faster than a product with low MVT. From Morana et al. (2007) it is understood that products that have been less affected by MVT, and thus has a higher remaining value, is more attractive for a firm to retrieve back. Therefore, Morana et al. (2007) also claim that a firm under this situation is also keener to offer incentives for the customer to ease the product acquisition, hence the probability of successful product acquisitions also increases. Thirdly, Morana et al. (2007) show that the remaining value of a product after its initial life, also affects the selling firm's incentive to design the product to facilitate secondary usage. Hence, if the remaining product value after the first use is high, it is also more viable for a firm to emphasize this.

Another aspect concerning the product acquisition is the concept of transaction costs (Morana et al., 2007). The idea of transaction costs was initially raised by Coase (1937) and describes the coordination and information exchange costs that arises between two parties. Hence, it is thus necessary to take these costs into account when evaluating the product acquisition. Morana et al. (2007) argues that in order to promote product acquisitions at the end-of-life, the transaction costs should be as low as possible.

Further, a vital activity in the closed-loop supply chain is the reverse logistics. The reverse logistics comprises the physical transport of products and material, from the point of use to the point of disposition (Morana et al., 2007). According to Blackburn et al. (2004) there are two different types of flows when designing the reverse logistics flow; efficient flow or responsive flow. The main difference between the flows is where in the chain the testing and sorting activities are performed. In an efficient flow the testing and sorting activities are centralized and therefore postponed. The products are collected and transported to a central warehouse, where the products are evaluated and sorted into e.g. refurbish, replacement stock, and scrap (Blackburn et al., 2004). In a responsive flow the sorting and testing activities are decentralized and therefore made earlier in the supply chain. Products are collected and directly evaluated before they are transported to a central warehouse. By using this flow, products evaluated as restock and scrap don't need to be transported to the central warehouse which maximizes the asset recovery and minimizing the delay cost (Blackburn et al., 2004).

Moreover, as the reverse logistics concerns how the product returns should be handled, it can be seen that the reverse logistics activity relates to the product returns process (Lambert et al., 2017).

Furthermore, Blackburn et al. (2004) claim that the choice of which flow to pursue should be based on the products MVT. The efficient flow is more time consuming and takes a longer time. However, it is based on economies of scale, and products with a low MVT should use this type of flow by the reason that they don't lose much in value during the extra time it takes for the efficient flow. Instead, if the product has a high MVT, it loses much value per time unit. Which makes it more profitable to use a responsive flow since it is faster (Blackburn et al., 2004).

2.3.2.2 Key Partners and Stakeholders

Key partners and stakeholders are those actors that a firm needs to have a relationship with, in order to create and deliver the value proposed in the value proposition (Osterwalder et al., 2010). Hence, this section will elaborate on which actors that are needed within a forward and a reverse supply chain. Further, it will address how the activities outlined in the previous section may be divided between the different actors and what supply chain structures there are.

According to Govindan et al. (2015), the actors within a forward supply chain traditionally includes i) *Suppliers*, ii) *Manufacturers*, iii) *Transporters*, iv) *Warehouses*, v) *Retailers*, and vi) *Customers*. Suppliers are a party contributing with a part of the supply chain, either by e.g. producing a good or a service or transporting it. Manufacturers are the ones producing or assembly the good. Transporters are the actors taking care of the transportation of the goods, e.g. between manufacturer and retailer. Warehouses perform activities concerning the storage and distribution of a good. Retailers are often responsible for selling the good to the end-user, i.e. the customer (Govindan et al., 2015).

When assessing the constellation of a CLSC, it is vital to address the distinct stakeholders and actors within the reverse supply chain as well. In addition to the roles of the actors mentioned in the forward supply chain above, Atasu & Boyaci (2010) state that the roles may be extended and that there are more actors within a reverse supply chain. These are namely: i) *distributors and retailers*, ii) *end-users and consumers*, iii) *collectors*, iv) *refurbishers*, and v) *recyclers and processors*. The distributor's and retailer's roles may be extended as they could engage in activities such as testing, sorting, and grading. End-users and consumers will also more actively take part in the reverse supply chain as they will have a role when the goods should be returned during the take-back process. Refurbishers are the actors taking care of the refurbishing activities needed in order to enable parts of the reverse supply chain. They could also engage in other activities such as testing, sorting, and grading. Recyclers play an important role in the reverse supply chain facilitating the recycling activities, which are needed when re-use is no longer a valid option for a good (Atasu et al., 2010).

Furthermore, Olsson et al. (2018) state that, within a future market for second-life EV batteries, a number of probable actors have been identified. Firstly, Olsson et al. (2018) claim that EV OEMs will be an actor identified here. The EV OEM's may take the role as providers of the used EV batteries, which they retrieve from the sold EVs. Further, the EV OEMs may also extend their current business scope, thus performing activities such as product disposition, refurbishing and remarketing (Olsson et al., 2018). Secondly, Olsson et al. (2018) have identified that recyclers, i.e. dismantlers, may take part as an actor within the future industry. The role of the recyclers is not yet fully known but Olsson et al. (2018) argue that they may engage in activities such as product disposition, i.e. testing and sorting. Further, they may also extend their scope into refurbishment of used EV batteries. Moreover, Olsson et al. (2018) have identified that logistics companies will take part in the industry, responsible for e.g. freight transports. Finally, customers are expected to be present within the supply chain for second-life EV batteries (Olsson et al., 2018).

Depending on what type of structure the focal company chooses to have, the included actors within the resulting supply chain will be affected and also the scope of their roles. The way a firm can organize the scope and ownership of the activities performed within their supply chain, can be described as a continuum between two extreme points (Hobbs, 1996; Williamson, 1975). This continuum described by Williamson (1975) may be recalled as the concept of *vertical coordination*. The first extreme point illustrates, according to Hobbs (1996), Williamson (1975), a supply chain setup where the firm chooses to incorporate the whole supply chain within its own firm. Hence the inter-firm cooperation within the supply chain can be regarded as non-existing. This supply chain is often recalled as a *full vertical integration* or *hierarchy form*, thus all activities performed in order to deliver the goods are owned and controlled by the focal company (Hobbs, 1996). Powell, Staw & Cummings (1990) acknowledges that the rationale for a firm to pursue a fully vertically integrated approach is due to the fact that the option of allocating part of the supply chain outside the boundaries of the firm imposes too large transaction costs compared to the costs related to doing it in-house. Also, since the activities are done within the scope of the firm, a benefit achieved by this form is that it gives reliability as the firms have total control over the operations and activities performed within the supply chain.

Further, according to Williamson (1975) the second extreme point describes a scenario when a firm chooses to purchase all its resources, e.g. components, products, services, etc. on the spot market. Hence, the activities performed within the intra-firm part of the supply chain may be considered as non-existing. This is often recalled as *vertical disintegration* or *market form* (Hobbs, 1996). According to Powell et al. (1990) the benefit a firm may obtain by adopting a market approach, encompasses namely: increased sourcing options, flexibility, and business opportunities. When a focal company chooses to place part of the activities needed in their supply chain outside their own vertical scope, this is often recalled as *outsourcing* (L. Ellram & Billington, 2001). Hence, the concept of outsourcing describes the process of either carving out earlier in-house activities or allocating future planned activities in the supply chain, to be provided by an external actor (L. Ellram et al., 2001). Kremic, Tukel & Rom (2006) state that the rationale behind letting an external actor, e.g. supplier, taking care of an activity may be categorized within three dimensions, namely: i) *cost-driven*, ii) *strategy-driven*, and iii) *politics-driven*. The same authors state that the logic behind cost-driven outsourcing is to take advantage of decreased costs which may stem from an external actor being more efficient in providing the solution. This efficiency is often seen to come from mechanisms such as specialization and economies of scale (Kremic et al., 2006). In order to reap the benefits of cost-driven outsourcing, an actor cannot neglect the potential transaction costs that arise when outsourcing activities (Kremic et al., 2006). The main driver behind strategy-driven outsourcing is to improve the business performance at one or more dimensions. For example increasing the flexibility or be able to focus more on the focal companies core business (Kremic et al., 2006).

According to Powell et al. (1990) the continuum between the hierarchy and market form, offers multiple different ways of organizing the division of labor in the supply chain, i.e. the *network form*. The network form may be seen as a mixture of the characteristics between the hierarchy and the market form (Powell et al., 1990). Powell et al. (1990) and Hobbs (1996) claim that common types of the network include, among others, a concept known as a *strategic alliance*. A strategic alliance is a partnership where two or more firms engage to fulfill a common strategic purpose, often in order to co-create value (Hobbs, 1996). Hence, the strategic alliance is a type of collaborative partnership that aims to maximize value for both firms by utilizing the resources and advantages that both parties may contribute with. According to V. Kumar et al. (2016), a collaboration between firms within second-life supply chains may be important to unlock the potential of these markets. Moreover, V. Kumar et al. (2016, p. 269) state that *"Collaborations between supply chain partners may help to realize financially beneficial and innovative options... the dynamics of these inter-firm relationships may offer insights into the potential of second-life retailing in reverse logistics in creating new markets and profitable operations"*.

2.3.2.3 Key Resources

Osterwalder et al. (2010) illustrate that in order to create value, the activities performed by the firm and its partners is key, but in order to enable these activities, it is necessary to have the right resources available. Resources may be physical assets, i.e. manufacturing plants, machines, etc., intellectual assets, i.e. patents, trademarks, data, etc., human assets, i.e. know-how, skills and competencies, and financial assets, i.e. cash, credits, stocks, etc. (Osterwalder et al., 2010). The traditional linear business model regards resources as having a finite life, often spanning from retrieving raw material, production, consumption, and finally scrapping, hence ending the linear life of the good. The fundamental idea behind the CE is to turn this linear flow and bend it into a loop, hence keeping the resources in an ecosystem. McDonough & Braungart (2002) argue that by closing the resources loop, a firm may be eligible to generate more value and for a longer period, compared to the linear alternative.
Jiao & Evans (2017) propose that for business model encompassing second-life EV batteries, a key resource will be partnerships. Further, Jiao et al. (2017) state that these partnerships will enable the actors to develop new capabilities and to capture additional value by mutual operations. Moreover, V. Kumar et al. (2016) argue that an additional key resource that may help to facilitate the partnerships in the second-life business model is trust. Bräuer (2016) states that

firms developing business models for second-life EV batteries need to ensure that they have the correct technological equipment at hand, e.g. testing equipment. Further, developing technological skills and knowledge within the organization is important in order to succeed with the establishment of a business around second-life EV batteries (Bräuer, 2016).

2.3.2.4 Channels

Osterwalder et al. (2010) state that the concept of channels encompasses in what ways a focal company communicates and engages with its customer segments. Moreover, the channels is a tool for the focal firm to i) Inform the customers about the value proposition, ii) Ease the customers in evaluating the value proposition, iii) Allow customers to buy different products and services, iv) Deliver the value proposition to customers, v) Provide additional products and/or services after point of sale (Osterwalder et al., 2010). Further, Osterwalder et al. (2010) state that channels consist of three parts, namely i) *Communication channels*, ii) *Distribution channels*, and iii) *Sales channel*.

The communication channels encompass how a firm reaches and communicates with its customers (Osterwalder et al., 2010). Furthermore, Urbinati et al. (2017) state that how a company promotes and communicates its circularity is connected to the degree of circularity of the company. To achieve a high degree of perceived circularity the company should communicate its circularity through all channels they have. Further, by engaging and involving the customers in the communication channels, the perceived circularity may improve. If the circularity of a firm is well communicated it can become a part of their positioning against the competitors (Urbinati et al., 2017).

The sales channels describe how a focal firm sells the value proposition to a customer (Osterwalder et al., 2010). Further, Park & Keh (2003) state that sales channels may either be direct or indirect, where a direct sales channels are established by the focal firm, e.g. online sales, and indirect sales channels are handled by an intermediary actors, e.g. retailer.

According to Thomé, Vieira & dos Santos (2012), distribution channels encompass how a focal company provides the product and/or service to the customer. Hence, the distribution channels include activities that make the product and/or service available for consumption. According to Palmatier, Stern & El-Ansary (2016) one way that the distribution may be done is directly by the focal company, hence the focal company solely handles the activities needed. Another distribution channel is through intermediaries, e.g. wholesalers and retailers. Hence, these intermediary actors provide the goods and/or services to the customer (Palmatier et al., 2016).

2.3.3 Value Capture

The last dimension of the CEBM is to formulate how the firm should capture a fraction of the value created by the activities together with its partners and customers, more specifically Lüdeke-Freund et al. (2019) state that value capturing relate to how a firm earns money from implementing a CEBM and how it affects the revenue and cost dimension of the business. Osterwalder et al. (2010) argue that capturing revenue is closely linked with the pricing model chosen. Further, the same authors elaborate on a sample of pricing models useful namely: i) *Asset Sales*, ii) *Usage Fee*, iii) *Subscription Fee*, iv) *Lending, Renting and Leasing*, v) *Licensing*, vi) *Brokerage Fee*, and vii) *Advertising*. Focusing on the revenue dimension of CEBM, Lüdeke-Freund et al. (2019) claim that this includes strategies such as e.g. charging price premiums, generating additional revenue from complementary products and services, and service-based pricing models, i.e. charge per functional unit delivered. Moreover, Bocken et al. (2014) state that by adopting a CEBM approach, actors may capture brand value stemming from an increasingly environmentally aware customer base. Hence, by implementing a circular resource loop, a firm may not only gain direct value and cost-saving, but also facilitate their customer attractiveness, thus potentially extending their potential market share. Also, Bocken et al. (2014) mention that this may increase a firm's ability to price premium, therefore serving to accelerate its revenues.

According to Tukker (2004), Tukker (2015) and Reim, Parida & Örtqvist (2015), a focal company adopting a PSS within the value proposition may use a set of different value capturing mechanisms. Firstly, for value propositions encompassing a product-oriented PSS, Reim et al. (2015) claim that the associated pricing strategy is based on the sales of the product. Hence, the customer is charged for the transfer of the asset. Further, the value captured may also stem from additional services provided in relation to the sold product (Tukker, 2004, 2015). Secondly, Reim et al. (2015) argue that when the PSS sold is based on a use-oriented logic, the associated value capture mechanism is based on continuous payments. Hence, the customer is charged for the access to the value proposition by paying a fee for a certain time slot, e.g. leasing. Finally, Reim et al. (2015) propose that the encompassed pricing strategy for PSS categorized as result-oriented is based on the bought result. Hence, the provider is getting paid for the specified functional result that it provides to the customer. Thus, the customer only pays the agreed sum if the agreed-upon result is fulfilled. Further, Tukker (2015) argues that another pricing strategy possible for result-oriented PSS is that the customer 'pays per service unit'. Hence, the provider charges the customer for the specific amount of service units that it has provided to the customer (Tukker, 2004, 2015).

Osterwalder et al. (2010) state that a firm typically has a cost structure that can either be assigned to as a cost-driven, i.e. focusing on having a lean and low-cost organization, respectively a value-driven one, i.e. less focus on cutting cost, often found within premium value propositions, or somewhere between these two endpoints. Cost that are typically associated with CEBM are according to Lüdeke-Freund et al. (2019): i) *labor costs*, ii) *repair and refurbishing costs*, iii) *maintenance costs*, iv) *logistics costs*, v) *material costs*, and vi) *waste handling and recycling costs*. Bocken et al. (2014) claim that by using a CEBM, firms may benefit from lower costs and hence, improve their profit level. The lower costs may stem from a reduction costs purchasing new resource input due to the circular flow as well as reduced costs for recycling and scrapping components and products, hence used products that previously have been deemed as scrap may now actually be regarded as a potential value resource that may give the firm with new revenue streams (Bocken et al., 2014).

2.4 Analytical Framework

In this section, a synthesis will be derived based on the gathered literature and concepts, assessed earlier in the theoretical framework. The goal with the synthesis is to produce a framework that may be used in order to answer how a circular economy business model (CEBM) and its associated supply chain could be designed for second-life EV batteries. This framework is depicted in figure 2.1

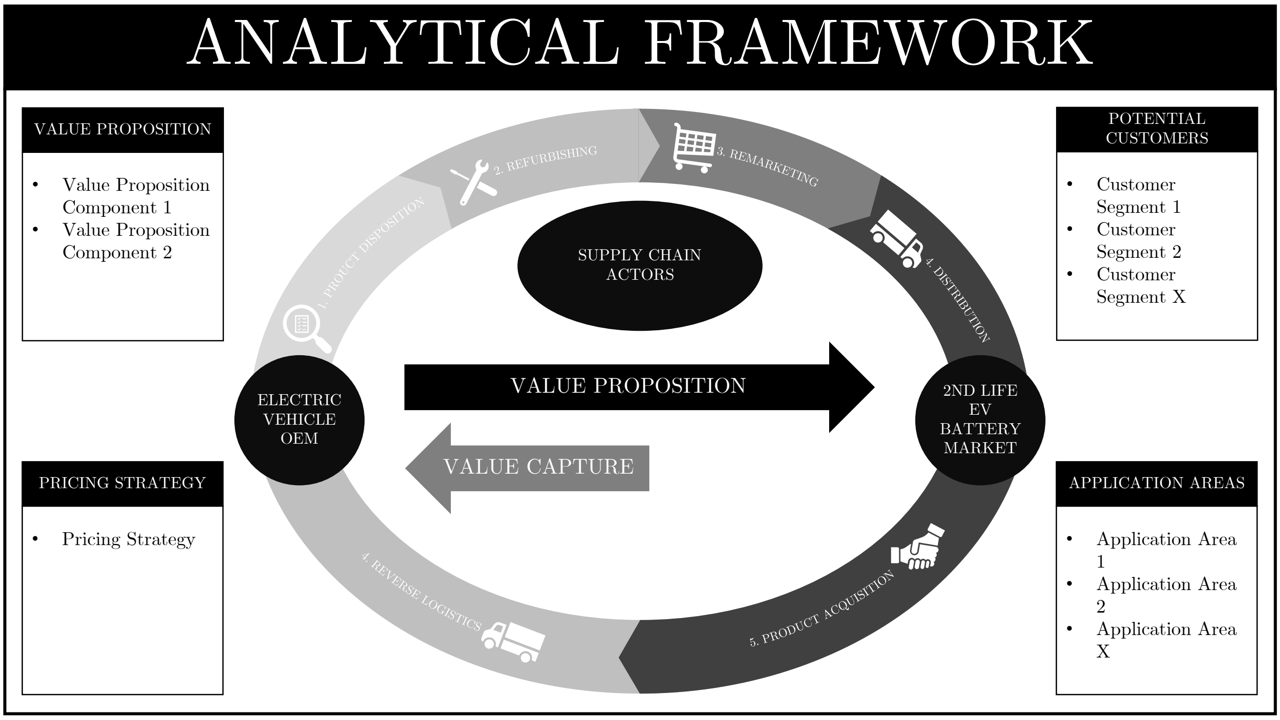

Figure 2.1: The figure depicts the potential future supply chain for second-life EV batteries. The scope of the thesis is limited to the part targeted in the black dotted box.

2.4.1 Business Model Components

The first part of the synthesis considers the concept of customer segments. According to Olsson et al. (2018) and Osterwalder et al. (2010), deriving appropriate customer segments is an important step prior to developing suitable value propositions. As this research aims at deriving value propositions for potential CEBM for second-life EV batteries, developing customer segments will also be key. Hence, it is found vital to include potential customer segments in the synthesis framework.

2.4.2 Value Proposition

Osterwalder et al. (2010) identified that developing relevant value propositions are key when developing CEBMs. Further, it has been identified that potential differentiators for a value propositions are i) *Performance*, ii) *Customized solutions*, iii) *Brand impact*, iv) *Price*, v) *Cost reduction potential.* For a second-life EV battery business model value proposition, all differentiators have been deemed as suitable to study. Moreover, when assessing a future value proposition for second-life EV batteries, the characteristics of the product and/or service needs to be understood. According to Jiao et al. (2016, 2017) second-life EV batteries and their complementary services are of a complex nature. In the literature it was found that a way to derived value propositions is to use PSS. As the second-life EV batteries have been deemed as complex and in need of additional services, it is probably suitable to research whether it would be viable to design a value proposition based on a PSS.

2.4.3 Value Creation and Delivery

When assessing the value creation and delivery dimension of a CEBM, it has been found that it is relevant to base the empirical data gathering upon the four dimensions presented by Osterwalder et al. (2010). Hence, this synthesis framework will use the following dimensions i) *Key activities*, ii) *Key actors*, iii) *Key resources*, and iv) *Channels*.

Firstly, the key activities within a supply chain associated with a potential CEBM for second-life EV batteries will be explored. As the scope of this thesis takes its start from the point where the OEM already has collected the batteries, the activities that will be explored will start from here. In a traditional forward supply chain, purchasing is often the first step, however in the forward supply chain for second-life EV batteries, purchasing together with material control, will be represented by the activity product disposition. Further, the activity produced in the traditional supply chain will in the forward supply chain for second-life EV batteries to be represented by the refurbishing activity. The forward supply chain encompasses the activity sales and this will be represented by the activity remarketing, which is an extension of the sales activity also including finding suitable application areas etc. Finally, the synthesis framework will include the distribution as the last activity. Moreover, the reverse supply chain will incorporate product acquisition and reverse logistics as well, within the analytical framework.

Secondly, the key actors in the supply chain have also been identified as a viable part to include within the synthesis framework. Further, combining the insights from a traditional supply chain with potential actors in a supply chain for second-life EV batteries, the scope of this thesis makes it interesting to study the following actors i) *OEM*, ii) *Battery service providers*, iii) *Logistic service providers*, and iv) *Customers*. Thirdly, the key resources identified as important to include within the synthesis framework is the concept of partnerships. Partnerships such as strategic alliances and their potential to be used within CEBMs for second-life EV batteries provide a good basis for the research. Finally, the theory states that channels is a concept that is interesting to explore when determining how the value creation and delivery should be structured. The concept of channels includes communication channels, sales channels, and distribution channels. However, the communication channels are left out of the scope of empirical research in this study due to the focus to supply chain design. Hence, only sales channels and distribution channels will be included in the empirical data gathering.

2.4.4 Value Capture

The last dimension of the synthesis framework concerns how the OEM should design its value capture mechanism. As it was found that the product characteristics makes it viable to research how a PSS may be designed for second-life EV batteries, it is thereby also suitable to include the associated potential value capturing mechanisms (Tukker, 2015). Thus, the pricing strategies that will be considered are i) *Product-oriented PSS pricing strategy*, ii) *Use-oriented PSS pricing strategy*, and iii) *Result-oriented PSS pricing strategy* (Reim et al., 2015; Tukker, 2004, 2015).

3 METHODOLOGY

In this chapter, the research approach and methods that have been used to answer the research questions of the study, will be presented and discussed. Firstly, an overview of the sampling methods will be given. Secondly, a description of the data collection procedures and methods will follow. And finally, a section will follow that contains a critical discussion about both the data analysis and the research quality of the results of this master thesis.

This master thesis serves to explore how a business model and its associated supply chain should be designed for second-life EV batteries, hence the research approach taken needs to be adapted to this. According to Fraenkel & Wallen (2003) a qualitative research approach is often useful when the goal is to determine characteristics of an unexplored phenomenon, and also within settings where one may only have access to partial information. As this master thesis aims to explore a not yet existing business model by observing and interpreting, it is deemed as suitable to adopt a qualitative research method. There are mainly three research approaches available to choose from, namely i) *Deductive*, ii) *Inductive*, and iii) *Abductive* (Bryman & Bell, 2015; Dubois & Gadde, 2002). A *deductive* research approach builds, according to the same authors, on the idea of the formulation of an initial hypothesis based on current theory, which subsequently is put to test. An *inductive* research approach instead starts by extracting data which then is analyzed with the aim to develop a theoretical model from the empirical findings gathered. Further, Thomas (2003, p. 2) states that *"The primary purpose of the inductive approach is to allow research findings to emerge from the frequent, dominant, or significant themes inherent in raw data, without the restraints imposed by structured methodologies"*. Finally, the *abductive* research approach is a third research approach that differs from the two other approaches (Dubois et al., 2002). Dubois et al. (2002, p. 559) state that *"An abductive approach is fruitful if the researcher's objective is to discover new things — other variables and other relationships"*. Further, Dubois et al. (2002, p. 559) claim that *"Studies relying on abduction, the original framework is successively modified, partly as a result of unanticipated empirical findings, but also of theoretical insights gained during the process. This approach creates fruitful cross-fertilization where new combinations are developed through a mixture of established theoretical models and new concepts derived from the confrontation with reality"*. Due to the explorative aim of the study, combined with an iterative development of the theoretical framework, the researchers have utilized an abductive research approach, as this is believed to be most suitable in order to facilitate deriving accurate findings.

In this thesis, the insights and findings gathered about how vehicle OEM's view the development for CEBM and their associated supply chains, are based on data collection conducted at a single OEM. According to Eisenhardt (1989), Gerring (2004), Yin (2011) and Yin (2015) argue that a study conducted at a single company or firm may be recalled to as a single case study. Moreover, Gerring (2004, p. 341) claim that the concept of the case study is defined as *"an in-depth study of a single unit (a relatively bounded phenomenon) where the scholar's aim is to elucidate features of a larger class of similar phenomena"*. Hence, this has been a single case study. According to Dubois et al. (2002), there have earlier been an attitude that single case studies are a weaker research method compared to case studies consisting of multiple cases. However, Dubois et al. (2002, p. 558) argue that this is not necessarily true, stating that *"when the problem is directed towards the analysis of a number of interdependent variables in complex structures, the natural choice would be to go deeper into one case instead of increasing the number of cases"...* Moreover, Yin (2011) argues that when designing a single case study, there are five components that the researchers need to take extra notice of. These are according to Yin (2011, p. 27) "*i) a study's questions, ii) its propositions, iii) it's unit(s) of analysis, iv) the logic linking the data to the propositions; and iv) the criteria for interpreting the findings*". Moreover, Yin (2011, p. 14) states that "*How can you generalize from a single case? . . . The short answer is that case studies...are generalizeable to theoretical propositions and not to populations . . . in this sense, the case study . . . does not represent a "sample," and in doing a case study, your goal will be to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization)*". Moreover, L. M. Ellram (1996, p. 100) states that "*a single case, like one experiment, is suitable when that case represents a critical case to test a well-formulated theory, an extreme or unique case, or a case which reveals a previously inaccessible phenomenon*". Hence, with regard to the aim, context and the research approach taken, the use of a single case study is deemed as suitable.

3.1 Sampling and Data Collection

This section encompasses a description of the sampling methods utilized in the study. Further, the process of how the necessary data has been collected from the selected sample in order to answer the research questions will be presented.

3.1.1 Sampling Method

According to L. M. Ellram (1996), the case study may use a *purposive sampling method* when determining the case to study. As the agenda for this master thesis is rather exploratory and aims to reveal information about a specific context, it was found suitable to only incorporate a single case. This case was chosen due as the specific OEM was beginning to explore how it should design their business model for second-life EV batteries, hence making the casing suitable to study. Bryman et al. (2015) state that within *qualitative research*, a common sampling method used is *theoretical sampling*. Further, the same authors state that theoretical sampling is a method where a researcher initially selects a sample of participants that are deemed as potentially useful for the purpose of the study. When the data collection has been conducted with these initial participants, the researchers gather their findings. From these drafts they derive a path forward for the empirical research (Bryman et al., 2015). Hence, from the initial findings, the researchers conduct a brief analysis in order to derive insights about what other areas to conduct data collection within and also which subjects that are suitable for this. In this study, sampling was conducted by commencing initial interviews with a small number of employees at the OEM. The outcome of these initial interviews was twofold in terms of sampling input, firstly these employees recommended us to reach out to other actors within their network. These actors were both internal employees within the OEM but in some cases also external actors outside the OEM organization. After the first interviews were conducted, an initial analysis of the collected data was done in order to determine which areas needed further research, hence the researchers choose to select a sample of candidates from the recommended population which was seen as suitable to continue the research with. Secondly, the initial interviews with the OEM employees also generated results regarding areas of the business model that the researchers found interesting to conduct further studies within. An example of this is how the initial interviews staked out what potential application areas that could be viable and thus the researchers choose to contact external customers in order to further research these areas, which was not previously thought of before the initial interviews.

3.1.2 Sample Size

A natural question within research is to determine when enough data has been collected. According to Bryman et al. (2015), this limit of data gathering, may be described from the concept of theoretical saturation. Further, Bryman et al. (2015, p. 394) propose that theoretical saturation occurs when *" i) no new or relevant data seem to be emerging regarding a category, ii) the category is well developed in terms of its properties and dimensions demonstrating variation, and iii) the relationships among categories are well established and validated".*

Within this study, the initial interviews conducted at the OEM guided the researchers in their way of finding initial codes and categories for which the thesis should focus on. These, in combination with suitable prior codes extracted from the literature review, staked out what other interviews that were needed in order to fill the gaps of the research aim. Hence, additional interviews were conducted up until the point where the researchers found that no new insights occurred and thus it was deemed that enough data had been sampled in order to reach theoretical saturation for the thesis. In the case of this thesis, this occurred after 17 interviews. An overview of the interview subjects may be found in table 3.1.

3.1.3 Data Collection

As the aim of this study is to explore a relatively uncharted area, the researchers found that it is necessary to align the data collection process to this type of situation. According to Newcomer, Hatry & Wholey (2015) a common interview type used within qualitative research in similar situations is the *semi-structured interview*. The concept of the semi-structured interview may refer to a broad range of definitions but the fundamental idea behind this notion is that it offers a general set of interview themes that is somewhat open-ended in their nature. Further, for each of these interview themes the interviewer may formulate questions. According to Bryman et al. (2015), an advantage of the semi-structured interview is that the interviewer more easily can adapt the interview according to the input given during progress, and also that it offers more freedom as it is allowed to change the order of the interview areas while conducting it. According to Newcomer et al. (2015), the semi-structured interview type however suffers from several disadvantages that the researchers need to be aware of despite the obvious advantages it entails. Firstly, due to the nature of the semi-structured interview, it may consume a lot of time as it requires the interviewer to go through a large amount of notes or recordings after the interview that may be more unstructured compared to the data that may be collected in a structured interview. Secondly, another disadvantage is that the researchers may need to prepare more for the interview in order to fully enjoy the benefits of its unstructured setup, e.g. in order to ask follow up questions that are relevant the interviewer needs to grasp the area of research to a level that allows the formulation of questions on spot. The characteristics of the semi-structured interview, and the advantage of being open-ended and flexible was the reason why semi-structured interviews was used within the study(Bryman et al., 2015; Newcomer et al., 2015).

In order to gather an adequate amount of data, three different interview guides were crafted. The logic behind developing these different interview templates was to grasp different perspectives of the actors identified as potentially part of a business model for second-life EV batteries. Hence, interview templates were developed with specialized focus for: i) *OEM employees*, ii) *External experts*, and iii) *Potential customers*. These interview templates may be found in their full details in Appendix 1.

An initial set of interviews were scheduled in collaboration with a manager at the OEM that had a good overview of suitable interviewees. Before these interviews, the interviewees were contacted via email. The purpose of this initial contact was to briefly give them an understanding of the aim of the study and also to ask them about whether they would like to participate in an interview. The researchers sent an interview template to the interviewees that accepted the interview invitation. This template was sent in advance in order to give the interviewees enough time to prepare for the interviews.

As the data analysis moved further, more data was needed to be collected from other respondents outside the OEM. These interviewees were found both by reference of earlier interviewees and by using business network services, e.g. *Linked In*. The researchers utilized a successful approach of reaching out to high-level executives, often CEOs, in order to improve the chances of getting respondents to the study. After initial contact, these interviewees also received an email with the attached interview template, following the same process as described above for the OEM employees.

The interviews were conducted either through face-to-face meetings, video calls, or by phone. The majority of the interviews conducted at the OEM and with external experts were done through face-to-face

INTERVIEWS AND INTERVIEWEES INCLUDED IN THE STUDY					
INTERVIEWEE CODE	INTERVIEWEES ROLE	ACTOR TYPE	INDUSTRY	DATE	DURATION
OEM 1	Mid Level Management	OEM	Automotive Industry	2020-02-07	01:08
OEM 2	Mid Level Management	OEM	Automotive Industry	2020-02-17	01:08
OEM 3	Technical Expert	OEM	Automotive Industry	2020-02-19	00:59
OEM 4	Mid Level Management	OEM	Automotive Industry	2020-02-19	01:12
OEM 5	Mid Level Management	OEM	Automotive Industry	2020-02-20	00:58
OEM 6	Technical Expert	OEM	Automotive Industry	2020-02-20	01:01
OEM 7	Mid Level Management	OEM	Automotive Industry	2020-02-25	01:35
EXTERNAL EXPERT 1	Researcher	External Expert	University	2020-02-25	01:03
OEM 8	Mid Level Management	OEM	Automotive Industry	2020-03-02	00:57
EXTERNAL EXPERT 2	Researcher	External Expert	University	2020-03-17	01:25
EXTERNAL EXPERT 3	Researcher	External Expert	University	2020-03-17	01:25
CUSTOMER 1	Top Level Management	Customer	Energy Technology Provider	2020-03-18	01:03
CUSTOMER 2	Top Level Management	Customer	Energy Provider	2020-03-24	01:04
CUSTOMER 3	Top Level Management	Customer	Energy Provider	2020-03-26	01:14
CUSTOMER 4	Top Level Management	Customer	Energy Technology Provider	2020-03-26	00:57
CUSTOMER 5	Top Level Management	Customer	Energy Technology Provider	2020-04-08	00:58
CUSTOMER 6	Top Level Management	Customer	Energy Provider	2020-04-16	01:03

Table 3.1: The table depicts the interviews and the encompassed interviewees included in the study.

meetings. The interviews held with the customers and the external experts were done later in the study, and due to the situation of *COVID-19* affecting the entire global landscape, it was not possible to perform these interviews in person, rather they were done remotely.
During the interviews, the researchers first described the purpose of the study in order to ensure that the interviewees understood why it was conducted. Further, the interviewers ensured the interview subject that full anonymity would be guaranteed, as the report does not mention either name or title that can connect the insights shared with a specific person. Before the interviews were commenced, a request to record the interviews were done as the researchers found the benefits of this important. According to Andersson (1985), the advantages that may be gained from recording interviews are i) Mitigating misunderstandings, ii) Enhancing the focus of interviewers by avoiding the reliance on notes. The majority of the interviews within this study were permitted to be recorded. The interviews conducted mostly lasted for around 60 to 90 minutes depending on the available time of the interviewee.

3.2 Data Analysis

According to Burnard (1991) a methodology that may be used to begin analyzing the data, is to compile the diverse set of collected data. In the case of this study, the researchers began by retrieving the *field notes* written during the interviews, then complementing these field notes with additional information from the *audio recordings*. Hence, information that not had been noted in the field notes due to the time constraint was added from the recordings. Further, the information written down was checked against the audio recordings in order to ensure the reliability of the notes. This also gave the researchers the opportunity to read through all the field notes, which according to Burnard (1991) is an important aspect in the early phase of analyzing qualitative data.

The next step of the data analysis is often to develop early categories or headings freely from the gathered data (Bernard, 2017; Burnard, 1991). Further, Burnard (1991) states that this is often recalled as the concept of *open coding*. Bernard (2017) states that within inductive research, it is often useful to read through the collected field notes and highlight words or sentences that are deemed as important, as they often come to serve as potential candidates for themes, i.e. categories. The researchers of this study began by going through the field notes and highlighting areas found to be interesting within the field notes. Further, similar quotes or ideas from the field notes were grouped together in order to begin crafting a structure and categories within the data. Moreover, the researchers found it useful to structure the data using an electronic spreadsheet where the different interviews were represented by a unique column, and thus similar open codes were initially placed in a unique row. Hence, for each row an initial category was derived which was written in a cell to the far right of the open codes. Thus, from these early categories which were placed in a unique row, one could find all relating open codes in the columns beside it. According to Bernard (2017), this way of searching for repetitions in the collected data is a useful way to structure the empirical findings.

According to Miles & Huberman (1994), another way to develop useful categories is to start from existing notions within the current research area. Hence, by extracting useful *theoretical themes*, the researcher may establish a useful structure where one may connect the initial empirical codes with accepted concepts in literature (Miles et al., 1994; Miles, Huberman, & Saldaña, 2014, 2020). In this study, the researchers choose to utilize the theoretical concepts extracted within the theoretical framework in this report. Hence, the three dimensions of the CEBM were found as a useful approach that could be used as a theoretical compass acting as the intermediary between theory and the empirical findings. The researchers more explicitly put the three dimensions of the CEBM as the *primary categories* in the leftmost column of the electronic spreadsheet, each one on a unique row. Thereafter, the *initial categories*, and their associated *open codes*, were allocated under the suiting *theoretical category.* The alignment between the open code and the theoretical categories is described by Fawcett, Waller, Miller, Schwieterman, Hazen & Overstreet (2014). Fawcett et al. (2014) state that the use of theoretical categories may help foster a good data structure. According to Burnard (1991), the next step in analyzing the data is to continue the refinement process of the categories established for the data set. Hence, very similar to an iterative process, the categories should be refined over again by collapsing and merging different categories until the point where the researchers deem this work as saturated. Further, Burnard (1991) and Bernard (2017) argue that from these refined categories, it is often useful to categorize them according to a *higher-level category.* In this study, the initial categories were refined, by merging and extracting open codes, thus an extrapolated list of categories was derived. By arranging this list in accordance with similarity and relation among categories, the researchers established a higher-order category for which the earlier categories were grouped within. Hence, from now on the initial categories are known as *empirical subcategories.* The developed higher-order categories were named as empirical main categories. The list of empirical main categories, and their associated subcategories and open codes, were then placed under the most suitable theoretical themes. This way of iteratively reducing the complexity in the collected data is a technique that both Bernard (2017) and Miles et al. (2020) promote in order to enhance the comprehensibility of the empirical findings. Further, Fawcett et al. (2014) argue that this iterative process may also help readers of the works to trust the findings.

A visual example of the data analysis process may be seen below in figure 3.1. This figure illustrates the connection between theoretical themes and how they relate to empirical primary categories, empirical subcategories and open codes.

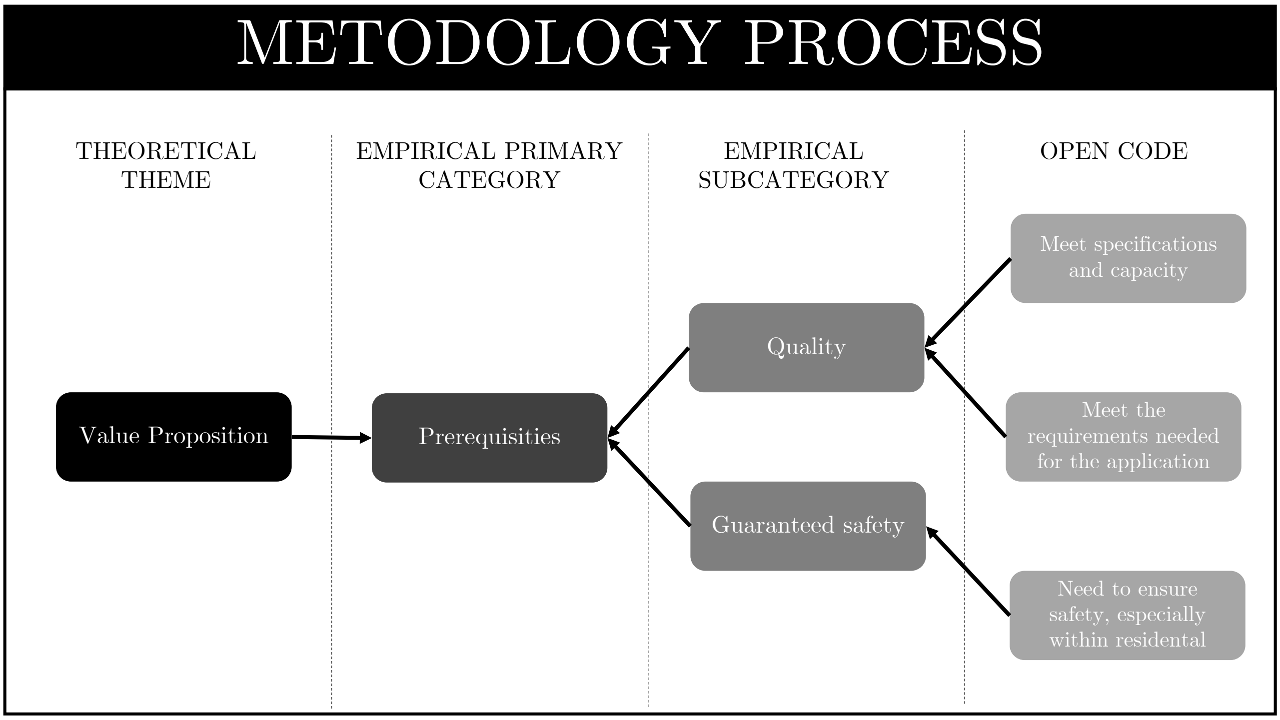

Figure 3.1: The figure describes the connection between the theoretical themes and their relationship to empirical primary categories,empirical subcategories and open codes

Utilizing the structured empirical data in the electronic spreadsheet the empirical findings were derived hence helping to partially answer the research questions. The how dimensions of the research questions were answered by combining the analyzed empirical findings together with important insights gathered from the theoretical framework developed in chapter 4.

3.2.1 Research Outcome

The main outcome of this study have been to design three potential circular economy business models that OEM may utilize when entering the emerging industry of second-life EV batteries. Moreover, this study has also contributed by presenting a detailed comparison of the three derived business models, hence elaborating upon how they differ regarding the three dimensions of a CEBM. Moreover, the outcome of this study also incorporates a set of barriers and prerequisites that OEMs need to consider when setting up a business model around second-life EV batteries.

3.2.2 Research Quality

When performing a scientific study, it is deemed as highly essential that the scientific community trust the findings published within the scope of the study Bryman et al. (2015), Bryman & Bell (2011). Traditionally, the trustworthiness of a research study have according to Bryman et al. (2011) been measured according to how well the research is at establishing *validity*, which may be measured both *internally* and *externally*. Further, Bryman et al. (2015), Bryman et al. (2011) state that *objectivity* and *reliability* have been common key indicators of the trustworthiness of scientific studies. However, according to Halldórsson & Aastrup (2003) these types of quality criteria are most suitable for studies of *quantitative character*.

Moreover, Halldórsson et al. (2003, p. 331) claim that *"More importantly, much of the writings in logistics to date do not distinguish between the nature of the research approach (qualitative vs. quantitative) when stressing the issues of research quality"*. Hence, as this study is a qualitative single case study, other criteria for measuring quality needs to be derived that suits the nature of the study. Halldorsson, Altuntaş Vural & Wehner (2019) states that in order to promote the quality of case studies, it is important that the research process is described clearly and thoroughly to ensure that the reader may determine the rigor of the adopted research approach. Moreover, Halldórsson et al. (2003, p. 331) state that *"Researchers addressing logistics problems by qualitative research approaches should take into account the issues of truth-value, transferability and contextualism and trackability and explicit when considering the criteria for evaluating their research efforts"*.

Hence, the following criteria are found suitable to use as a basis when analyzing the quality of the study i) *Credibility*, ii) *Transferability*, iii) *Dependability*, and iv) *Confirmability* (Halldórsson et al., 2003; Halldorsson et al., 2019).

In this thesis *credibility* has been secured by first listening again to the records of the interviews, hence the researchers have ensured that the different realities of the interviewees really was reflected in the research findings. Further, the interviews were coded into empirical codes, and similar codes where structured together to offer a good way to overlook the data collection. This process was done iteratively hence the data collection and analysis phase were done simultaneously. Finally, similar empirical and theoretical codes were matched together to create a connection between the theoretical framework and the empirical findings.

Transferability refers to how the findings derived within the study may lead to general claims, hence the applicability of the general claims in other settings first needs to be judged by the reader (Halldórsson et al., 2003). Further, Halldórsson et al. (2003) state that in order to ensure transferability, the researchers need to be transparent and clearly describe how the research was conducted and how the findings were derived using rich context descriptions. In this study transferability was promoted by the researchers by being as transparent as possible regarding the methodology used. Within the appendix of this report, the interview guides have been attached in order to enable other researchers to understand how the empirical findings of the study were gathered. Further, the data analysis section has thoroughly described how the data was condensed in order to find patterns that later was used when answering the research questions. Hence, it is believed that the study may be conducted again in another setting.

Dependability was promoted within this study by utilizing a variety of different tools during the data collection. These tools consisted of field notes, pictures, sketches, and voice recordings. Hence, the use of these tools aimed at facilitating the documentation of the empirical findings, thus helping to ensure dependability and trustworthiness within the study.

Finally, the quality of this research has been assured by ensuring *confirmability* within the study. Confirmability has been promoted by letting the first selection of interviewees make suggestions on further interviewees. Moreover, the researchers also expanded the pool of respondents to other customer types as the research progressed, hence promoting the confirmability of the research.

4

EMPIRICAL FINDINGS

In this chapter, the empirical findings derived within the thesis study will be presented. The findings consist of two parts. Firstly, findings related to the three dimensions of the Circular Economy Business Model i.e. i) *Value propositions*, ii) *Value creation and delivery*, and iii) *Value capture* will be presented, since they are the key dimensions of a CEBM. Secondly, the chapter will also highlight prerequisites and potential barriers for the implementation of second-life EV battery business models.

4.1 Value Proposition

This section will describe the empirical findings related to how a value proposition for second-life EV batteries may be established.

4.1.1 Application Areas

This section will address potential application areas that have been identified as viable for second-life EV batteries according to the collected empirical data. Identified advantages will be highlighted and also, specific characteristics will be discussed. Application areas provide insights about how the value propositions should be designed for the related markets, hence it is a suitable area to base the rest of the value proposition on.

Backup Power

The use of second-life EV batteries as backup power in factories and commercial buildings is a viable application area. Today many of the factories have a diesel generator which takes a couple of minutes to start when the electricity stops. This creates a gap with no electricity which results in that many machines need to be restarted, thus valuable time is wasted. A battery can give electricity immediately to the machines, which keep them running although it´s a power failure. Thereby, valuable manufacturing time can be saved.

Frequency Stabilization

Another application area for second-life EV batteries concerns the concept of frequency stabilization. Within a grid it is important to regulate the demanded and set frequency of the electricity, i.e. the hertz within the grid. When a grid contains classical energy sources such as hydropower, nuclear power, and/or coal power, there is a natural inertia that regulates spikes or changes of frequency within the grid. Another way to stabilize this frequency is to instead use a battery for controlling the grid frequency. Hence, instead of alternating the rotating mass that provides the inertia, e.g. a hydropower plant can instead keep the rotating mass at a steady pace and let the battery compensate for the needed changes within the grid by increasing or decreasing the voltage provided.

Energy Storage Systems (ESS)
Today, many countries are transitioning towards renewable energy sources such as wind power and solar power, etc. These energy sources are not as stable as traditional energy sources, e.g. nuclear power, thus often recalled to as intermittent energy sources. Due to the nature of these energy sources there is a need for regulating the variation in input stemming from these sources, e.g. the output of a solar plant may vary on an hourly basis due to clouds. Hence, there is a need to bridge the gap between production and usage of power. The concept of energy storage systems aims to fulfill this by providing a way to allocate power which may be consumed at a later point in time. A way to provide storage for the energy is to use second-life EV batteries which can be charged when there is a surplus of electricity and then used later. An example of this is how solar panels may charge the battery ESS during the day and then withdrawn from the battery during the evening when there is a high demand for power. This is an application area that has been identified as having a high potential as it fits the nature of second-life EV batteries.

Grid Investment Deferral
It was found that it is possible to use second-life EV batteries in order to decrease the need for expanding grids. The need to expand an electricity grid may stem multiple different reasons but the fundamental cause is an increase in demanded power, either locally or at a national level. Customer 5 argued that *"The investments needed to expand the grid is often highly expensive and may determine whether a business idea is profitable or not"*. One example of grid investment deferral that has been identified as viable is within the growing business of providing fast-charging stations for EV. Further, due to the high output of power needed for quickly charging the car, there will be a need for high input of power to the charging station, hence the existing infrastructure may often not be enough. In order to get this power, the actor needs to purchase the demanded power from a grid operator and in many cases the actor will need to bear the investment, either fully or partly. Also, the actor will also need to pay a fee for having access to a high-power input. An alternative to increase the capacity of the grid to achieve the required power, is to use second-life EV batteries in order to provide a high available power balance when fast charging the electric cars. Hence, instead of sourcing the high power from the grid, the power is allocated from a stack of second-life EV batteries. These batteries can then be charged at a slower pace using the existing grid capacity, hence spreading the consumed power over a longer time will result in optimizing the available capacity.

Another example of grid investment deferral is to use batteries to reduce investments needed at a national level where there is a large imbalance between energy production and consumption in different regions in a country. Hence, the imbalance between the regions require large amounts of energy to be transported. If the imbalance increase, which may have in Sweden when the nuclear power plants in the south are closed, there will be a need to increase the transportation capacity between north and south. A way to mitigate investments of grid capacity is to locate batteries at a strategic location in the grid, hence aiming at compensating for these imbalances. Customer 2 states that *"The usefulness of adopting second-life EV batteries within these applications provide a low marginal value compared to new batteries as the investments are done over a long investment horizon, however, if second-life EV batteries can provide the same specifications as new batteries, they could potentially be attractive as they provide a sustainable advantage as the demand for new productions is eliminated"*.

Peak Shaving
Another application area for second-life EV

OVERVIEW OF THE EMPIRICAL FINDINGS		
KEY DIMENSIONS		EMPIRICAL FINDINGS
VALUE PROPOSITION	Application Areas	• *Backup Power* • *Energy Storage Systems (ESS)* • *Frequency Stabilization* • *Grid Investment Deferral* • *Peak Shaving* • *Portable Charging Stations* • *Internal Use*
	Product Characteristics	• *Battery Pack VS Battery Modules* • *EV Battery Technology* • *Lifespan of EV Batteries*
VALUE CREATION AND DELIVERY	Key Activities	• **Forward Supply Chain** - *Product Disposition* - *Refurbishing* - *Distribution and Warehousing* - *Installation and Customization* • **Reverse Supply Chain** - *Disassembly* - *Return Flow* - *Recycling*
	Key Actors	• *EV OEM* • *Battery Service Provider* • *Customer Segments* - *Private Grid Owners* - *EV Charging Infrastructure Providers* - *Public Grid Owners* - *Commercial Properties* - *Residential Properties*
	Key Resources	• *Battery Control/ Management System(BMS)* • *Battery Tracking System* • *Contractual Agreements* • *Second-Life EV Batteries* • *Technical Skills* • *Technological Equipment*
	Channels	• *Communication Channels* • *Distribution Channels* • *Sales Channels*
VALUE CAPTURE	Pricing Strategies	• *Transaction-Based Pricing* - *Servitization-Based Pricing*
FACTORS INFLUENCING THE CEBM	Prerequisites	• *Design for Second-Life* • *Price* • *Safety* • *Specification Fulfillment* • *Steady Supply of Used EV Batteries*
	Barriers	• *Technological Uncertainty* • *Customer Perception* • *Circular Economy Business Model Characteristics* • *Laws and Policy*

Table 4.1: An overview of the empirical findings gathered within the scope of this study.

batteries is the concept of peak shaving. The aim of peak shaving is to shift the use of electricity from peak hours where the demand, and the price, often is very high, such as afternoons and evenings. This demand is instead allocated at times with low demand, where both the price of electricity is lower and the load on the grid is lower. Within peak shaving applications second-life EV batteries may be used as energy storage which hence can provide electricity for the user during peak hours. Hence, even though the user does not rely on incoming electricity, this does not affect the user as it retrieves the electricity from the battery. The battery may instead be charged during non-peak hours hence the user may benefit from a lower energy price per kWh. Further, this may also reduce the required load on the grid, hence posing a value for both the user and the grid operator as it can reduce the demanded power. Hence, the user may reduce its costs as it can reduce the required load-amount, which often is very expensive during peak hours. Customer 2 stated that *"local grid operators may benefit from using second-life EV batteries for local peak shaving in order to reduce the overall load within the local grid"*. Hence, the local grid operator can limit the needed incoming load from the national grid operator, hence this enables the local grid operator to reduce costs. But it can also give a socioeconomic benefit as the national grid operator, which often is a governmental company, may benefit from a relief on the often, overloaded national grid.

Further, instead of charging the batteries from the grid during non-peak hours, peak shaving applications may also be combined with renewable energy sources such as solar panels where the battery is charged by them instead.

Portable Charging Stations
Finally, another application area is the use of second-life EV batteries within portable charging stations. The logic here is to provide a portable charging infrastructure of electric vehicles as this could be needed at locations that have either a seasonal character or during events. Hence, as the demand for the charging electric vehicles at the specific location is not of a permanent nature, it may not be economically viable to invest in fixed infrastructure for a demand that is temporary. An example highlighted by Customer 3 stating that *"Portable charging stations have been used at a ferry port in Sweden that had a strong seasonal character in their demand, however, this was done with new batteries but it could probably be done with second-life EV batteries instead, and thereby achieve better profitability"*. Hence, using second-life EV batteries within these types of applications could be a way to make the business case of the solutions more attractive and due to their flexible nature it is probably easy to replace the exhausted batteries.

Internal Use
A possible use for second-life EV batteries is to use them within internal applications at the OEM. This application area is a special case as it does not involve any external customers, rather the batteries are used within the OEMs business. Hence, some of the previously mentioned application areas can be seen as part of this, as these can be used within the internal business as well. Some potential application areas highlighted are for example i) *ESS for renewable energy*, ii) *Back-up power*, iii) *EV charging*, iv) *Peak shaving*, v) *Grid investment deferral.* A potential advantage of internal use is that it is easier to coordinate due to the minimization of external actors, which may be beneficial at an early stage when testing and evaluating the technology and potential application areas for second-life EV batteries.

4.1.2 Product Characteristics

A part of the value proposition is the characteristics of the battery. The product characteristics in combination with the application area determines how the value proposition should be designed for a specific customer segment. Hence, it is natural to extend the value proposition with findings related to the characteristics of the battery.

Battery Pack VS Battery Modules
An aspect that was highlighted in the interviews with OEM employees and the experts was the question of whether the battery modules should stay within their casing, i.e. used as a complete battery pack, or if the battery pack should be disassembled into battery modules. An advantage of using whole battery packs is to avoid reengineering hours on customizing and developing new systems for managing the separated modules. If battery packs are broken, a loss in engineering may occur as the EV batteries usually already contains a *battery management system* (BMS), safety systems, and cooling equipment. Following from this, using whole battery packs may also be more financially viable as costs for customization may be minimized compared to the option of separating the battery into modules. A few OEM employees stated that the advantage of breaking the pack is to achieve more flexibility when designing second-life applications. The reason is that this reduces the space needed to store the modules and also since they easier can be located in crowded surroundings where space is scarce. One example of this is urban environments where the rents of land is high. A few OEM employees claim that they have received indications by potential future customers that argue that this aspect of the space constraint will be critical for some second-life applications. On the other hand, one customer states that the space constraint is not an issue for most applications within EV charging applications, and especially within fast charging.

EV Battery Technology
There are typically two types of EV batteries namely *Plug-In Electric Vehicle Batteries* (PHEV) and *Battery Electric Vehicle Batteries* (BEV). The PHEV batteries usually have a much lower capacity than the BEV batteries as they are designed to be combined with an internal combustion engine. Hence, they also consume less space than the BEV counterpart. Due to the design and characteristics of these two battery types, they also have different advantages. Further, the PHEV is designed to provide high power during a short time, compared to the BEV which are designed with the purpose of lasting longer, hence they have a higher capacity measured in kWh but cannot provide high power in kW at a level similar to the PHEV.

It was found that due to the chemical technology used, the EV batteries are most suitable for storing electric energy over shorter time periods, around 1-2 days. The reason for this is due to power leakage from the battery, i.e. the electric energy stored in the battery declines over time. Further, it was found that EV batteries are best suited for use within applications that stores energy in intervals up to a day.

Lifespan of EV Batteries
It was understood that the lifespan of the batteries is affected by mileage, time, surrounding temperature, and usage. Further, it was found that fast charging may have a negative impact on the estimated lifespan of the battery. The performance of an EV battery decreases at a slow and mostly linear pace to a certain point. When that point has been reached, the decline of the performance will accelerate. One OEM employee stated that “ It is currently hard to know when this point will occur, but it has been seen that it occurs later than previously expected”. It was found that when a battery contains a manufacturing defect, i.e. an error that has occurred due to a faulty manufacturing process, this defect often impacts the performance of the battery within the three first months. Therefore, batteries that are older than three months seldom are affected

by new manufacturing defects, hence these batteries are likely to have a stable and estimated decline in performance.

4.2 Value Creation and Delivery

This section will present the empirical findings related to the value creation and delivery dimension. An insight shared by all of the interviewees is that there currently is no established value chain present for second-life EV batteries, hence the following data indicates what a future value chain could encompass, based on the thoughts of the interviewed actors which have an extensive knowledge within the industry.

4.2.1 Key Activities

Below, the findings for the activities within the supply chain will be presented. The activities are divided into activities within the forward supply chain and activities within the reverse supply chain.

Forward Supply Chain

In this section, the findings related to the key activities identified within the forward supply chain will be presented.

The first step when a battery has returned from its first life use is to perform a test activity where the so-called *state of health* of the battery is conducted, i.e. product disposition. This test measures the health of the modules within the battery in order to determine whether there are any issues within the battery that needs to be dealt with before the battery is distributed. When the battery has been tested and checked for quality issues, the batteries are sorted depending on the results of the testing activity. If a battery has a state of health that exceeds the required level, or if there are any other quality issues that make it unattractive for second-life applications, the battery is sorted out and sent for recycling. Those batteries that are deemed as sufficiently good for second-life applications are then either sent for refurbishing or directly to distribution.

When the batteries have been tested the performance of the batteries is known. Batteries which performance does not reach the specifications have to be refurbished to increase their capacity and performance. In this process, individual modules are exchanged in a way that results in that the refurbished battery reaches an acceptable SoH and can thereby be used in a second-life application, i.e. *refurbishing* the used EV batteries.

The next key activity is *remarketing*, as it was found that an activity that is needed is the activities related to putting the second-life EV battery to market again. Hence, processes found under remarketing include i) Sales and ii) Handling customer requests, e.g. warranty issues.

Batteries that have passed the testing and quality check, and also those batteries that have been refurbished, should be placed for distribution, possibly in a battery warehouse, operated either externally or internally. It was found that this warehouse either could be operated directly by the OEM or by an external provider. The distribution activities will include transports from the testing and refurbishing facility. Further, transports to the customer or to the installation and customization provider will be needed.

It was found that the *installation* of the second-life EV application at the customer will be an activity in the supply chain. The installation activity will be needed to assemble the EV battery in the application at the customer and ensure that the second life EV battery operates properly. Further, related to the installation, an activity encompassing customization of the second life EV battery and its control systems have been identified.

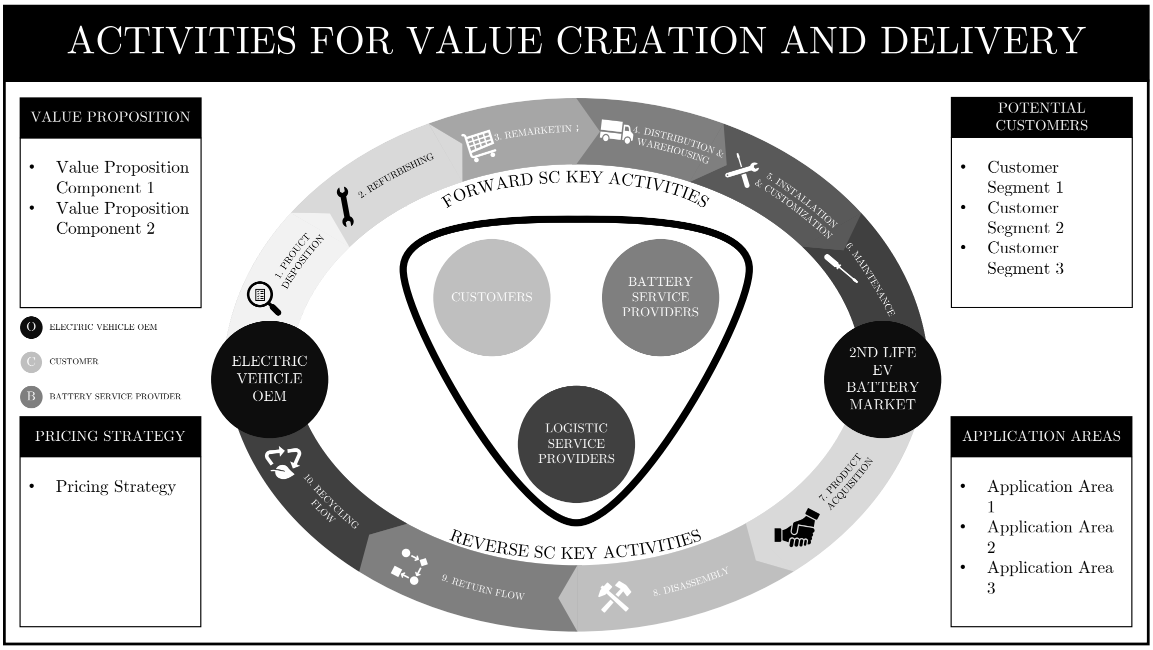

Figure 4.1: The activities for value creation and delivery

However, it has been seen that there are different opinions on whether this is a necessary and suitable activity or not. OEM 2 stated that *"I believe it may be feasible, and in some cases necessary, to customize the batteries for the use in customer applications"*. However, this statement was contradicted by Customer 5 stating that *"For the business case, it is better to customize the original second-life EV battery systems as little as possible and use the internal control system, as this is just an extra cost"*.

Another potential activity for second-life EV battery applications is the maintenance of the systems. It is seen as viable to have a maintenance activity in order to ensure that the safety of the system is under control. Customer 1 stated that *"Maintenance of second-life EV batteries will probably be important in order to achieve optimal performance of the systems"*. Maintenance activities are also a way to detect potentially degraded batteries that no longer may remain in the system.

Reverse Supply Chain

In the section below, the findings about the activities within the reverse supply chain are presented.

When a second-life EV battery has been identified as degraded to that extent that it is no longer fruitful to use it within the second-life application, there will be a need for a return flow that retrieves the batteries from the customer. The first step in the reverse supply chain is to disassemble the batteries from its current installation in a safe and proper way.

After the disassembly the used second life EV batteries should be transported to either an OEM or a recycler, i.e. *return flow*. During this transport it is necessary to protect the batteries according to current safety regulations.

The final step of the supply chain is the *recycling* of the battery. The efficiency of battery recycling activities is estimated to increase at a steady pace during the following ten years. Currently, EV battery recyclers in all countries except China are charging actors that want their batteries recycled. In China, where the processes for EV battery recycling currently are most developed, actors that hand in their batteries for recycling will get paid. The same pattern is forecasted to happen in other markets such as Europe and the US.

4.2.2 Key Actors

In this section, the key actors identified within a future supply chain for second-life EV batteries will be presented. Further, the role and potential range of the scope of the different actors within the supply chain will be elaborated upon.

OEM

The OEM is currently a vehicle manufacturer that has begun to transform its business to incorporate EVs. Hence, the EV OEM will have a future supply of EV batteries that will ramp up in line with the increasing sales of EV globally. The OEM has identified that the future supply of incoming EV batteries may be an issue that the OEM needs to deal with. Further, it was seen that the OEM had thought of the possibility to utilize the incoming EV batteries within a second-life application. However, it was found that since it is outside the scope of the OEMs core activities, it may be unlikely that the activities needed in a future second-life EV battery supply chain will be performed in-house, i.e. fully vertically integrated. OEM 7 argued that *"In order for us to perform the activities in-house there will be a huge need for developing and/or acquiring multiple new resources such as sales activities, installation and customization activities, maintenance activities, logistics and warehousing activities and finally administration activities"*. Also, since the OEM currently has no experience within these kinds of activities it is considered as a barrier.

Battery Service Provider

It was found that an alternative to develop these activities and capabilities in-house is to instead use one or a few battery service providers to handle the second-life EV battery activities identified. A *battery service provider* is an external actor that has the right resources and capabilities to provide second-life EV battery services, e.g. product disposition, refurbishment, installation and customization, and maintenance. In this scenario, the OEM would merely supply the batteries to the battery provider which then would perform the other activities, either in-house or by sourcing from another supplier. An advantage of this setup was highlighted by OEM 5 *"As this (second-life EV battery application activities) is outside our core, it is better to let another actor perform it. I also believe that it could probably be done more efficiently by an external party"*. Hence, engaging in partnerships is seen as highly important by the majority of the interviewed actors as the resources for performing the necessary activities are rather complex.

Logistics Service Provider

Further, it was identified that a third actor probable to occur in a business model for second-life EV batteries is the logistic service provider. The role of the logistic service provider could be two-fold. Firstly, it could take care of the freight transports of the batteries between the OEM and a possible battery service provider. Further, transports between the battery service provider and the customer could also occur. Moreover, transports for spare parts and returns could also take place. Secondly, a logistic service provider could also be responsible for warehousing activities in the case that either the OEM or the battery service provider chooses to outsource these activities to an external actor.

Customer Segments

In this section, the researchers have matched the derived and identified customer segments with the potential application areas for second-life EV batteries. The association between customer segments and application areas are based on the empirical evidence gathered in the study. In table 4.2, the customer segments and their matched application areas are presented. Moreover, in the section below these customer segments will be further described.

One type of customer that was identified was *private grid owners*. This segment often encompasses local and national grid providers. Some of these actors does merely own the grid and thus buying electricity from other providers, while other, often larger actors, both own the grid and produce the electricity that they put into the grid. A majority of the interviewed customer expressed that these segments have an interest in the following application areas namely: i) *Peak shaving*, ii) *Frequency stabilization*, iii) *ESS*, and iv) *Grid investment deferral*. Further, it was found that these types of companies traditionally prefer to invest in their own equipment as their business model often circulates around owning assets over a longer time horizon and utilizing this to capitalize on.

Another similar customer segment identified is the *public grid owners*. The public grid owners facilitate the national grid which all private grid owners buying electricity from, which result in that many of the private grid owners are dependent on the private grid owners and vice versa. The application areas they preferably are interested in are i) *Grid investment deferral*, and ii) *Backup power*. A public grid owner makes investments for a long time, the plan is that the products should manage between 40-100 years before they need to be replaced. Further, it was mentioned that reliability is of top priority when selecting products for this segment.

A third customer segment identified is the one encompassing *EV charging infrastructure providers*, which offers infrastructure for EV charging such as charging boxes, smart connectivity solutions, and fully integrated solutions. These segments encompass companies that have different vertical scope within EV charging business, but the common theme is that they all work with implementing charging infrastructure. These are actors mainly interested in the following application areas for second-life EV batteries: i) *Grid investment deferral*, ii) *Portable charging stations*, iii) *ESS*, and iv) *Peak shaving*. Customer 1 stated, *"Two of the most promising application areas for grid investment deferral are fast charging, as this can be an enabler for economic viability and also ESS systems for private home charging applications. . . here, private customers combine solar panels, ESS, and EV charging as a system"*.

CUSTOMER SEGMENTS AND ASSOCIATED APPLICATION AREAS	
CUSTOMER SEGMENT	SUITABLE APPLICATION AREAS
Commercial Properties	• *ESS* • *Peak Shaving* • *Grid Investment Deferral*
EV Charging Infrastructure Providers	• *ESS* • *Peak Shaving* • *Grid Investment Deferral* • *Portable Charging Stations*
Private Grid Owners	• *ESS* • *Peak Shaving* • *Grid Investment Deferral* • *Frequency Stabilization*
Public Grid Owners	• *Backup Power* • *Grid Investment Deferral*
Residential Properties	• *ESS*

Table 4.2: An overview of the identified customer segments for second-life EV batteries and their associated application areas

It was identified that using batteries within private households and apartments is seen as an attractive customer segment, i.e. *residential properties*, for the ESS application connected to a renewable energy source e.g. solar panel. The customer segment requires the second-life EV batteries to have a higher guarantee on safety as they are located within proximity of households. A potential way to resolve this issue is to place the battery storage in a building that is separated from the households.

Finally, a customer segment is the *commercial properties*. This segment includes actors such as workplaces, shopping malls, and other commercial properties, which includes larger commercial and public housing owners. The findings showed that this customer segment mainly has any interest in the following applications for second-life EV batteries: i) *ESS*, ii) *Peak shaving*, iii) *Grid investment deferral*. When second-life EV batteries are used within commercial applications the regulations for safety may be less restrictive than for residential applications, hence making it easier to implement within this customer segment. This is something that the interviews with the OEM employees also indicate.

4.2.3 Key Resources

During the interviews, six different assets was identified as key resources to enable a second-life EV batteries. First, it was found that in order to enable the remarketing activity of the second-life EV batteries, a sales organization possessing relevant and suitable *technical skills* will be needed. The technical skills are required since the sales organization must be able to know how they should fulfill customers specifications and provide excellent service to the customers. Further, the specific *skills related to the installation and maintenance activities* of the second-life batteries at the customer's application must be achieved. This resource is significant since the second-life EV batteries need to be installed in a secure and good way. If the person installing the second life EV battery lacks knowledge and skills the risk for accidents during the lifetime increases. These skills will probably be found at a battery service provider. Another identified key resource is the tangible asset of the *second-life EV batteries* and the associated *battery control systems* that are needed to control it, i.e. battery management system (BMS). Almost all the second-life EV batteries have a BMS in their first life, hence it could be possible to use the same BMS in the second-life application. The battery control system is important since it enables the customer to ensure a safe battery application. Furthermore, the second-live EV battery is the main asset and is required in all second-life EV applications. Moreover, *technological equipment* needed when testing, refurbishing, installing, and maintaining the batteries needs to be constructed. This is required since the quality and state of health of the second-life EV batteries must be known. This technological equipment will facilitate this process. In order to keep track of the batteries to make sure that the OEM can live up to e.g. producer responsibility, it may be necessary to develop a key resource in the form of a *battery tracking system* that controls where the physical batteries are located. Finally, it was seen that in order to control the IPRs of the BMS, it may be needed to set up proper *contractual agreements* dealing with this issue.

4.2.4 Channels

It was found that it seems unlikely that direct sales will be a feasible option for OEMs to communicate and put their second-life EV batteries to the market. Rather, other indirect channels seem more likely as the second-life EV batteries business is not regarded as core to the vehicle producers. Hence, an identified sales channel proposed by the employees at the OEM is to use an external partner to handle this business. This provider or providers could potentially be responsible for all activities regarding the second-life and the value delivery processes to the customers. This was also indicated by two experts highlighting that this is outside the scope of the OEMs current business, hence it is more likely that an external actor will be used to handle the value delivery. Furthermore, the different customer segments will probably prefer to be served by different sales and communication channels as they have different preferences. Moreover, the distribution of the value propositions to the customer may need to be adapted depending on the customer segment and value propositions, hence this may require the distribution channel to be altered as well.

4.3 Value Capture

This section will present the empirical findings related to how second-life EV batteries applications may be priced and sold. Two different pricing models emerged from the empirical evidence, namely i) *transaction-*

based pricing and ii) *servitization based pricing.* Below, the two pricing models will be presented in detail. The empirical findings relating to the value proposition dimension also affect the value capture mechanisms, hence the two pricing models are affected by the different potential value propositions derived above.

4.3.1 Transaction-based pricing

Transaction-based pricing is the traditional way of acquiring a good. The seller sets a fixed price for the product, and the buyer purchases the product by paying the entire amount upfront. This event can be referred to as the point of sale. At the point of sale, the ownership of the product is transferred from the seller to the buyer and the two parties don't need to have any relation after the point of sale. The advantage with this model, was that apart from an instant monetary compensation, that the risk for the OEM probably could be decreased as it no longer possessed the battery. Further, a third advantage could be that the OEM was more used to this type of pricing model. A disadvantage could be related to the loss of ownership, which could be troublesome in the advent of new regulation regarding producer responsibility, hence transferring the ownership to a second-life customer could increase the risk of losing track of the battery. Another disadvantage, is that it may be less attractive for the customer to rely on second-life applications as the perceived risk of buying a second-life battery is high. Hence, using this type of pricing model could hamper sales opportunities as the customer could be reluctant to choose second-life batteries over new ones.

It was found that the customer found the transactional pricing models of second-life EV batteries to be useful within or some customer segments. Further, it was indicated that customer segments such as private grid owners and commercial property owners could be interested in procuring the batteries, i.e. traditional product-based transactions, as their business model often is based around ownership of an asset over a long time. Hence, pricing models where the ownership is transferred as this would be more attractive for these kinds of customers. However, it was found that even though the ownership of the batteries is transferred in this type of pricing model, the customers may still be interested in complimentary services. Customer 4 stated, *"I believe that Energy Providers are most interested in acquiring the ownership of the batteries, but it would probably be interesting to get the possibility to purchase services such as installation and maintenance from a supplier"*.

The transactional ownership model may however not be optimal for other types of customers which have a business model where the ownership of batteries is outside the core of their business. They mentioned that examples of these companies could be private companies or organizations that want to combine charging solutions with solar panels, but they do not want to make a large investment in batteries hence the transactional model could be unattractive. Customer 1 stated *"Private companies that do not have ownership of power infrastructure as a core would probably appreciate to avoid making investments in batteries"*. Further, if the characteristics and specifications of the battery is unknown a volatile, e.g. lifespan or performance, some customers could be afraid of buying second-life EV batteries as this could pose an investment risk due to the uncertainty of technology.

4.3.2 Servitization-based pricing

It was seen that another potential pricing model could be to retain the ownership of the second-life EV batteries and instead charge the potential customers for usage, i.e. using a servitization-based pricing model. Thus, instead of charging a fixed price for the transfer of the ownership, the customers could be priced according to how many kWh they used of the battery. It was seen that this pricing model may be more complicated and require the use of an external partner as the OEM would neither have the competence nor the resources required to set up this kind of pricing model. OEM 5 stated, *"An advantage of retaining the ownership of the batteries is that it could make it easier for us to guarantee a producer responsibility as we then still have the legal ownership of the batteries"*. Hence, even if the second-life EV batteries applications are sold and handled by a third-party actor, the OEM would still be able to have a certain level of control over the batteries and therefore be able to ensure that they return for recycling. Another advantage stemming from this is that as the recycling business is expected to turn profitable in a couple of years, the OEM would then be able to capitalize on the return flow easier. With the retained ownership and the control coming from this the OEM could also have better control over the flow of used batteries to delimit them from ending up at non-authorized spare part dealers, which could pose a risk for the OEM, both due to producer responsibility but also brand impact. Finally, another advantage found with this model is that the OEM may reduce the risk for the customer in such a new, unexplored market. Which they do with the retain ownership pricing model.

From the customers it was found that for those customers that thought that the transaction-based pricing model was unviable, a servitization-based pricing model as described above would be more attractive. Firstly, Customer 1 stated that *"An advantage of using this type of pricing model would be that it decreases the perceived risk for us as a buyer of the product significantly"*. Hence, as the customer can be guaranteed a certain level of performance it will be less afraid of trying second-life EV batteries. Further, this type of pricing model could be beneficial to use initially when setting up a second-life EV battery market due to the risk hampering aspect. Another advantage raised is that it is more attractive for either company that the batteries are outside the core of their business or for actors that are smaller and thus have limited investment capacity. Finally, this pricing model would fit for external charging providers that e.g. set up fast chargers, as it would greatly reduce the needed investment hence making the business case for establishing the charging station more fruitful.

4.4 Factors Influencing CEBM for EV Batteries

This section will encompass prerequisites and potential barriers that have been identified for the implementation of a CEMB and the associated supply chain for second-life EV battery applications.

4.4.1 Prerequisites

In order to establish a CEBM based on second-life EV batteries, it has been found that a number of factors need to be fulfilled. Hence, these actors could be seen as prerequisites that relate to the three dimensions of the CEBM. These factors will be elaborated on in this section.
A potential prerequisite is the question about whether EV batteries should be designed to facilitate second-life usage. Hence, the design of the EV batteries enhancing the second-life application may be seen as a facilitator for the value proposition. OEM employees mentioned that it is possible to design the battery so the design facilitates a second-life

usage. It was found that one way to promote second-life usage is to change the design so it is easier to disassemble the battery. Hence, a future refurbishment process of the batteries could be done easier. Some evidence proclaims that this will never happen since it probably would make the performance of the battery worse for the first life and also more expensive for the first life customer. On the other hand, other collected data shows that some of the interviewees had the opposite opinion. It was mentioned that designing the batteries for second-life as well as first life was a requirement for the EV market to exist and that it soon will be the reality.

Another prerequisite for second-life batteries is that they must be offered at a price lower than new batteries in order to be an attractive alternative. Thus, offering an attractive price is a prerequisite associated with the value capture, i.e. price mechanism of the business model. Customer 3 expanded this statement by adding that *"it is not necessary to only take the upfront cost into account of the pure battery, rather the total cost of the installation must be cheaper than a new one"*. Another customer argued that if a situation occurs where there are two equally priced solutions fulfilling their specifications, they will choose the solution that contains second-life EV batteries, as their sustainability policy advocates them to select environmentally advantageous solutions.

Moreover, the matter of guaranteed safety of the second-life EV batteries will be a prerequisite. As the batteries contain large amounts of energy and at the same time are used within a second-life application, the risk of errors within the batteries needs to be either eliminated or at least controlled so the safety perspective may be ensured for the customer. Hence, enabling the safety of the second-life EV batteries is both part of the value proposition and the value creation and delivery as it may be facilitated by some of the previous key activities, e.g. installation and maintenance. Customer 1 stated, *"Guaranteed safety is key in order to use second-life EV batteries, especially within applications close to residential areas"*. It was found that a way to ensure this safety is to avoid "breaking the pack", i.e. keeping the battery modules within the protective casing. This protective casing is designed to keep the batteries intact and safe in case of collisions or other external impacts, when used within cars. Customer 3 stated, *"It is important to mitigate the risks of the batteries catching fire as it could pose a risk for our business"*. A way to reduce the risk for residential applications could be to locate the batteries within an external building remote from the residential building.

Furthermore, one prerequisite identified is that the batteries need to meet the specifications and capacity required for the intended application area. Specification fulfillment relates to the value proposition of the batteries, i.e. how well the offered value proposition fulfills the demand of the customers. Customer 3 stated, *"An important aspect is to be able to know how long the battery will last and how fast the degradation of the performance will occur"*.

In order to use second-life EV batteries within their business, it is necessary to ensure a steady flow of these batteries. Hence, the available volumes of second-life EV batteries must be at a known level that is stable enough. Thus, this prerequisite relates to the value and creation dimension of the CEBM as the OEM and the battery service provider will not be able to create and deliver the value proposition to the customer if a steady supply of used EV batteries does not exist. Customer 4 said that *"In order for us to achieve economies of scale within the operations, the available quantity if a certain battery must also be big enough, since otherwise the unique configuration costs for each battery type will be too high compared to the cost-saving gain of using second-life EV bat-*

teries". Hence, this will be one of the most troublesome aspects to resolve as the batteries are expected to have a rapid innovation curve during the coming years, with an expected improvement rate of their performance between 2-15% over the coming five years. Thus, this will also continue to affect the lack of standardization of the batteries, creating non-continuous flows of second-life EV batteries.

4.4.2 Barriers

Within the empirical data gathered, barriers perceived as potential obstacles for a business model for second-life EV batteries occurred. These barriers are listed and elaborated upon below.

An insight found is the issue of how the value second-life EV batteries should be determined, and hence what price OEMs should charge their customers for future applications based on this technology. Further, an insight by an industry expert interview is that due to the high innovation rate of the EV batteries, it is currently not known what technology that future batteries will use. An example given is if the batteries, which currently are made of precious and expensive metals, change its internal components to use fewer metals, the attractiveness for the recycling industry to further enhance their process may halter, as they currently most benefit from the value extracted of these metals. Another issue regarding the technology is the issue of intellectual property rights (IPR) when setting up applications with second-life EV batteries. This is due to the fact that in order to e.g. utilize built-in systems such as the battery management system (BMS) in the battery, it may be required to share data transfer protocols and other software to both potential customers but also battery service providers. OEM 6 stated however *"The issue of protecting IPR rights of the BMS is not actually a significant problem as this may be addressed rather easily by insight setting up contractual terms around the usage"*. A way to mitigate the risks regarding IPR is to protect it by setting up an agreement regarding how this may be used.

Moreover, it has been identified that a risk is the fear of a bad reputation and branding for the company if the battery was involved or the reason behind any accident or incident. For example, there is a risk that the second-life EV batteries should start a fire, which may result in negative consequences for the OEM. With regard to that risk, the OEM has decided to not aim for the residential ESS market for their second-life batteries for now.

Another barrier for OEM are the worries that have been found about the large number of people who have a negative opinion and perception about EV batteries, and especially second-life EV batteries. Customer 5 stated *"It is common to hear people say that they are afraid of batteries as they think that they may start to burn and explode. One of my customers once said to me, should we have a bomb in the garage?"*. Another customer stated that it often has to defend the battery safety in arguments with people who are negatively adjusted to batteries. It was found that consensus prevails it will take some time before a majority have a positive opinion and perception of batteries.

It was also found that customers may require and value to know the origin of the second-life EV batteries they are buying. They want to know that the minerals and materials inside the batteries are extracted and produced in a fair way, with good working conditions for the employees.

Another obstacle identified concerns the nature of the CEBM, as External expert 3 stated: *"When companies move toward CEBM and the associated supply chain structure, there will naturally be a larger network of actors involved...this implies that there will be a need for increased coordination and* *collaboration...this may require more time and resources spent on these issues compared to a traditional linear model"*. Further it was found that as the CEBM naturally is about closing the loop and enabling a return flow, a range of additional activities will follow such as reverse logistics, testing and refurbishing, etc.

Finally, an area that may impact the way second-life EV battery applications can be implemented is upcoming laws and policies, imposed either on a regional, national or an international level, e.g. EU directive. It was derived that a potential future legislation that will affect how second-life EV batteries can be sold is the revised EU Battery Directive what probably will come into effect during the coming yearsx. It is still uncertain to what extent this will affect the possibility or requirements for second-life applications. However, a probable implication is an increased end of life commitment for OEMs in the producer responsibility, hence increasing the need for control over the second-life EV batteries within the second-life supply chain. Another area of legislation affecting the viability of second-life EV batteries concerns fire safety at different application areas. Customer 4 states that *"Stricter rules for residential fire safety could be problematic for second-life EV battery applications within residential buildings, or at least require extended safety measures"*.

5 DISCUSSION

In this section, the empirical findings derived within the scope of this thesis will be analyzed and discussed. This will be done by utilizing the theoretical framework in order to analyze three business models with different characteristics derived from the empirical findings. Firstly, the logic with the business model and how it works will be described. Further, each business model will be analyzed from the view of the three business model dimensions; *value proposition*, *value creation and delivery*, and *value capture*. The purpose of the chapter is threefold, firstly it aims to understand the characteristics of the proposed business models and the associated supply chains, secondly, it strives to assess their advantages and disadvantages, and thirdly it will try to determine which customers and application areas they are most suitable for. The design of the three business models are based on the empirical findings and the literature derived in the analytical framework. Hence, the business models designed is a combination of the identified characteristics of CEBMs according to theory, which has been adapted and extended with the empirical findings gathered within the scope of this study.

5.1 Business Model 1

The first business model is built on a *product-based sales logic*, where the fundamental idea is that the OEM sells the second-life EV batteries to a customer, hence transferring the ownership of the batteries to a new actor. In this business model, the OEM does not interfere with the customer after the point of sale, rather the customer is expected to take care of the required services. A visualization of business model 1 is presented in figure 5.1.

5.1.1 Value Proposition

The value proposition offered to the customer in this model is solely a product, i.e. the second-life EV battery provided by the OEM. As the purpose of a value proposition is to distinguish your offering from the competitors, it needs to be competitive (Osterwalder et al., 2010). In the case of this business model, the value proposition is rather straightforward as it merely encompasses the sole battery, i.e. a rather commodity. Hence it may be claimed that it most probably competes against other value propositions in terms of providing additional value to the customer or by reducing costs for the customers (Lüdeke-Freund et al., 2019). Thus, the value provided to the customer is ultimately coming from gaining the ownership of a product, i.e. the second-life EV battery. As the second-life EV battery most likely will have an inferior performance compared to new batteries offered on the market, the OEM needs to assign a price that is either equal or lower compared to a new battery, when measured in relative performance.
A competitive advantage for the value proposition encompassing second-life EV batteries compared to new batteries is the environmental aspect. If the second-life EV battery

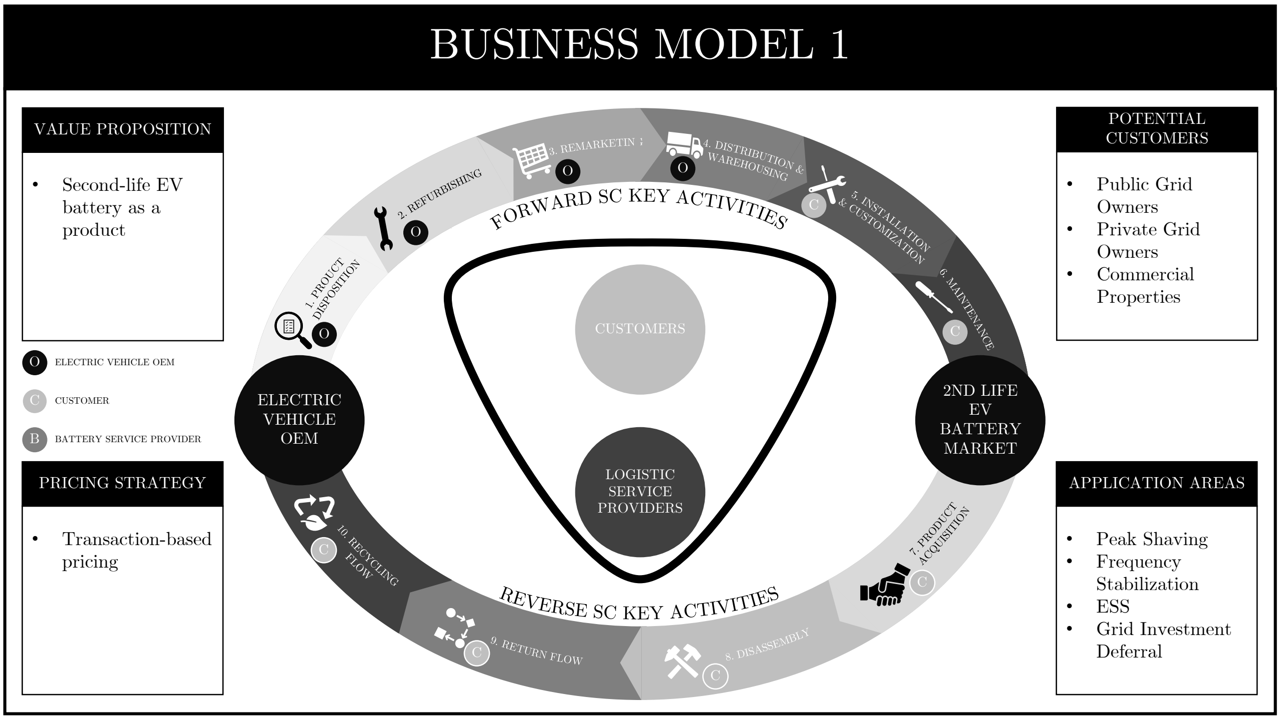

Figure 5.1: The extended analytical business model framework populated with the specific characteristics of Business Model 1.

already have been produced, it was found in the empirical evidence, that it is for some actors more attractive to purchase this battery compared to a new one, if the performance is the same. However, a disadvantage of setting up a value proposition entailing the second-life EV battery as a product relates to the technical uncertainty. As it was identified that an important prerequisite for many customers is to get a battery that fulfills the specifications requested, there will be a dilemma due to the uncertainty the OEM expresses of the performance of the second-life EV batteries. Hence, as it is currently unknown e.g. how fast a second-life EV battery will degrade, there will be a risk that the value of the product vanquish faster than expected (Olsson et al., 2018). Therefore, if the battery is sold as a product, the actors bearing the risk, in this case, will thus be the customer as the ownership is transferred completely. Moreover, this risk could, therefore, be an obstacle when setting up the value proposition according to the sales of a product. A way to mitigate this obstacle could be to have a warranty policy that ensures the customer that the OEM will handle any faulty batteries that do not fulfill the specifications. However, this will not completely resolve the issue, and will probably impose other negative consequences such as transaction costs when handling the warranty issue (Coase, 1937; Williamson, 1975). On the other hand, an advantage of selling the second-life EV batteries as a product is that the risk for the OEM may decrease, as the ownership is transferred to the customer.

5.1.2 Value Creation and Delivery

From the empirical findings it was seen that the business model chosen will have an impact on which customers that most likely will be interested in purchasing the value proposition (Osterwalder et al., 2010). Hence, as it was found that that different customers prefer different application areas due to their needs, it is useful to analyze which customers that this business model is suitable for. From the empirical findings it was identified that the two major customer characteristics that affect whether a customer would be interested in buying the second-life EV battery as a product is i) *Customer size* and ii) *Customer business model*. Firstly, the size of the customer will have an impact on the buying power the customer has, hence this impact to what extent the customer can make a relatively large investment. Thus, if the customer is deemed as large it is more likely that it will be able to buy the battery as a product. Secondly, the type of business model that the customer utilizes will determine what kind of value proposition that they are interested in acquiring. An example here is the private grid owners which business model was seen as being based on ownership of infrastructure and properties over a long time horizon. Hence, they are used to make revenue by owning an asset and then charging customers over time.

Combining these two insights it can be seen that the customer segments that most likely would be interested in procuring the second-life EV batteries as a product will be i) *Public grid owners*, ii) *Private grid owners*, iii) *Commercial properties*. All these three customer segments traditionally have a business model that revolves around the ownership of assets, hence it is likely that they would be interested in owning the second-life EV battery. Moreover, in general the public grid owners and the private grid owners are rather large actors that thus have the monetary resources to spend on purchasing the batteries as a product. The commercial property segment is a segment that encompasses sub-segments and hence it needs to be understood that there are different actors in this segment that may value this business model as more or less viable. However, no additional services such as installation and maintenance are offered in business model 1. Thus, the actors acquiring second-life EV batteries from this business model must have some sort of knowledge about battery technology, either internally or from an external provider.

Moving on to the application areas most likely to be enabled for this business model, it may be seen that for the public grid owners they are interested in i) *Grid investment deferral* and ii) *Back-up power*. The private grid owners have the strongest interest in using second-life EV batteries for i) *Peak shaving*, ii) *Frequency stabilization*, iii) *ESS*, and iv) *Grid investment deferral*. The customer within the commercial property segments will use second-life EV batteries in the following application areas i) *ESS*, ii) *Peak shaving*, iii) *Grid investment deferral*.

The value creation and delivery within this business model will be done solely by the OEM, hence the activities and capabilities needed must be developed and acquired internally in the organization of the OEM. The first activity needed to be established within the supply chain entailed in this business model is the product disposition of the EV batteries, as it is assumed that the OEM already possesses the batteries retrieved from its previous use within vehicles. Secondly, after the batteries have been sorted there will be a need to refurbish or repair batteries deemed as good enough for second-life EV use but with some minor defects. From the empirical findings it was seen that the interviewed OEM currently lacks extensive experience of performing these two activities in-house, hence if the OEM will pursue this business model there will be a need to develop this. This could potentially be a disadvantage for this business model as it may require additional time and costs when setting up these two activities vertically in the organization. In order to handle the second-life EV battery business, the OEM will also need to enable the sales and logistics to the customers. Hence, there will probably be a need to have a dedicated department handling the contact with the customers. The activities here will encompass both pure sales activities but also aim to resolve other issues such as warranties and other related questions from the customers. It was found that the OEM interviewed has experience of these types of activities within its current business, but it will be necessary to set up a sales organization that posses battery specific knowledge required to handle this kind of sales.

The distribution of the second-life EV batteries to the customer could probably be done via a third-party logistics provider, which the OEM currently is used to deal with. If the OEM chooses to pursue this vertically integrated business model, there may be a risk that it may need to develop specific safety delivery packagings to protect the batteries. This is an aspect which currently not yet is established but it is important to consider as the regulations regarding this may be tightened in the future. From the empirical findings it was identified that the OEM does not consider these activities as belonging to their core strategy, hence the scope of their current business will be extended outside the core. Hence, this may be a barrier to the implementation of this business model as it may interfere with the overall corporate strategy. A disadvantage with this value creation and delivery setup is that it does not provide easy tools or practices for traceability of second-life EV batteries. Thus, when the batteries are delivered to the customer, the ownership of the legal rights for the OEM also ceases to exist. However, future regulations regarding producer responsibility may require OEMs to have an absolute, non-transferable requirement to recycle the battery at the end of its life. Hence, in this case the OEM may need to establish activities that improve control over the batteries after being sold, which already is required in China.

5.1.3 Value Capture

This business models fundamental logic is the sales of the second-life EV battery as a product, hence the pricing model is also based on this single *asset sales* transaction. The value captured in this model by the OEM is solely based on the price which the customer pays for the batteries, as no additional services are being offered (Osterwalder et al., 2010). However, a barrier to utilizing this pricing model is that it has been identified that it is hard to determine an accurate price for a second-life EV battery (Olsson et al., 2018). Hence, utilizing the price model of assets sales could be troublesome for the OEM as it either may price the battery too high, which could lead to less sold products. Or the case when the OEM charges a too low price which could lead to both a deficit but also that it may be troublesome for the OEM to increase the price of the battery later as it has established a price at the customers already. Related to the value capture of this business model is the costs that it required. Firstly, the OEM will need to make *investment costs* for setting up the supply chain activities needed to provide the batteries. Secondly, *transaction costs* will probably arise during the sales process (Hobbs, 1996). An advantage of this model is that the OEM will be able to take part in a direct monetary compensation at the point of sales, as the price is paid directly. Hence, the OEM may enjoy a low tied-up capital with this business model. Further, another advantage with this model is that after the point of sales, the OEM will not have any other unexpected costs arising from the use of the customer, other than potential warranty costs.

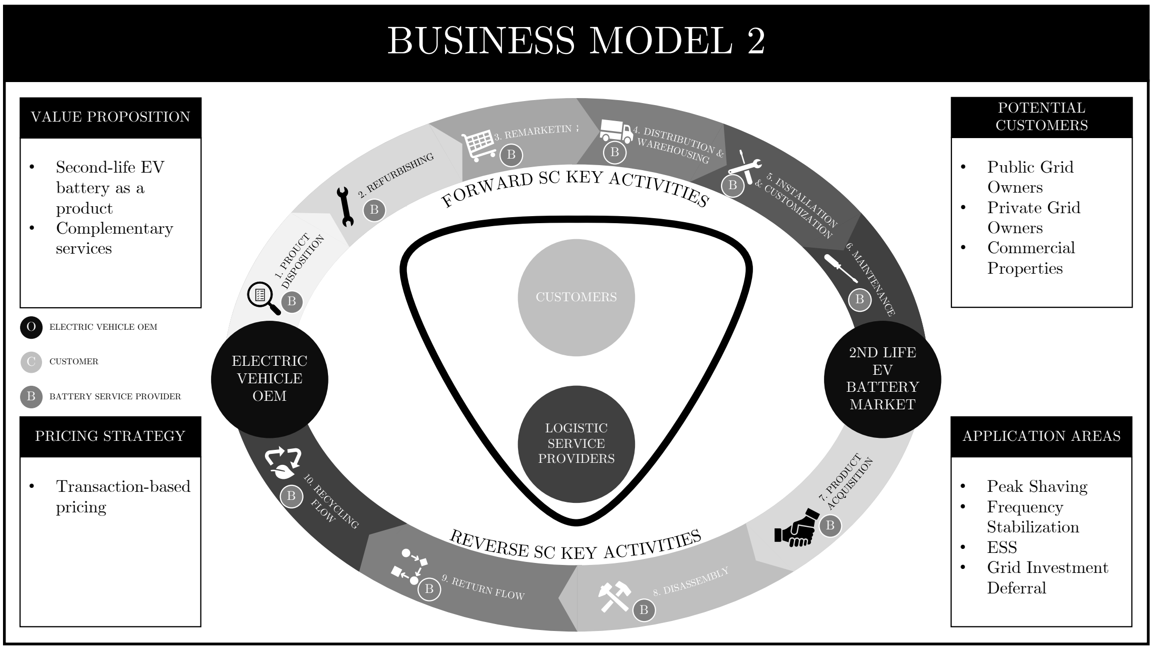

Figure 5.2: The extended analytical business model framework populated with the specific characteristics of Business Model 2.

5.2 Business Model 2

The second business model differs from the Business Model 1, as it not does not only encompass the OEM and a customer as actors. Rather, the logic is to utilize an external battery service provider that can help to facilitate the required activities for the second-life EV batteries business. A visualization of business model 2 is presented in figure 5.2.

5.2.1 Value Proposition

The value proposition offered to the customers is based on the second-life EV battery as the core product but with the option to provide additional services to the customer, prior, during, and after the purchase. Therefore, the value provided in this business model is extended compared to business model 1 which merely provided value to the customer based on the ownership of the product. In this model, value is added also by services such as customization, installation, maintenance, disassembly, return flow, and recycling. This is in line with what Tukker (2004, 2015) states about the additional services provided in a product-oriented PSS. Hence, this is a one point of contact solution where it can source the entire package around the second-life EV battery application. Thus, reducing the capabilities or activities the customer needs to consider do either develop internally or sourcing from another provider, compared to business model 1.

It is therefore likely that this will lower the barriers perceived by the customer when integrating second-life EV batteries within its business, as the complexity of the purchasing is lowered. With this business model, the OEM can ensure that the battery is maintained properly, as the value proposition encompasses these services. Thus, an advantage here is that the risk for malfunctioning batteries due to inaccurate handling may be reduced, wherefore the concern of safety issues may probably be mitigated. Moreover, as the value proposition is based on a product with additional complimentary services being provided, the customer buying logic is that it may optimize the total cost of ownership by the integrated services (Tukker, 2004, 2015). Further, the provider may benefit from both additional revenue streams and an increase within the duration and frequency in the customer relations (Baines et al., 2007; Reim et al., 2015; Tukker, 2015). An advantage of these improvements in customer relations is that it may help to foster traceability of second-life EV batteries. Hence, as a risk identified within business model 1 is that the OEM may lose the control of the second-life EV batteries, e.g. for producer responsibilities, the utilization of business model 2 may resolve this issue.

A disadvantage that this business model encompasses, in similarity with business model 1, is that the customer still needs to bear the risks that the ownership of the second-life EV batteries entail (Tukker, 2015). Further, the customer still needs to procure the batteries, thus an *initial investment* will be needed which will require the customers to have a certain amount of capital (Baines et al., 2007). On the other, hand from the OEM's point of view this may be regarded as an advantage as the OEM can discontinue the ownership of the batteries and transfer it to the customer, hence reducing the tied-up capital and enjoy direct payments.

5.2.2 Value Creation and Delivery

It may be seen that from the empirical findings, the customer segments that may be encompassed by the business model 2, will be rather similar to those identified as potential for business model 1. Firstly, this business model does not change the core of the value proposition, i.e. the product, compared to business model 1. Hence, the actors identified as valuing the ownership of an asset as a competitive advantage will still consider this business model as viable for them. Therefore, the business model 2 will not pose any barriers for actors basing their business model around long-term utilization of e.g. infrastructure assets for capitalization. The main difference of the value proposition established within this business model compared to business model 1, the additional services provided. The rationale of providing these services is, excluding the increased business scope, to mitigate the barriers conceived by certain customer segments to procure second-life EV batteries as just a product. Hence, as the additional services may reduce the complexity perceived by the customers, this may also help to unlock other customer segments that do not possess the technical skills or capabilities needed to install and maintain the battery system, either by themselves or by sourcing the service from other actors. Therefore, the customer segments identified as potentially being interested in purchasing the value proposition encompassed in business model 2 are: i) *Public grid owners*, ii) *Private grid owners*, iii) *Commercial properties*, and iv) *Residential properties.* It should be noted that these segments are rather broad segments where subsegments may exist. Hence, part of the segments found to be unlocked by the reduced complexity for the customer within this business model, as compared to business model 1, may be located within one of these customer segments.

From the customers segments identified above, the associated application areas found as potentially suitable will also be highlighted here. The public grid owners have the strongest interest in using second-life EV batteries for i*) Peak shaving*, ii) *Frequency stabilization*, iii) *ESS*, and iv) *Grid investment deferral.* The customer within the commercial property segments will use second-life EV batteries in the following application areas i) *ESS*, ii) *Peak shaving*, iii) *Grid investment deferral.* The customer segment residential properties are deemed as interested in the application area: i) *ESS*.

In order to create and deliver the value proposed within this business model, the supply chain setup and constellation will differ compared to the one outlined in business model 1. The main idea in the value creation and delivery aspects of this business model is to incorporate an external battery service provider into the supply chain. Thus, the OEM will not solely be responsible for performing the activities in this setup. The scope of responsibility for the OEM will be limited to providing the second-life EV batteries to the external battery service provider. Thus, the second-life EV batteries will be provided as they are, hence the OEM will not perform any sorting or testing internally. The OEM will therefore only collect the batteries from the first life users within the vehicles and deliver them to a battery service provider. The setup concerning the delivery of the battery from the OEM to the battery service provider is not concerned within this business model, rather it describes the fundamental scope of the activities performed by the OEM.

The battery service provider will, compared to business model 1, take responsibility for the activities found as necessary to deliver second-life EV battery applications, i.e. product disposition, refurbishing, remarketing, distribution and warehousing, installation and customization, disassembly, and reverse flow. Hence, the OEM needs to find a service provider that has the right capabilities and experience of performing the required battery specific tasks found to be necessary prior to delivery of the second-life EV battery to the customer. In order to decrease the need for the OEM to set up a remarketing organization related to the second-life EV battery business, it will also be recommended that this activity is located within the scope of the activities performed by the battery service provider. Hence, the battery service provider will serve as a full-service provider taking responsibility for the majority of the activities concerning the second-life EV batteries, while the OEM will merely supply the batteries (Olsson et al., 2018).

Apart from the sales activities and the quality control activities, the battery service provider will also offer the customer additional complementary services within this business model (Tukker, 2015). In business model 1, this was not included as it was identified as outside the scope of the OEM's business. However, in the case of the battery service provider this is deemed as suitable to include in this business model as it extends the business opportunity here. The complementary activities identified as possible within this study are i) *Installation and customization*, ii) *Maintenance*, iii) *Disassembly*, iv) *Return flow*, and v) *Recycling*. Hence, the customer will be able to establish e.g. maintenance contracts with the battery service provider is able to reduce the needed battery service competence located in-house at the customer. An advantage stemming from the increased customer contact through the extended relationship between the customer and the battery service provider, is that the traceability of the second-life EV batteries may increase (Tukker, 2015).

The traceability is deemed to improve as the frequency and duration of the customer contact will be increased, wherefore the battery service provider will have better insights into how the batteries are being handled at the customer. Further, as the battery service provider offers the customer disassembly and disposal services for the used batteries, a reverse supply chain for the batteries back to the OEM, or directly to a recycler, may be unlocked. Hence, as the OEM has obligations regarding producer responsibility that may increase in future legislation, this could mitigate the effort of locating and controlling the batteries for the OEM. An implication of this model is that the end-customer has conducted all of its contact with the battery service provider, hence it is no longer reliant on the OEM. Therefore, a risk could be that the customer does not care what type of battery that the service provider offers to the customer, thus the battery service provider could potentially act opportunistic and change or add additional OEMs as suppliers of the second-life EV batteries. Hence, the competition could increase which eventually could hamper the monetary compensation that the OEM could receive. However, the researchers do not deem this as a major risk as it probably could be resolved by engaging in a close relationship with the battery service provider. Further, the complexity of the business setup may increase as the constellation increase with an additional actor. However, compared to business model 1, the OEM will only have to handle one relation with the battery service provider as does not engage in contact with the customer, hence the OEM may enjoy a decrease in transaction costs. Further, an advantage of this business model is that the OEM will be able to focus more on its core business as the activities needed in order to provide and establish the second-life EV battery business is handled by an external actor, i.e. strategic outsourcing (Kremic et al., 2006).

Within this business model, the constellation described to handle the activities only incorporates a *single battery service provider*. To further decrease the risk which may stem from relying on a single provider, e.g. opportunistic behavior or if the actor turns bankrupt, the OEM may add additional battery service providers. A disadvantage of doing so is that it may impose more resources on handling the additional relations and the logistic activities of distributing the second-life EV batteries to the providers. However, in the case of entering different markets this may be necessary. An advantage stemming from this business model compared to business model 1, is that it may increase the safety of the second-life EV battery applications. The reason for this is due to the fact that the battery service provider offers the customer qualitative installations and maintenance services, hence the OEM could be more secure in that the batteries are handled in a secure manner as the OEM can provide safety instructions and trainings to the battery service provider, which may not be financially justifiable in business model 1. A benefit stemming from this is also that it may be better for the OEM's brand impact, as it reduces the risk for accidents within the second-life EV battery installations which otherwise negatively could affect the brand identity of the OEM.

5.2.3 Value Capture

The value captured within this business model may be divided into a twofold structure. Firstly, the OEM enjoys a monetary compensation when the battery is being sold to the customer, hence its gets paid similar to the pricing model as described in business model 1 (Tukker, 2015). Secondly, the battery service provider retrieves revenue from the complementary services being offered to the customer and therefore this business model contains additional revenue streams compared to business model 1 (Tukker, 2004, 2015). From this, it might be concluded that the OEM does enjoy larger or extended revenue streams compared to business model 1, but this is not true. Rather, one needs to consider the value the OEM may save from eliminating the needs for investments related to establishing second-life EV battery capabilities in-house. Also, the OEM may save substantial amounts from reducing the scope of the activities such as sales and logistic activities, hence the eliminated variable costs of the second-life EV battery business should also be considered when measuring what value this business model provides for the OEM.

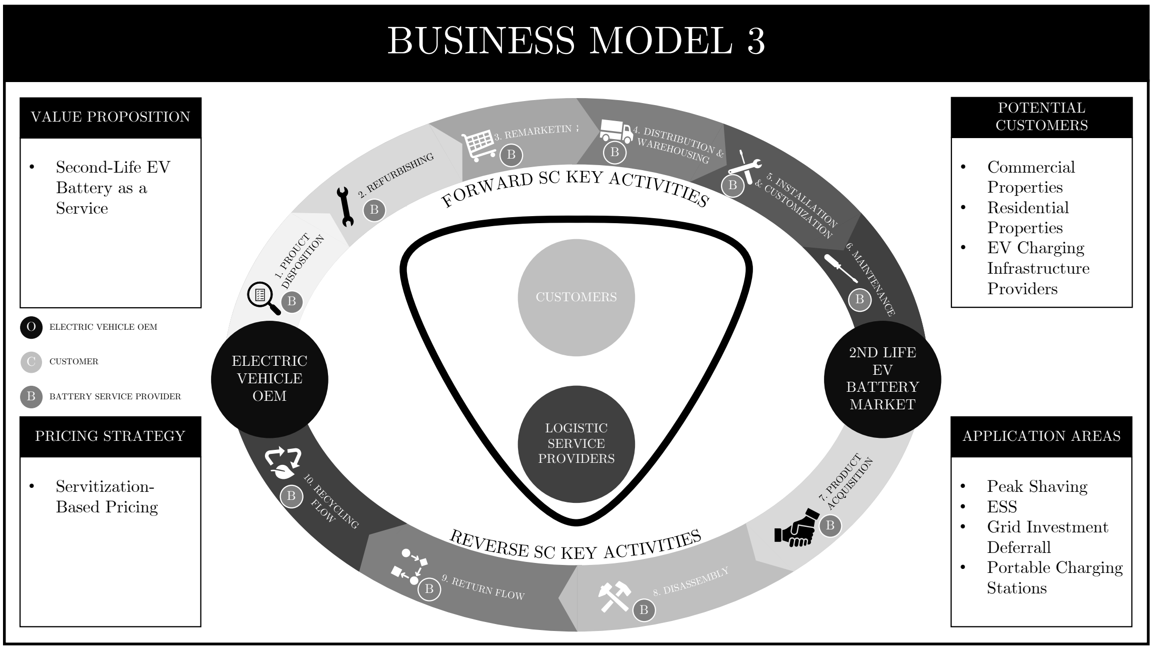

Figure 5.3: The extended analytical business model framework populated with the specific characteristics of Business Model 3.

5.3 Business Model 3

In this third business model, the collaboration between the OEM and the external battery service provider that was described in business model 2 is further extended. The relation between the OEM and the third-party provider will be a collaboration that serves to maximize the mutual value of both actors by providing the value of the second-life EV batteries to the customer as a service. A visualization of business model 3 is presented in figure 5.3.

5.3.1 Value Proposition

The core in this value proposition is different, compared to the two previous business models outlined, as it does not revolve around the product. Rather, the logic behind this value proposition is that the customer is offered *the utility that the second-life EV battery* usually creates, i.e. battery storage capacity, instead of the ownership of the battery. Therefore, the customer is still able to achieve and gain the same utility that buying a second-life EV battery would have offered, but instead the customer procures a *service* that offers this value. In this business model, the customer purchases the service buy describing and outlining the specification that it wants to have fulfilled, e.g. a certain level of kWh in storage or a power capacity in kW it wants to have. Thereafter, this specifications is set to be delivered by the provider and customer may thus only concern about procuring the specifications according to their demand. The seller does instead retain the ownership of the batteries and charges the customer according to the used amount of services (Tukker, 2004, 2015). Hence, the value proposition may be seen as a PSS system which uses the second-life EV battery as the product and then adds on additional services needed in order to provide the utility to the customer. As the business model encompasses a structure where the customer buys the value proposition around a functional unit, e.g. kWh, the business model may best be described as a *result-oriented PSS*-model(Baines et al., 2007; Reim et al., 2015; Tukker, 2004, 2015).

One implication of implementing a result-oriented business is that it eliminates entry barriers that the customers otherwise would have perceived when contemplating whether or not to procure a second-life EV battery. Firstly, the need for the customer to make a substantial investment can be eliminated or at least heavily mitigated, depending on the setup for customization. Hence, the customer does not need to have the financial resources available for an upfront investment, which the empirical findings have identified as being a potential hinder for some customer segments when deciding about if they should use batteries or not (Tukker, 2015). Secondly, as the ownership of the batteries is retained by the seller, the customer may also enjoy a reduced perceived risk of the technology. As a major hassle identified for potential customers when deciding about whether they should buy new or second-life batteries is that currently the technology uncertain of the second-life EV batteries is rather high. Hence, the customer does not know if the second-life EV battery may fulfill the specifications outlined by the customers. When a customer instead procures the utility of the second-life EV batteries a result-oriented value proposition, the customer may be guaranteed that it will always have the right capacity available. Therefore, this value proposition reduces the entry barriers for customers, which may be useful when setting up a business in a newly, not yet established market where the uncertainty overall is deemed as rather high.

A disadvantage of this model is that the OEM instead needs to increase its risk burden as it retains the ownership of the batteries, hence it will not enjoy the same direct monetary compensation and asset relief as in the two other business models. The OEM will also see an increase in tied-up capital when retaining the ownership of the second-life EV batteries in the result-oriented model. Another advantage offered by this type of value proposition for the customer is that it may help reduce the costs otherwise associated with the ownership of a product, especially since it provides clear information about the total cost of ownership of the utility. Hence, as the customer no longer needs to care about e.g. maintenance and repair, it has full control over the cost structure as it is very straightforward what it pays for, i.e. charged per functional unit used (Tukker, 2015). An implication for the OEM that this business model encompasses is the retained ownership.

The OEM may enjoy advantages from this as it improves the potential for the OEM to re-use the second-life EV battery at multiple applications and also that it may improve the end-of-life activities. Firstly, the OEM may thus use the second-life EV battery within multiple applications, e.g. subsequently at different customers, hence the resource utilization of the batteries may be improved which the OEM may gain increased revenue from. Secondly, as the OEM retains the ownership of the batteries, it can also more efficiently plan how and when the batteries should be recycled when it reaches end-of-life. Hence, as the current market for recycling second-life EV batteries is not fully developed, the OEM may benefit monetary from e.g. postponing the recycling of the batteries to an optimized point in time. Thus, as the OEM retain the ownership, this optimization may be much easier compared to if the OEM needs to regain the batteries due to producer responsibility, in business model 1 and 2. An advantage of this model that may benefit the environment is that due to the retained ownership of the second-life EV batteries, the OEM will also be keener to design the batteries for longer endurance. Hence, as the OEM wants to optimize the utilization of its resources, i.e. longer life-span of the second-life EV batteries, this will may also help to reduce the environmental impact in two ways. Firstly, as fewer batteries are scrapped directly, and secondly as fewer new batteries need to be produced (Lüdeke-Freund et al., 2019).

5.3.2 Value Creation and Delivery

Within the empirical findings, it has been derived that the customer segments being interested in procuring the utility of a second-life EV battery accordingly to this business model, i.e. a result-oriented model, differs a bit from the ones identified within the first two business model. Firstly, it may be concluded that a key selling point is whether the customer's business model is built around the ownership of an asset or not. Hence, actors such as private grid providers that may have established their complete business model around the asset ownership of a product, may prefer to also procure the second-life EV battery as a product, i.e. business models 1 and 2. Hence, as the ownership of the second-life EV battery is retained in this model, this imposes a barrier for the segments generally interested in asset ownership. Secondly, the retained ownership of the OEM also imposes other changes with regards to the scope of segments.

As the customer no longer has to bear the initial investment in the second-life EV batteries, this may also unlock the utility for actors that otherwise would not have afforded to procure the batteries. Hence, actors with less capital available, e.g. smaller firms or private persons, could potentially much easier be targeted with this business model. Further, another insight affecting the possible segments for this business model is also related to the business model of the customer. Hence, for customers not characterized by having a core which revolves around energy storage or solutions, the two other business model have, at least to some extent, required them to have a certain level of understanding regarding the technical aspects of the second-life EV batteries. However, when purchasing the second-life EV batteries as a value proposition based on a result-oriented model, the customer merely needs to specify what specifications and needs it has and hence the seller will provide a purposeful solutions. Thus, due to the fact that this model mitigates some technical barriers for the customers, this also opens up earlier customer segments that otherwise would have stayed unlocked. Thus, the customer segments deemed as viable for the business model 3 are i) *Commercial properties*, ii) *Residential properties*, and iii) *EV Charging Infrastructure Providers.*

From the customer segments outlined above, a number of associated application areas have been identified and derived. Firstly, the customer segments commercial properties are mainly interested in the application areas i) *ESS*, ii) *Peak shaving*, iii) *Grid investment deferral.* Secondly, customers within the segment residential properties have expressed that the following application areas are viable i) *ESS.* Finally, the customer segment EV Charging Infrastructure Providers will most likely be interested in the application areas i) *Grid investment deferral*, ii) *Portable charging stations*, iii) ESS, and iv) Peak shaving.

To establish the value proposition of this business model, measures to create and deliver it to the customers need to be set up. In this business model, the value creation part is similar to the one proposed in business model 2 with some important differences. Firstly, the scope of responsibility for the OEM encompasses, likewise business model 2, that it should collect the second-life EV batteries from its first life application, and then provide it to the battery service provider. In business model 2, the OEM transfers the ownership to the customer after the point of sales, however as this business model is based on a result-oriented PSS model, the OEM will retain the ownership of the batteries in this business model (Tukker, 2015). Hence, the OEM will therefore be the legal owner of the second-life EV batteries prior, during, and after its use within the customer applications. Hence, the OEM's legal role will be extended in the supply chain, however, this does not necessarily mean that it will have a major effect on the scope of the organization required inside the OEM to handle the activities. This is true since a battery service provider may take responsibility for the sales organization within this model as well (Olsson et al., 2018). However, it is worth noting that the OEM needs to be aware that this business model may require that it has, or can establish, the right legal resources inhouse in order to draft the contractual agreements in a satisfying manner. Hence, if this is identified as costly, this could potentially be a disadvantage of this business model as the core idea behind the business model 3 is the retained ownership of the second-life EV batteries at the OEM and the possibilities it unlocks.

The activities performed by the external battery service provider will be similar to the ones done in business model 2. Firstly, the battery service provider will need to perform activities related to the quality control of the batteries, i.e. sorting, testing and refurbishment. Secondly, the provider will also need to establish a suitable sales organization that can respond to the requirements of the customer and that have the right competence needed in order to sell a service. Moreover, the services earlier offered as complementary services, i.e. installation and customization, maintenance, disassembly, return flow, and recycling, will no longer be part of the service offering that the customer may request. The services will of course still be done, but it will not be part of the portfolio of services that the customer actively may choose to pursue, as it pays for the result and thus does not need to care about how the utility is provided. An advantage here is that the battery service provider may take advantage of the opportunity to optimize the activities needed in order to withhold the performance of the offered value propositions. Hence, as the battery service provider now more actively will know e.g. the timing required for maintenance, it can optimize its resources better, hence enhancing the efficiency for the provider (Kremic et al., 2006).

Further, an advantage that the OEM can enjoy here does also stem from the optimization of resources, as it by retrieving data from the battery service provider about customer behavior, can utilize these insights when designing the EV batteries. Hence, by retaining the ownership of the batteries, the OEM will also be able to more carefully extract understandings of how the second-life EV batteries are being used and thereby utilize this feedback-loop within their development processes. As this business model encompasses a more complex and advanced setup of routines and activities needed to create and deliver the value, this will require the OEM and the battery service provider to have a closer collaboration with each other. This collaboration may be done in different ways, however, one way to do it would be to set up a strategic alliance. As both the OEM and the battery service provider contribute with resources in this constellation, it could be a way for both actors to maximize the value for both parties. Hence, by forming a strategic alliance the OEM may benefit as it can extract larger values in combination with the battery service provider over a longer time period, compared to what would be possible within business model 1 and business model 2. Further, the strategic alliance may also reduce the risks for opportunistic behavior as the mutual dependency halters the benefits of conducting such behavior (Hobbs, 1996).

Another advantage that the OEM may achieve from this business model is that the control and traceability of the second-life EV batteries can be guaranteed. Hence, as the

OEM retains the ownership of the batteries it can be sure that it can control how and where the batteries are being used but also how the end-of-life activities, i.e. recycling, should be conducted. Thus, this business model does promote, more than business model 2, the ease for the OEM to fulfill increased requirements for producer responsibility. A potential disadvantage of this business model is that due to the increased legal involvement of the OEM, it can also be a risk if an accident occurs (Olsson et al., 2018). Hence, if e.g. a thermal propagation occurs in a second-life EV battery, the OEM may due to the legal ownership be more affected compared to the case when the ownership has been transferred, i.e. business model 1 and business model 2. Hence, this may thereby have a negative impact on hand the brand identity of the OEM, and on the other hand also financially if legal pursuits are made, e.g. lawsuits.

5.3.3 Value Capture

As this business model is built around a result-oriented PSS model, this will also mean that the value capture mechanisms differ compared to the previous pricing models described in business model 1 and business model 2. As the core determinant of the price paid in this business model is the *functional unit*, e.g. kWh delivered and/or stored via the battery, the pricing mechanism will also be crafted from this. Hence, the strategic alliance between the OEM and the battery service provider needs to determine a suitable price for this functional unit. Next, the battery service provider charges the customer this price multiplied with the volume of the unit consumed (Tukker, 2015). Hence, the pricing mechanism will be more complex and will require the use of some kind of monitoring, either manually or automatically, to determine what price the customer should be charged. Another pricing strategy that could be viable is to charge the customer a fixed price for the result provided, i.e. charge for a *functional result* (Tukker, 2004).

The costs related to this business model will be similar to the ones outlined in the previous business model. However, a significant difference will be that the services earlier provided as complementary now will be performed within the result-oriented price. Hence, the customer will not be charged extra for these services, apart from special services such as e.g. customization, etc. Thus, the battery service provider needs to ensure that these costs are understood and calculated when the strategic alliance is determining the profit potential for the value proposition. Hence, from this topic, a key part of the value capture part in this business model is the profit-sharing issue between the two parties.

As the OEM and the battery service provider both engages with different resources and capabilities, contractual agreements for how value should be shared between the parties needs to be outlined. This should be done prior to conducting business in order to reduce the risks for later misunderstandings and conflicts, which otherwise could occur and thereby hamper the relation and collaboration between the two parties. Moreover, the scope of the profit-sharing should be outlined in this agreement and cover aspects that may be seen as related but potentially outside the scope of the collaboration. Part of these activities that may fall under this is additional services, e.g. customization, and recycling revenues that the OEM extracts when sending the batteries to their end-of-life disposal, hence these collaborative issues may be seen as a disadvantage of this business model. Another disadvantage for the OEM within this business model stems from the need to retain the ownership of the batteries. Hence, a negative implication is that it may affect the financial bottom line of the OEM, as the tied-up-capital increase.

5.4 Business Models Comparison

In this section, a comparison of the three business models designed in this master thesis will be presented and discussed. The discussion will compare the business models with regard to the three different dimensions and factors influencing CEBM for EV batteries. Moreover, the insights from the analytical framework, and the similarities and differences of the related findings will be discussed. The comparison of the business models is presented in table 5.1.
The three business models designed within this study have a value proposition that differs depending on the different sub-areas. Firstly, it was found that the application areas found as suitable are different. The application areas identified have been associated with a potential customer segment, hence the combination of the application area and the customer segments has a significant impact on the chosen business model for second-life EV batteries. This is in line with Osterwalder et al. (2010), who claim that the value proposition needs to be designed in accordance with the demand and requirements of the potential customer segments. Moreover, the allocation of the risk of ownership of three business model have been distinguished as an important differentiator between the business model. As business model 1 allocates the risk merely at the customer, whereas in business model 3 the risk is taken by the OEM and the battery service provider. According to Tukker (2004, 2015), in business models having a value proposition based on result-oriented PSS, the provider of the services faces the risk and uncertainty related to the ownership of the goods used to derived the revenue. Hence, when comparing the business models it is reasonable to emphasize how the ownership of the risks is altered when moving between a traditional product sales business model, i.e. business model 1 where the customer bears the risk, compared to a business model based on providing a result, i.e. business model 3 where the OEM and the battery service provider bears the risk (Tukker, 2004, 2015).

Another insight categorizing the different business models is how well the specification can be fulfilled for the customer. Hence, depending on the chosen business model, the probability for the customer to retrieve a solution that fulfills its requirements and demands is changed. As the value proposition of business model 1 and business model 2 transfers the ownership of the second-life EV batteries to the customer, the associated risk mentioned above is also reflected to the customer. Hence, the risk that the procured solutions do not match the specification also increases. However, business model 2 mitigates this risk due to the complementary services being offered, thus reducing the risk that the customer e.g. does not possess the required skills or knowledge to utilize the capabilities of the EV batteries in-house. Business model 3 on the other hand removes most of the risks associated with specification fulfillment as the provider, i.e. the OEM and the battery service provider, is responsible for fulfilling the specified result of the customer. Thus, as long as the customer has the capabilities needed to specify a purposeful result, the risk of not achieving the wanted result could probably be mitigated. Hence, for customers used to deal with battery technology business model 1 and business model 2 may be useful as it probably have the competencies needed, thus being advantageous for those segments. However, if the OEM wants to target other customer segments it would be more advantageous to utilize business model 3. Thus, as the analytical framework derived that it is useful to determine how the performance is affected by the different value propositions, it has been found that depending on which actor the perspective is taken, the three business models differ.

BUSINESS MODEL COMPARISON				
KEY DIMENSIONS		BUSINESS MODEL 1 *Second-Life EV Battery as a Product*	BUSINESS MODEL 2 *Second-Life EV Battery as a Product with Services*	BUSINESS MODEL 3 *Second-Life EV Battery as a Service*
VALUE PROPOSITION	Application Areas	• ESS • Peak Shaving • Grid Invesment Deferral • Frequency Stabilization	• ESS • Peak Shaving • Grid Invesment Deferral • Frequency Stabilization	• ESS • Peak Shaving • Grid Invesment Deferral
	Customer Segments	• Private grid owners • Public grid owners • Commercial properties	• Private grid owners • Public grid owners • Commercial properties • Residential properties	• Commercial properties • Residential properties • EV Charging Infrastructure Providers
	Risk of Ownership	• Risk of Ownership at Customer	• Risk of Ownership at Customer	• Risk of Ownership at Seller
	Specification Fulfillment	• No guarantee that the customers specifications are fulfilled	• No guarantee that the customers specifications are fulfilled but additional services are offered which helps customers	• Guarantee that the customers specifications are fulfilled
VALUE CREATION AND DELIVERY	Supply Chain Activity Responsibility	• **OEM**: EV Battery Supply, Product Disposition, Refurbishing, Remarketing • **Customer**: Installation, Customization, Maintenance, Disassembly, Recycling	• **OEM**: EV Battery Supply • **Battery Service Provider**: Product disposition, Refurbishing, Remarketing, Installation, Customization, Maintenance, Disassembly, Recycling • **Customer**: Installation, Maintenance, Repair, Disassembly, Recycling*	• **OEM**: EV Battery Supply, • **Battery Service Provider**: Product disposition, Refurbishing, Remarketing, Installation, Customization, Maintenance, Disassembly, Recycling
	Relationships and Partnerships	• Relationships must be established and maintained with several customers	• Close partnership with one or a few third party battery service providers providing the battery activities	• Extremely close partnership (strategic alliance) with a battery service provider that provides the activities linked to batteries
	Required Initial Investment	• All activities and capabilities must be developed internally	• Establishing close partnership s with third party provider(s)	• Establishing a strategic alliance with a third party service provider • Ownership of Second-Life EV batteries which results in tied-up capital
VALUE CAPTURE	Price Model	• Charge one time at the point of sale	• Charge one time at the point of sale • Charge for additional services	• Charge for number of functional units provided • Charge for providing a specified result
FACTORS INFLUENCING THE CEBM	Safety Handling	• Low due to the low level of control the OEM has over the battery after point of sale • Risk that the installation and/or maintenance is done by an non-authorized actor	• High since the installation and maintenance are made by authorized actors. • Second-Life EV batteries are not monitored and controlled	• Very high since all the operations and services are performed by authorized actors
	Traceability	• Traceability is poor due to the non existing contact with customers or batteries after the point of sale	• Traceability is promoted due the increased frequency and endurance of customer contact via the battery service provider • No legal contractual obligation for customer to return the battery to OEM	• Total control over the Second-Life EV batteries since the OEM owns them
	Technology Uncertainty	• High uncertainty for the customer • Quality and life time of the Second-Life EV battery is unknown • Warranty can reduce the uncertainty	• High uncertainty for the customer • Quality and life time of the Second-Life EV battery is unknown • Battery service provider official service may decrease the perceived risk • Warranty can reduce the uncertainty	• No technology uncertainty perceived by customer due to the fact that the customers purchase a service and not a product
NOTES		*: Customer may choose to perform these activities in-house or by sourcing from another external provider		

Table 5.1: The table shows a comparison of the three business models.

Business model 1 offers the least risk for the OEM, but a consequence and disadvantage of this is that a barrier may be perceived by the customer as the risk of not achieving specification fulfillment may be posed. Hence, the OEM may risk losing revenue opportunities if it tries to minimize the other risks. A disadvantage of business model 1 is that the OEM will have less control of the batteries, as the potential for traceability is reduced. Moreover, the OEM could also risk being affected by the lower level of safety of the handling of the second-life EV batteries that business model 1 offers.

On the other hand, business model 2 and especially business model 3 may facilitate a risk reduction for the customer, hence the barriers for it to procure the value propositions may be eliminated, or at least mitigated. Further, an advantage for OEMs with these two business models is that they improve the traceability of the second-life EV batteries which have been identified as in important aspect to consider as emerging laws and policies may require this. Further, an advantage of business model 2 and business model 3 is that they may lead to better safety as it will be installed and maintained by personnel with the right competencies, hence the risk for negative brand impact in case of e.g. accidents may be reduced. However, a disadvantage for the OEM and the battery service provider is that it needs to take larger risks regarding the specification fulfillment, and for business model 3, risks associated with the ownership of the second-life EV batteries.

From the empirical findings it has been derived that the key activities within a CEBM for second-life EV batteries could be extended, compared to the original set of key activities established within the analytical framework (Lambert et al., 2017). Hence, the activities of installation and customization, maintenance, disassembly, and recycling have been incorporated into the framework, thus extending it with the empirical findings. The activities performed within the supply chain for the three different business models do not differ, however the actor responsible for performing the activities is different. An advantage of business model 1 is that the OEM solely is in charge of the activities, hence coordination between different actors does not exist. On the other hand, a disadvantage is that the OEM needs to establish all the necessary activities in-house, compared to business model 2 and business model 3 where the battery service provider is responsible for the majority of the activities. Hence, business model 2 and business model 3 offer the OEM an advantage as it requires the least resources, capabilities, and investments in order to establish a business model around second-life EV batteries. Moreover, an additional advantage of business model 2 and business model 3 is that it facilitates relationships with the end-customer, hence offering a way to achieve a feedback loop into the development processes, which otherwise would have been lost, as in business model 1.

Another main difference identified within the three business models designed is how value is captured. An advantage of business model 1 is that it offers the OEM an easy pricing strategy, i.e. asset sales, that it is used to deal with. However, a disadvantage with this pricing mechanism is that it may be hard for the OEM to know how to price the second-life EV batteries, hence a risk may be that the OEM sets a too low initial price that can be hard to change later on. An advantage with the pricing strategies found in business model 2 and business model 3, is that it offers the OEM and the battery service provider a way to achieve additional revenue streams. Also, they may help to increase the sustainability of the revenue streams as it can utilize them over a longer time span, especially in business model 3 where the OEM and the battery service provider can utilize the second-life EV battery as long as possible, hence crafting revenue streams from the result-oriented pricing strategy(Tukker, 2004, 2015).

6 CONCLUSION

The purpose of this master thesis has been to explore what types of business models and associated supply chain designs that are suitable for vehicle OEMs to adopt in order to enable second-life EV battery applications. To fulfill the purpose, an analytical framework was developed encompassing three dimensions of a CEBM. Utilizing this analytical as a backbone for the research, a case study was conducted exploring the views of a set of interviewees at a vehicle OEM. Further, the data collection was also extended with additional interviewees encompassing external experts and potential customers for second-life EV batteries.

From the empirical data gathered during the semi-structured interviews, a set of findings have been derived. The future market for second-life EV batteries may encompass, but are not limited to, the following customer segments namely i) *Private grid owners*, ii) *Public grid owners*, iii) *EV charging infrastructure providers*, iv) *Residential properties*, and v) *Commercial properties*. For these customer segments, potential application areas where second-life EV batteries have been deemed as suitable are i) *Backup power*, ii) *ESS*, iii) *Frequency stabilization*, iv) *Grid investment deferral*, v) *Internal use*, vi) *Peak shaving*, vii) *Portable charging stations*. Within the study, it has been identified that a set of prerequisites exists that needs to be fulfilled in order to enable the use of second-life EV batteries. Firstly, the OEMs need to ensure that the batteries are *safe and fulfill the requirements* the customers specify. Secondly, it has been found that a prerequisite that needs to be met in order for the market to take off, is that the OEMs can deliver a *steady supply of batteries*, preferably the OEM should also consider designing these batteries for use within second-life applications. Finally, the *price* set for the second-life EV batteries should be lower compared to the price a new battery is put to the market for.

By combining the insights of the analytical framework and the empirical findings, *three potential business models* for second-life EV batteries have been designed. In *business model 1* the fully vertically integrated OEM offers the second-life EV battery solutions as a product to the customer. *Business model 2* extends business model 1 with a battery service provider who offers additional complementary services as installation and maintenance. Finally, *business model 3* keeps the same actors as in business model 2, however, the pricing mechanism is swapped to a result-oriented PSS model.

As highlighted in the introduction chapter, a few earlier studies have explored how business models for second-life EV batteries may be designed (Jiao et al., 2016, 2017; Olsson et al., 2018). In the studies by Jiao et al. (2016, 2017) the business models of some EV stakeholders were highlighted. Further, Jiao et al. (2016) proposed that there is room for additional studies exploring how the value capturing mechanisms of a business model for second-life EV batteries should be designed. This study is contributing by exploring how vehicle OEMs could design their value capturing mechanisms in the emerging market for second-life EV batteries. Further, the study by Olsson et al. (2018) proposed four business model scenarios that vehicle OEMs may pursue for the second-life EV market. This study has extended the research of how vehicle OEMs may adopt CEBMs and their associated supply chains for second-life EV batteries, by doing a comparative study exploring the potential for three different CEBMs. Hence, this study contributes by exploring the potential for the three business model doing a detailed comparison of the three identified core dimensions for a CEBM. Moreover, this study has also contributed by matching customer segments with potential application areas and then addressing suitable CEBMs for this. Further, this study has also built on the study of Olsson et al. (2018) by further looking into potential barriers and prerequisites for CEBMs for second-life EV batteries, as encouraged by Olsson et al. (2018).

6.1 Managerial Implications

It has been identified that an important aspect that the OEMs need to consider when entering the market for second-life EV batteries is to promote the *traceability* of the batteries. A way to achieve this is to choose either business model 2 or business model 3, where the latter one offers the highest degree of traceability. Further, an important insight gained within this study is that what currently halters the market from evolving is not the uncertainty of the customers, many are already prepared and waiting for the market to take off. Rather, it is the OEMs that are lagging behind, hence they need to accelerate their engagements and collaborations in order to be ready when the supply of second-life EV batteries take off.

Further, as the market for second-life EV batteries currently does not exist, the characteristics of the present actors and their roles are yet to be fully explored. Hence, the details of the partnerships required to perform the second-life EV battery business models proposed in this model, i.e. battery service providers, can currently be cumbersome to assess. Therefore, the discussion about what types of actors that will take this role is currently in progress, and the answer is yet to be determined, hence affecting what types of business models that the OEM's will be able to use in the future second-life EV battery landscape.

Due to the non-existing market, it is hard to price according to competition. Further, as the market for first life batteries barely have begun to evolve today, there is also much uncertainty regarding how the price of new batteries will develop during the next decade. As the price of used EV batteries depends on the value either paid or retrieved from the recycler, the development of the recycling technology will also have a great impact on the potential price that a customer will be ready to pay for second-life EV batteries. Thus, if the rate of process innovation at the recycler is reduced, there is a risk that the potential value of second-life EV batteries may suffer. Therefore, an issue that the OEM currently faces when developing their CEBM for second-life EV battery applications is how to price their future applications, hence this could pose a barrier when setting up the business model.

Further, connected to this rapid development of the EV batteries another problematic barrier for the use of second-life EV batteries arise. As the batteries evolve quickly, this may probably cause a rapid incline in performance over the coming years, while at the same time the increase in volumes sold will potentially shrink the prices of the batteries. As the batteries that are candidates for use within second-life applications already are a couple of years old and have degraded to a certain amount, there will be a dilemma between choosing old versus new batteries. Hence, a customer needs to get a value proposition that encompasses second-life EV batteries that are priced low enough to be more attractive than the better and cheaper new batteries.

Another barrier connected to the uncertainty of the battery technology concerns the rapid development of EV batteries that currently takes place. As the chemistry may change as often as every 24 months, there is a risk that standardization may not be achieved in a while. Customers that demand a steady flow of similar batteries may be reluctant to utilize second-life EV batteries as they could have issues of achieving economies of scale due to the variating flow of batteries.

An insight gained by the researcher in this study is the importance of acknowledging the uncertainty of how future legislation will be drawn. Hence, as major works currently are being conducted by influential governmental organizations such as the European Parliament, this will have an impact on how the second-life EV battery business model may be designed, according to the e.g. new laws and policies. One coming policy that OEMs need to consider when setting up their second-life EV battery business is the new battery directive that currently is drafted. It is yet to be known how this will affect the industry but decision-makers within the OEM should stay alert. Further, the scope of the producer responsibility of the OEM may be extended in the future and the requirements tightened. The outcome and impact of this change is still unknown, but a possible change is that the OEMs no longer may be allowed to use contractual agreements to eliminate the producer responsibility of batteries when selling the batteries to second-life applications. Hence, it could impose the OEMs a requirement that they always have to ensure end-of-life recycling for the EV batteries they originally put to market.

When the supply chain is extended with these activities the costs will also increase, but it has been seen that many actors forget to take this into account when calculating the business case. Thus, even though the CEBM may provide additional revenues, the costs will also increase, and therefore there is a risk that the profit margin will be lower when implementing a CEBM if the company fails to deal with the increasing scope of activities in a cost-efficient manner. Moreover, as the OEMs traditionally are not used to CEBMs, they need to acquire the right skill-set and capabilities in order to succeed with the adoption of this new business model logic. Finally, it may be concluded that the market for second-life EV batteries offer a great potential for OEMs to tap into, which could be done utilizing either of the three business models outlined in this paper.

6.2 Future Research

Currently, few research studies have been conducted in the borderlands between CEBMs and second-life EV batteries. This study has aimed to explore some of the characteristics of the business model projected to take place in this emerging market. Firstly, a number of limitations have been identified as affecting the outcome of the study. As the thesis is a single case study, the findings related to the OEM is only based on a single actor, hence there may be room for alternative views. Further, the proposed business models are designed according to the current state of technological innovation of EV batteries, hence this could be affected as they continue to develop. Moreover, as the market currently does not exists, this study could not include the views of the future battery service providers. Hence, their perspective of the future market and the business model are not reflected in the outcome.

In this theoretical field, there is yet room for exploration and some areas have been found as especially interesting. Firstly, the role of the emerging battery service provider is urged to be explored as this may shape the future industry and the utilized business models. Secondly, it could be useful to explore the detailed characteristics of the collaborations and the associated supply chain structure in the future industry. Thirdly, as the market currently does not exist, there is room for emerging actors with yet unknown roles. Hence, exploring these and the resources utilized could potentially be on the research agenda. Finally, as previously mentioned, exploring the upcoming laws and policies currently being drafted can contribute with important insights into how this future industry will develop.

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A

APPENDIX 1

Below, the three different interview templates used within the study are presented. One for each of the interviewee types; OEM employee, external customer, and potential customer.

A.1 Interview template 1 - OEM employee

The interview guide for the OEM employees is presented below.

A.1.1 Purpose

The purpose with this study is to examine in what way a circular business model could be designed and implemented for the second life of EV batteries. The goal with this interview is to address how the business strategy should be assessed for 2nd life battery applications. Further, the interview will look at market aspects such as competitive landscape and forecasted market size.The retrieved data will be used to answer the aim and the research questions of the study.

A.1.2 Anonymity

Complete anonymity is guaranteed in this interview; hence it will not be possible to connect the contents of this interview to your name. Neither, it will not be possible to link your name with the results or reports that will be published in the end of this study, not internally at your organization nor publicly in the report published by Chalmers University of Technology.

A.1.3 Recording

In order to make the information gathering process more efficient and to minimize the risk for factual errors, we kindly ask you would allow us to record the audio of the conversation occurring during the interview?

A.1.4 Questions

Gain understanding about the interviewees position and experience
Could you please introduce yourselves and your background?
Could you please describe your position?
Gain understanding about the organization's overall electrification strategy
1. What are your thoughts regarding electrification in your business?
2. How do you work with electrification?

Gain understanding about second-life battery strategies at the organization
1. Have you dealt with second-life battery activities?
2. Can batteries be used within other applications after first life?

Gain understanding of the market aspects
1. Are there any market for second life battery applications?
2. How big do you think that the market potential could be for second life battery applications?
3. What actors exists/would exists on a second life battery market?
4. How are your competitors dealing with second life battery applications?
5. What upcoming trends can be seen on the market?

Gain understanding of supply chain characteristics for second life EV batteries
1. How could a future supply chain for second life EV batteries look like?
2. What scope should your organization have in this supply chain?
3. Are partnerships necessary in order to enable this supply chain?

Gain understanding of pricing strategies
1. How should the price models for second life EV batteries look like according to you?

Gain understanding of external factors affecting the business model
1. Could any external factors affect a future second life EV battery business model?

Gain understanding of barriers and risks with second life EV batteries
1. What risks and barriers could affect the second life of EV batteries?

A.2 Interview template 2 - External Experts

The interview guide for the external experts is presented below.

A.2.1 Purpose

The purpose with this study is to examine in what way a circular business model could be designed and implemented for the second life of EV batteries. The goal with this interview is to address how the business strategy should be assessed for 2nd life battery applications. Further, the interview will look at market aspects such as competitive landscape and forecasted market size.The retrieved data will be used to answer the aim and the research questions of the study.

A.2.2 Anonymity

Complete anonymity is guaranteed in this interview; hence it will not be possible to connect the contents of this interview to your name. Neither, it will not be possible to link your name with the results or reports that will be published in the end of this study, not internally at your organization nor publicly in the report published by Chalmers University of Technology.

A.2.3 Recording

In order to make the information gathering process more efficient and to minimize the risk for factual errors, we kindly ask you would allow us to record the audio of the conversation occurring during the interview?

A.2.4 Questions

Gain understanding about the interviewees position and experience
1. Could you please introduce yourselves and your background?
2. Could you please describe your position?
3. What are your thoughts regarding electrification in your business?
4. How do you work with electrification?

Gain understanding of how batteries could create value for the actor
1. Could new batteries be substituted with second life batteries?
2. What requirements do you have for buying second life batteries rather new ones?
3. What value would second life batteries impose for businesses?
4. What demand do you see for these second life batteries? How big would that be the coming years?
5. What application areas do you see?

Gain understanding of potential business models
1. What potential business models could be used for second life battery applications?
2. What are the important characteristics of this?

Gain understanding of the market aspects
1. How big do you think that the market potential could be for second life battery applications?
2. What actors exists/would exist on a second life battery market?
3. What are the upcoming trends on the market?

Gain understanding of supply chain characteristics for second life EV batteries
1. How could a future supply chain for second life EV batteries look like?
2. What scope could different organizations have in this supply chain?
3. Are partnerships necessary in order to enable this supply chain?
4. What costs do think will arise when using second life batteries?

Gain understanding of external factors affecting the business model
1. Could any external factors affect a future second life EV battery business model?

Gain understanding of barriers and risks with second life EV batteries
1. What risks and barriers could affect the second life of EV batteries?

A.3 Interview template 3 - Potential Customers

The interview guide for the potential customers is presented below.

A.3.1 Purpose

The purpose with this study is to examine in what way a circular business model could be designed and implemented for the second life of EV batteries. The goal with this interview is to address how the business strategy should be assessed for 2nd life battery applications. Further, the interview will look at market aspects such as competitive landscape and forecasted market size.The retrieved data will be used to answer the aim and the research questions of the study.

A.3.2 Anonymity

Complete anonymity is guaranteed in this interview; hence it will not be possible to connect the contents of this interview to your name. Neither, it will not be possible to link your name with the results or reports that will be published in the end of this study, not internally at your organization nor publicly in the report published by Chalmers University of Technology.

A.3.3 Recording

In order to make the information gathering process more efficient and to minimize the risk for factual errors, we kindly ask you would allow us to record the audio of the conversation occurring during the interview?

A.3.4 Questions

Gain understanding about the interviewees position and experience
1. Could you please introduce yourselves and your background?
2. Could you please describe your position?

Gain understanding about the organization's overall electrification strategy
1. What are your thoughts regarding electrification in your business?
2. How do you work with electrification?

Gain understanding of how batteries could create value for the actor
1. How could batteries create value in your business? Could new batteries be substituted with second life batteries?
2. What requirements do you have for buying second life batteries rather new ones?
3. What value would second life batteries impose for your business?
4. Could you have a demand for these second life batteries?
5. How big would that be the coming years?
6. What application areas do you consider for second life batteries in your business?
7. Are there any other application areas as well?
8. How would you like to acquire batteries?

Gain understanding of the market aspects
1. How big do you think that the market potential could be for second life battery applications
2. What actors exists/would exists on a second life battery market?
3. How are your competitors dealing with second life battery applications?
4. What are the upcoming trends on the market?

Gain understanding of supply chain characteristics for second life EV batteries
1. How could a future supply chain for second life EV batteries look like?
2. What scope should your organization have in this supply chain?
3. Are partnerships necessary in order to enable this supply chain?
4. What costs do think will arise when using second life batteries?

Gain understanding of pricing strategies for value capture
1. How would you like to pay for second life batteries?

Gain understanding of external factors affecting the business model
1. Could any external factors affect a future second life EV battery business model?

Gain understanding of barriers and risks with second life EV batteries
1. What risks and barriers could affect the second life of EV batteries?

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