Towards a more circular business model: extended EV battery lifetime

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Abstract

As there will be an increasing supply of end-of-life (EOL) electrical vehicle (EV) batteries, solutions must be found to deal with them in a proper manner. Optimizing the resource flows of the content of these batteries is required and can be done with a circular approach. Extending product lifetime is one of these approaches and has the potential to sustainably and economically benefit the stakeholders involved. Previous work has shown that EOL EV batteries can be implemented in other types of applications that require battery energy storage systems (BESS) wchich is called battery second use (B2U). In this research a practice-oriented approach in combination with a multiple case study research design has been conducted to investigate the current status and potential uses for B2U. Fourteen different stakeholders relevant to the B2U market have been interviewed in a semi-structured manner and resulted in 294 different quotes that were organized into fourteen different coding sections. Results showed that the current market for B2U is at its forefront and with this study, the market has been analyzed, expectations for future development have been developed, and opportunities are formulated into recommendations targeting businesses and politics. B2U is needed for extending the battery's lifetime and minimizing energy input. However, battery recycling is gaining in profitability and will compete directly with B2U service providers in securing the resources they need, decreasing the already low profitability and difficult market for B2U. Transparent collaboration between the stakeholders is needed to optimally handle the resource flows and innovative business models need to be established to secure competitive advantage.

Keywords: Circular economy, circular business model innovation, battery second use, battery recycling, extended EV battery lifetime

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1. Introduction

The market share of electrical vehicles (EVs) has been increasing in recent years and this trend is expected to continue as the transition towards renewable transportation is taking more shape (Martinez-Laserna, et al., 2018). As a result, an increasingly number of batteries will become available coming from EVs that reach their end-of-life. New market opportunities for end-of-life batteries are becoming available and large-scale implementations to responsibly handle these batteries are required. In EVs, lithium-ion (Li-ion) batteries are most often used and this type of battery degrades in capacity during its life-cycle due to different degradation processes (Birkl et al., 2017). Whenever 20 to 30% percent of their initial battery capacity is lost, the EV batteries reach their end-of-life (Neubauer & Pesaran, 2011). This means that the EV batteries still have a remaining 70 to 80% of their initial battery capacity left. Since end-of-life EV batteries still have a significant battery capacity left, these batteries are still useful for many applications within other industries (Heymans et al., 2014; Martinez-Laserna, et al., 2018; Neubauer & Pesaran, 2011). The new applications discussed by these authors give the end-of-life batteries a second-life by repurposing them. These applications require large amounts of electricity storage capacity that discarded EV batteries can provide when bundled together.

1.1. Relation to the circular economy

The importance of extending the lifespan of products and their individual components is emphasized in the circular economy (Kirchherr et al., 2017).

*"*A circular economy describes an economic system that is based on business models which replace the 'end-of- life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable

development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations." (Kirchherr et al., 2017, p224)

In the circular economy model, slowing down resource flows by expanding the lifespan of a product and its parts play a major role (Bocken, 2016). There are several R-strategies developed that are able to have this kind of effect. These are shown in Figure 1.

Smarter product use and manufacture	R0	Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1	Rethink	Make product use more intensive (e.g. through sharing products, or by putting multi-functional products on the market)
	R2	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan of product and its parts	R3	Re-use	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function
	R4	Repair	Repair and maintenance of defective product so it can be used with its original function
	R5	Refurbish	Restore an old product and bring it up to date
	R6	Remanu-facture	Use parts of discarded product in a new product with the same function
	R7	Repurpose	Use discarded product or its parts in a new product with a different function
Useful application of materials	R8	Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9	Recover	Incineration of materials with energy recovery

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Figure 1: Various R strategies that are used in the circular economy (Potting et al., 2017)

In this specific paper the focus will be on R7: Repurposing. With repurposing, more value is created out of the raw material and therefore less of it is needed in the long run. It is important to stress that repurposing is an added part to the other R-strategies if the most circular approach is to be achieved. With these R strategies more circularity equals more environmental benefits (Potting et al., 2017). In the case of end-of-life EV batteries, repurposing is very applicable and is often called battery second use (B2U).

1.2. The market of B2U

More often than not, circular initiatives can become successful when economic incentives are also involved. Although there are additional costs associated with B2U, these costs can be offset by the additional revenues created with new applications (Bocken, 2016). The B2U market is an emerging market and there are many economic opportunities for it to be explored (King, 2019). Also in the study of Martinez-Laserna et al. (2018) it is shown that the B2U is a market that is constantly being developed by scientists and industries alike. For the B2U market to develop, innovation is required. This is what companies do constantly by looking at the potential business model opportunities and trying to understand what would benefit their business to grow. Business models describe how companies create, deliver and capture value also known as the value proposition (Teece, 2010).

To make business models work, innovation is required and essential for companies to survive (Chesbrough, 2010). This is also the case within the B2U market, but despite the fact that B2U offers many opportunities, it also presents its challenges. One study looked into a circular approach for extending EV battery life and developed circular business models for B2U (Olsson et al., 2018). The researchers emphasized the opportunities but also saw barriers that need to be overcome. The main finding of the study showed that it’s important to come up with new collaborations and business models together with other actors along the battery value chain. Similar barriers are also researched in a different study performed by Jiao & Evans (2016). Jiao and Evans studied different sustainable business models for B2U and according to the authors, battery ownership, inter-industry partnerships and policy support are three important aspects for B2U to work.

1.3. Research aim and scope

This study aims to create additional knowledge about the current B2U market to fill the knowledge gap and create recommendations for B2U. To gather a better understanding of the B2U market, stakeholders in this market are interviewed in a multiple case study approach. This research will give answers to the following research questions.

Main research question: Which opportunities can be identified and what recommendations can be formulated to facilitate upscaling use of battery second life in anticipation of the growth of End-of-(EV)Life batteries supply.

Sub question 1: What are the processes that influence the creation of new business models in repurposing end-of-life EV batteries?

Sub question 2: How does the current B2U market and its recent developments look like?

Sub question 3: What are the expectations of the future development of the B2U market?

In the literature review, knowledge is gathered regarding current research on B2U to develop a theoretical perspective. Herein, the reasons why B2U is beneficial are explained, next to other topics such as an explanation of the B2U value chain and the use business models. After the literature review the conceptual framework is introduced, showing the understanding of the different theoretical perspectives, called the propositions. Four propositions resulted from this. These are the internal and external adoption factors for B2U, the design of take-back systems and the theory on multi-stakeholder networks for B2U.

For methodology, a multiple case study research design is used, consisting of a practice-oriented approach based on the design of Verschuren & Doorewaard (2010). In this approach, the fourteen different stakeholders are perceived as the multiple case studies and are interviewed in a semi-structured manner with the propositions forming the basis of what was asked during the interviews. Other methods of gathering data are, but is not limited to personal observations, research papers, policy documents, websites and other forms of material on the internet.

Results highlighted the most important findings coming from the perspectives of the interviewees, being that B2U is in its early stage and requires a learning by doing attitude by the different stakeholders. Besides, market development and its trends are discussed that give insights into the current market development but also future prospects. The discussion section puts the results in perspective of the literature. Here the understanding of the current market and future market is further explained. Also, future research and the limitations of this study is explained. Finally, in the conclusion section, the most relevant findings are summarized and give an understanding of the most important takeaways.

2. Literature review

This section covers the literature review on the topic of battery second use. The literature review is used to present the current knowledge about battery second use (B2U) and the theories discussed during the research. First, the reasons why B2U is needed will be discussed. After that, the process of remanufacturing will be discussed, explaining when batteries will retire and in what way they are processed towards a second life in battery energy storage systems (BESS). Consequently to this, research on potential applications are explained to gather insights into current practices. Lastly, the role of business models is discussed and how they provide insights into the process of B2U.

2.1. Reasons for battery second use

There are several reasons why the adoption of B2U is beneficial for society, the environment and the economy. In this section, the reasons why B2U is needed are discussed. First discussed is the ability of B2U to be a key element in the adoption of renewable energy. Secondly, B2U has the potential to provide cost benefits to the initial costs of EVs. The last reason why B2U is beneficial has to do with its relationship to the circular economy and sustainable advantages. In the coming sections these reasons will be explained more in depth.

2.1.1. Upcoming trend of renewable energy

As mentioned, the first reason why the reuse of EV batteries would be beneficial has to do with the increasing use of renewable energy. Renewable energy is becoming increasingly important to solve the environmental problems the world is facing. However, the increasing supply of renewable energy and the unpredictability of the supply requires adaptations from the grid to a smart grid (Phuangpornpitak & Tia, 2013). Enabling technologies are critical in this shift. One of the enabling technologies that is part of the smart grid are BESS. BESS are energy storage systems designed with batteries as energy storage devices. These BESS can provide grid related services that would benefit the uptake of renewable energy (Eyer & Corey, 2010; Martinez-Laserna, Gandiaga, et al., 2018; Viswanathan & Kintner-Meyer, 2011). This is also where the repurposing of EV batteries would come in conveniently. For example, we know that Lithium Ion technology coming from EV batteries can be used for utility services and residential storage devices (Leadbetter & Swan, 2012). These applications are further explained in the application section.

2.1.2. Initial cost of EVs

Second, repurposing EV batteries lowers initial costs for batteries and contributes to profits. This would be beneficial for lowering the total initial cost of electric vehicles and thus lowering the cost barrier for potential EV customers (Neubauer & Pesaran, 2011). Some scholars have addressed this fact and have different opinions on this topic. Jiao & Evans (2016) support Neubauer and Pesaran in claims that battery second use is a promising approach to lower the cost-hurdle potential buyers experience. They also argue that this is not the case yet due to the limited number of batteries available due to the limited EV market share.

However, Martinez-Laserna et al. (2018) make the point that it remains still unclear if the costs of the initial batteries will be affected. They argue that battery prices are continually decreasing and that even with the profits from re-using the batteries, the effect it will have on lowering the EV price will be marginal. The study by Neubauer et al. (2015) also puts the profits of battery second use more in perspective. For them the only identified market that has a large enough demand for repurposed EV batteries is the market for energy storage services to the grid. They expect this market to be a low margin market and will therefore not affect the upfront cost of the EVs. This will then also result in a lower discount for potential customers of EVs. The discount presented to the potential customers would be interesting for them, but also. according to Martinez-Laserna et al. (2018), would not change the momentum of vehicle electrification into a disruptive process.

2.1.3. The circular economy and the sustainable advantages

As mentioned before, by giving EV batteries a second-life, less of the raw materials need to be harvested. This is important because the raw materials for manufacturing new EV batteries are under stress as demand increases (Olivetti et al., 2017; Väyrynen & Salminen, 2012). Co-currently, the practice of producing raw materials for EV batteries is not without its criticisms (Gaines, 2014; Martinez-Laserna et al., 2018) An example that has received negative attention is the mining of cobalt, which is mainly mined in the Democratic Republic of Congo (DRC)(U.S. Geological Survey, 2020). The DRC is the world's largest export country of cobalt, supplying approximately 70% of the world's cobalt mine production. Under bad working conditions, people from the DRC are working in the cobalt mining industry (Banza Lubaba Nkulu et al., 2018). According to the study by Banza Lubaba Nkulu, this includes not only healthy men that are fit for the job but also young children that are put to work and have exposure-related oxidative DNA damage. Besides these effect on the population, severe environmental pollution was also measured. The problems with acquiring the raw materials needed for EV batteries underlines the need for a more circular approach in the battery value chain.

2.2. The value chain of battery second use

In this section insights into the value chain of battery second use are discussed. The value chain can be described as an overview of all the phases that are involved in reaching a product or service (Kaplinsky & Morris, 2001). The development of the B2U value chain will create insight into the technical processes involved in the remanufacturing of first life batteries together with the relevant stakeholders. In figure 2 the developed value chain of B2U is given based upon an interpretation from Reinhardt et al. (2019) and Casals et al. (2019).

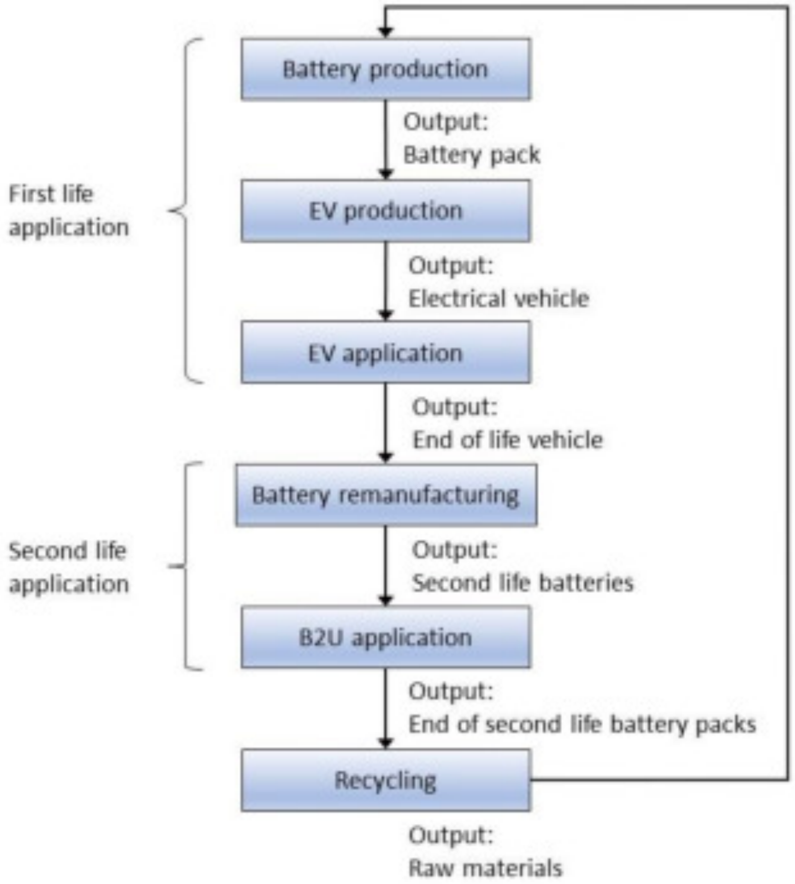

Figure 2: Value chain of battery second use. Based upon: (Casals et al., 2019; Neubauer & Pesaran, 2011; Reinhardt et al., 2019).

The first part of the value chain for B2U is the same as the production of the batteries designed for EVs. In this study the focus lies on EVs that have exclusive electric motor propulsion with its electricity coming exclusively from its battery pack. After the first life application of the battery in an EV, the next step is the battery remanufacturing for its second life application. In the end, recycling is performed to close the loop of raw materials.

2.2.1. Supply of the end-of-life EV batteries

Batteries that are removed from their first EV application can come from different sources. These sources are explained by Martinez-Laserna, Gandiaga, et al. (2018) and distinguished in their battery ownership model. There are three different streams out of which second life batteries can come from. The first are EV owners that own the entire car and therefore also the battery. The second and third come from leasing agreements with either the

EV manufacturer or a third party with which the owner has a leasing agreement on the battery.

If the owner of the battery is also the user of the EV, it is assumed that there are two reasons for replacing the battery in the car (Neubauer et al., 2015). The first reason would be if a warranty is expired and/or a performance level is breached. The other reason would be if there is some sort of economic motivation to do so. For EV leasing models it would be more straightforward as certain performance levels requires the batteries to be replaced.

The supply of batteries coming from EVs would be an increasing stream because of the increasing use of EV. However, in a study performed by Bobba et al. (2019), the authors argue that with reusing these batteries, the stream of raw materials is also delayed. If demand for the raw materials such as Cobalt and Lithium would increase, the relevance of recycling would become more important. For example, through recycling, these raw materials are extracted from the end-of-life EV batteries and can be used for the demand of raw materials in new batteries. Bobba et al. argue that a balance in this is needed for the EV battery value chain and also propose policy methods to try and regulate the supply of end-of-life EV batteries.

2.2.2. Analysis of the battery's state of health

Before deciding what to do with retired batteries that come from EVs, the state of health (SOH) must be examined to analyze their useability. The state of health reflects the energy and power capabilities of the batteries and are measured with the indicators of the battery's capacity and internal resistance (Xiong et al., 2018). Measuring these indicators can be done in different ways of battery screening technologies (Jiang et al., 2017, 2018; Zhang et al., 2014). It is important to know the SOH because the full life time of the batteries can be calculated with this information. Batteries will have a reduced battery capacity and power fading over time due to different complex ageing mechanisms ((Vetter et al., 2005). Vetter et al. accounts the ageing mechanisms as the result of multiple origins such as material parameters but also storage and cycling conditions. For second life batteries, it is shown that certain aging characteristics such as battery performance and degradation behavior are strongly influenced by the first life battery ageing history (Martinez-Laserna et al., 2018). According to Martinez-Laserna et al. it is therefore all the more important for the technical viability of B2U to monitor the SOH. Whenever the batteries seem fit enough for B2U, the manufacturing process starts.

2.2.3. Remanufacturing the retired EV battery

The processes described in figure 3 give an overview of the remanufacturing steps for B2U. In this overview, Hossain et al. (2019) describe how EV batteries are handled and refitted for a second life application. This flowchart is based on the fact that there are many different cell standards used by battery manufacturers. It can become complicated if there are different types of cells that need to work together in one application. Therefore, in this flowchart the cells are separated from their modules and refitted in new modules.

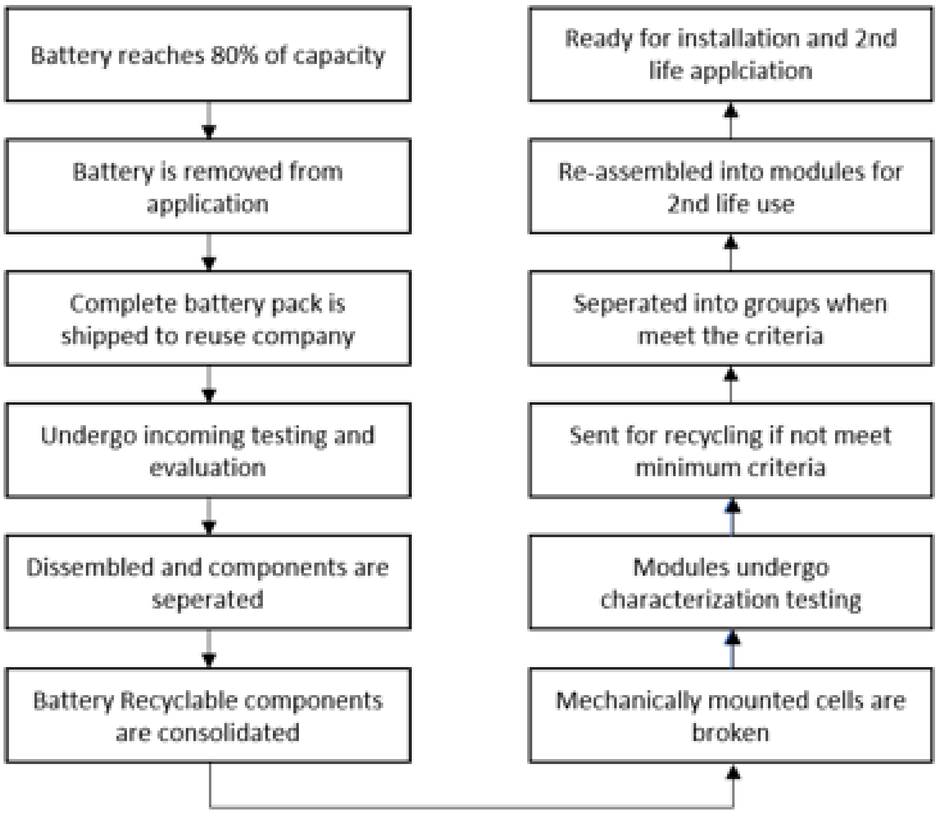

Figure 3: Remanufacturing process for B2U. Adapted from (Hossain et al., 2019).

The next step is the design of the new BESS for the second life application. In this research, a BESS is the term used to describe the final product coming from B2U. There have been several design approaches to the design of new BESS. The design approaches of the BESS depend on the second life application as different requirements are required. When the cells are separated from the EV battery pack, they are used to develop the new BESS. To get a better overview of what the BESS consists of Bowler (2014) describes the basic steps that results in a BESS in figure 4.

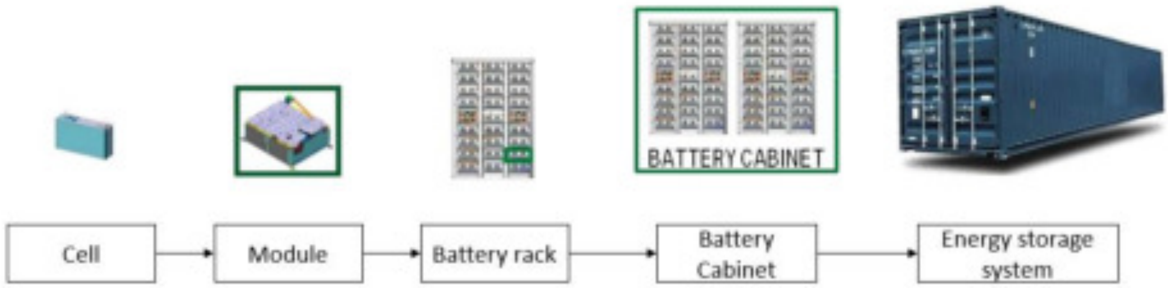

Figure 4: Steps from individual cell towards a BESS. Adapted from (Bowler, 2014).

2.2.4. Battery second use applications

To create an overview of the most important research that has been done on the topic of repurposing EV batteries, the tools Web of Science and Vosviewer have been used (VOSviewer, 2021; Web of Science, 2021). These tools make it possible to visualize scientific landscapes to create an overview of the research that has been done on specific topics. The description of the keyword search and the results can be found in appendix A.

The results show that some of the most cited articles on applications for repurposing EV batteries are related to papers that discuss BESS for grid services (Heymans et al., 2014; Neubauer & Pesaran, 2011; Viswanathan & Kintner-Meyer, 2011). These papers are all based upon estimations and simulation. The applications mentioned in these articles, according to the authors, can be realized with positive economic results. The authors in these papers also express their concern with the increasing use of renewable energy and the negative effect that it has on the grid. To get a better picture of the applications that are currently discussed in literature, the next part will focus on these applications.

The first application that will be discussed is that of Heymans et al. (2014). The authors used a MATLAB simulation to analyze the feasibility and cost effectiveness for the use of repurposed EV batteries in residential BESS. With residential BESS, the user has a battery pack installed to the electricity connection of their house and to the grid. The user can store energy during hours when the energy rates are low and use the energy when the energy rates are higher. This is also called load leveling for the grid because less energy is taken from the grid during peak demand hours. Heymans et al. show that this solution works but with minimal profits and therefore suggest that the government should provide subsidies to encourage this process. The advantage for the government lies mainly in a more leveled grid. This is beneficial because peaks in demand cause tensions on the grid and these will increase with the increasing production of renewable energy. The reason Heymans et al. expect minimal gains is because the batteries have a charge and discharge inefficiency that causes losses. The rates between the high and low hours are also minimal.

The second application discussed is researched by Neubauer & Pesaran (2011) and they foresee a more economically viable solution for repurposed EV batteries. The applications discussed in this article are based on an application study by Eyer & Corey (2010) for BESS to benefit the electricity grid. The BESS in these applications require larger energy storage compared to the previously discussed residential solutions. These applications go into the megawatts and requires numerous amounts of batteries. Neubauer & Pesaran looked at the BESS and made estimates of the ability of recycled EV batteries to carry out these applications. Their estimates, while limited to the assumptions and lack of proven data, suggest there is potential to reuse EV batteries and transform markets in need of cost-effective energy storage. The most promising application is called area regulation, which describes a similar process to load shifting. It is also a way of controlling supply and demand in the electricity grid, but in this case in a more centralized system. The BESS are a buffer to damp off the short-duration fluctuations.

In a different type of application, Ambrose et al. (2014) discuss B2U for rural energy access for communities. Rural areas in emerging countries might be a potential market for B2U because the households and other industrial settings require remote energy storage solutions. The authors in this study suggests that it’s economically viable to provide cost-effective BESS out of retired EV batteries for this particular market. Another different kind of study on an off-grid application is that from Tong et al. (2013). The authors proposed and designed an off-grid photovoltaic vehicle charge system that achieves similar performance to new batteries, but designed with a lower cost.

2.2.5. Environmental impact of battery second use

Remanufacturing batteries from electric vehicles requires many steps and is also labor intensive (Martinez-Laserna, Gandiaga, et al., 2018). To calculate how this impacts the total environmental impact, research has been done on the environmental impact related to B2U. The environmental impact of B2U has been investigated by Casals et al. (2017) with the use of a life cycle assessment (LCA) based on the CO_2-emissions ($LCCO_2$). Figure 5 shows the entire manufacturing chain and the processes that lead to CO_2-emissions. It is a combination of the $LCCO_2$ of an EV and a BESS.

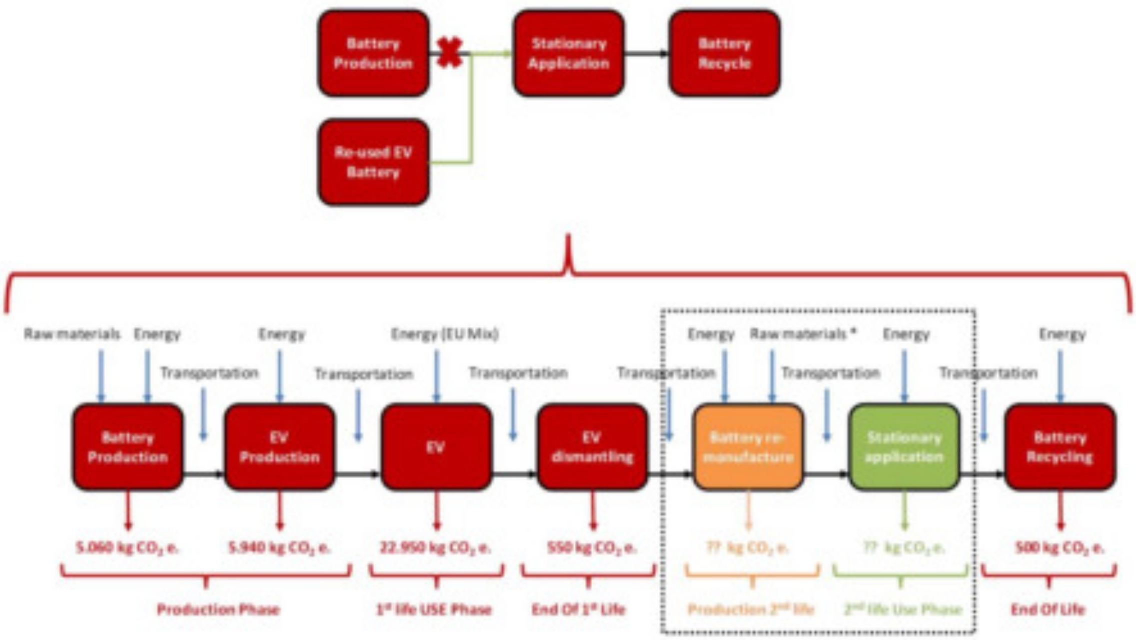

Figure 5: : Life Cycle assessment based on the CO2 -emissions for B2U (Casals et al., 2017).

For the B2U CO_2-emissions, multiple real-life cases of BESS have been used for the CO_2-emission calculation. Their results showed that B2U is only environmentally beneficial if the second life batteries are used within applications for renewable energy. If the batteries are under operation with electricity coming from pollutant energy sources, these CO_2 - emissions coming from these sources must be added to the total emissions acting as a multiplier factor (Casals et al., 2017). In this study it is also emphasized that different battery compositions are better fit in certain applications compared to others.

In two different studies by Ahmadi et al. (2017) and Bobba et al. (2018), another LCA for B2U was carried out and they came to a similar conclusion. The main focus of the first and second application must be on the use of renewable energy if it is to become environmentally friendly. This is one of the major steps in reaching a lower environmental impact. In another study performed by Casals et al. (2019) the results was that B2U can be beneficial for the circular economy. However, not all applications are suited for this. In their study, grid-oriented applications only offer environmental benefits if they are connected with renewable energy power sources.

2.3. The use of business models

Business models describe how companies create, deliver and capture value also known as the value proposition (Teece, 2010). Companies must constantly innovate their business models to keep their businesses running. They do this by adapting to the market and developing new products and services. Therefore, it is important for companies to have business model innovation as a constant process (Chesbrough, 2010). Business model innovation can also be coupled with other innovation theories. The perspectives of these coupled theories are used to understand how companies are able to adjust their business model and realign with their goals. The interest in this study focusses mainly on the perspectives of sustainable business models (SBMs) and circular business models (CBMs). The first part of this chapter these theories will be discussed. Hereafter, the business model canvas (BMC) and its variations will be explained. Lastly, research on the relation between business models and B2U is discussed.

2.3.1. Sustainable business models

SBMs are the link between sustainable innovation and economic performance (Boons et al., 2013). SBMs focus on revenue generation, as well as the negative impact on the environment and the different types of stakeholders, such as society (Bocken et al., 2018). In a study by Bocken et al. (2014) the attempt was to unify the wide range of different examples of SBMs. The aim was to create a common language and a set of archetypes that describe the SBM. The following archetypes were mentioned "Maximize material and energy efficiency; Create value from 'waste'; Substitute with renewables and natural processes; Deliver functionality rather than ownership; Adopt a stewardship role; Encourage sufficiency; Re-purpose the business for society/ environment; and Develop scale-up solutions " (Bocken et al., 2014, p42). These business model archetypes can be used to connect business model theory together with the development of new industrial sustainability. Antikainen et al. (2013) outlined the importance of the challenge to create SBMs that will provide a "win-win-win" situation. Aligning the stakeholders and balance their self-interest for sustainable impact is difficult and often requires newcomers to the market to disrupt the value chain (Antikainen & Valkokari, 2016). This is also embodied in the work of Aminoff et al. (2017) that explained how aligning ecosystems in the circular economy can be described as a disruptive innovation as managers usually tend to focus more on their own strategy rather than on the ecosystem level.

2.3.2. Circular business models

On the other hand, there are CBMs. The focus of these type of business model are established in the circular economy. The circular economy can also be described as a driver for sustainability (Bocken et al., 2018). In the study by Bocken et al. CBM innovation is proposed. By experimenting with different CBMs together with eight different companies, the aim was to find how BM innovation towards more CBMs can be achieved. The results of this experiment showed that both internal and external engagement for the development of SBMs is increased. Secondly, it helps testing business models and evaluate their assumptions. Third, collaboration with external stakeholders and partners helps to set up new experimentations. Their last finding was that experimentation requires cycles of feedback and iteration. CBM innovation is something that provides benefits for the companies that pursue sustainable actions and the findings by Bocken et al. underline the importance.

The circular economy has produced notable success stories, but there is still a reluctance to widespread adoption (Linder & Williander, 2017). In their study, Linder & Williander tried to understand why this is the case. Their findings show that with the return flow of resources, the risk associated is seen as larger because of the higher capital commitments. For example, it is often necessary for the original equipment manufacturer (OEM) to maintain ownership of their original product. Risk reduction in this respect is seen as an impedance and must be resolved if CBMs are to facilitate the circular economy. The same obstacle in reaching the circular economy with CBMs was found in the design of new revenue models by Oghazi & Mostaghel (2018). In this study the authors tried to find the challenges associated with the development of new CBMs by examining six companies in a multiple case study. The authors found that the higher risk and unexpected costs were one of the main challenges with the design of new CBMs. Another challenge that they found was the challenge with finding the right relationship with partners and customers. Finding the right fit for customer trends proved difficult as the fashion trends, technology developments, and cost structures are constantly shifting. Another study underlines the assumption that consumer behavior perhaps is the most important of these challenges (Planing, 2015). The author of this study sees the customer as an irrational decision maker in which it is purely motivated by the cost of the product.

2.3.3. The use of the Business model Canvas

In recent years the use of the BMC, created by Osterwalder & Pigneur (2010), has picked up. The BMC represents “a shared language for describing, visualizing, assessing, and changing business models” (Osterwalder & Pigneur, 2010, p12). The BMC consists of nine building blocks that represents a specific business model. In figure 6 the BMC is depicted.

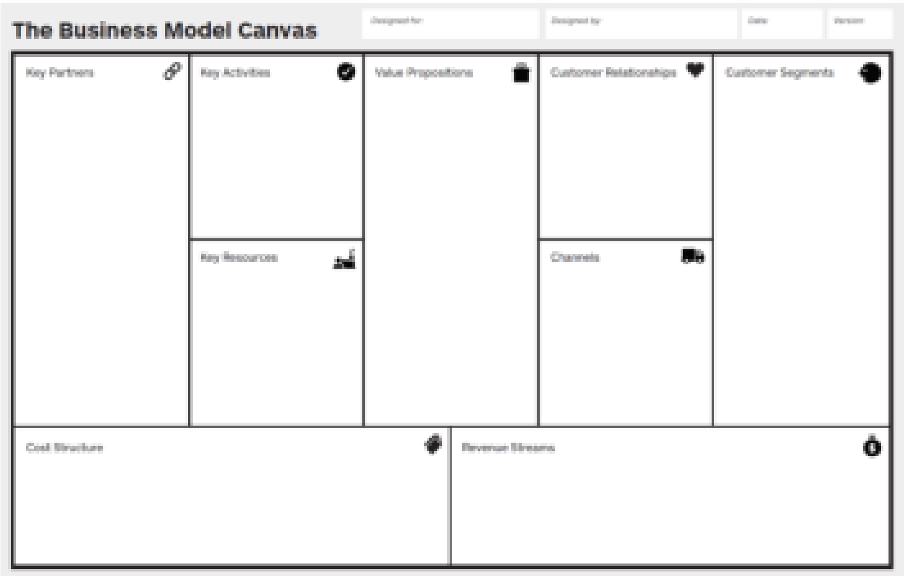

Figure 6: The business model canvas by Osterwalder & Pigneur (2010). Retrieved from: (Strategyzer, 2021)

However, the BMC also received some criticism. Hong et al. (2013) describes how a very important part of doing business is missing. The products and service’s competition, according to the authors, should be a key element and is currently missing in the BMC. On the other side, the authors do recommend using the BMC in combination with others variations of the BMC. In a study by Zandoval Bonazzi & Zilber (2014), the BMC is also considered beneficial. In this study the authors successfully used the BMC in combination with other innovation theories to understand the historic development and growth strategy of a specific company. This shows the usefulness of the business model canvas and proves the scientific relevancy of the tool.

In a different attempt, Joyce & Paquin (2016) created a triple layered BMC. A tool to develop new SBMs. In addition to the existing BMC, they have added two new BMCs. The first new BMC they proposed is the social stakeholder BMC (Figure 8). This BMC is used to explore the organizational social impact. The second BMC is the Environmental Life Cycle BMC (figure 7). This BMC is based upon the LCA theory and is used to measure the environmental impacts the business model has.

Figure 8: Social stakeholder BMC (Joyce & Paquin, 2016).

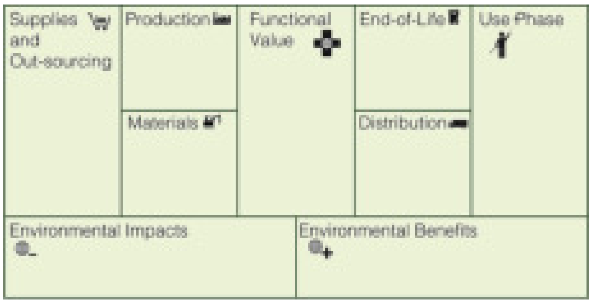

Figure 7: Environmental Life Cycle BMC (Joyce & Paquin, 2016).

The triple layered business model canvas resulted in a more comprehensive and fixed perspective on sustainable-oriented business model innovation. An interesting critic of the work produced by Joyce & Paquin is the work performed by Lewandowski (2016). In his words, his approach is “easier and more user friendly than the triple-layered business model canvas” (Lewandowski, 2016, p22). Lewandowski developed an extended framework for a circular business model canvas (CBMC). His CBMC is also an extended version of the BMC presented by Osterwalder & Pigneur and adds two additional building blocks to the existing nine. The first additional building block is the take-back system. This represents the main philosophy of the circular economy, to create the return flow of materials. “ ... reversed logistics may require different partners, channels and customer relations, and thus a new component can be distinguished in order to differentiate the specificity of forward and reverse logistics. “ (Lewandowski, 2016, p20). The second added building block is the adoption factors. The adoption factors are separated between internal factors and external factors that influence the process of becoming more circular. The internal factors are the organization's capabilities and the external are the political, economic, sociocultural and technological issues. The circular business model by Lewandowski is presented in figure 9.

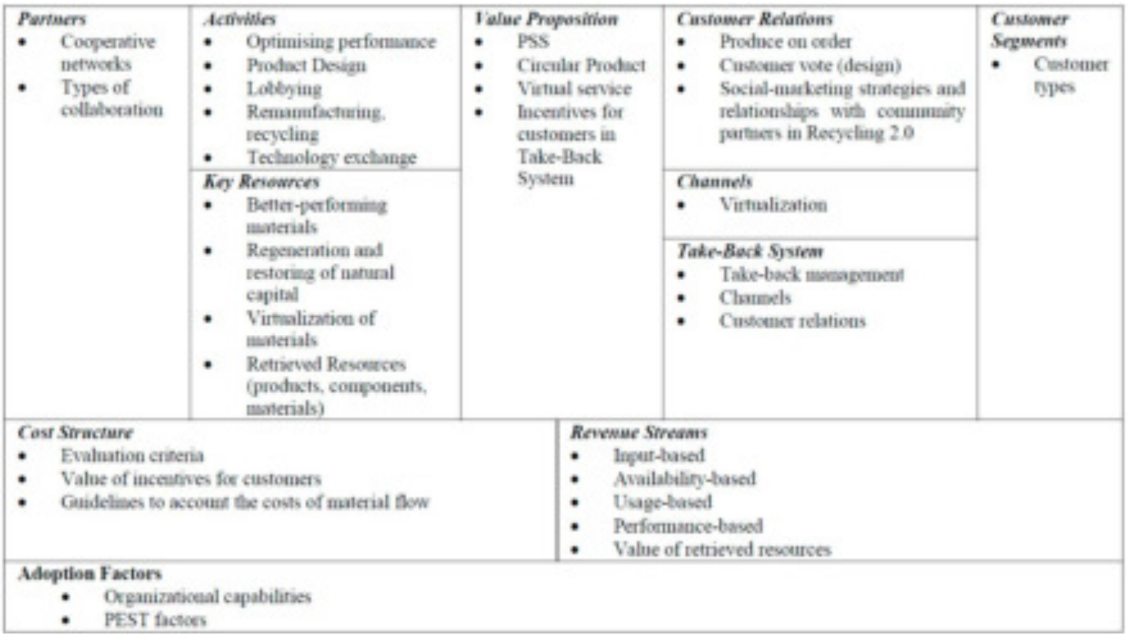

Figure 9: A framework of the circular business model canvas by (Lewandowski (2016).

2.3.4. Business model theory in combination with battery second use

Business model theory in combination with B2U has also been researched. However, there is a lack of research on the topic of B2U and the relationship with sustainable research theories such as sustainable business models (Reinhardt et al., 2019). In the study performed by Reinhardt et al. this is emphasized by showing that most studies on business model theory in combination with B2U focus on the economics rather than the sustainable aspects. Reinhardt et al. argue that this approach is much needed. Their study suggests a B2U business model framework with the focus on cross-sector multi-stakeholder mechanisms and collaborations. Their business model configuration is shown in figure 10.

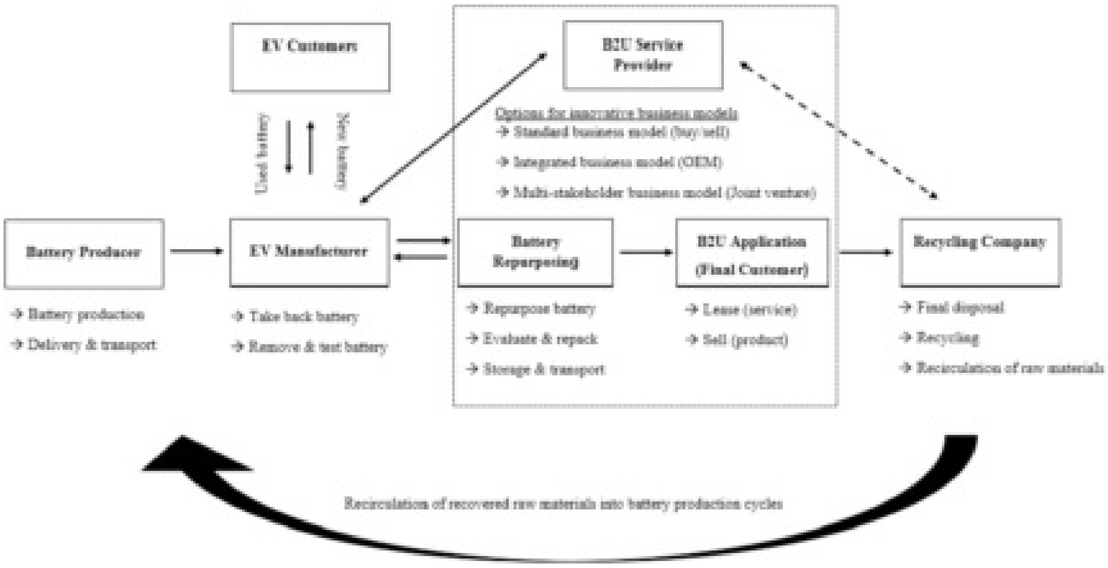

Figure 10: Conceptual battery second use innovative business model framework. (Reinhardt et al., 2019)

This business model introduces an external B2U service provider and separates the activities for B2U to this third-party. According to the authors, there should be a preference for a multi-stakeholder business model similar to the one they proposed. This should be considered instead of a more integrated business model. In the integrated business model, the activities for B2U are more integrated in the OEM's business model. The authors of this study argue that further research on the multi-stakeholder network is needed to prove this assumption. One added benefit in this situation would be the risk reduction created because the OEM are no longer responsible for the higher associated risk and unexpected costs explained in section 1.3.2..

In Reinhardt et al. (2020) a multiple case study was performed on the different ways sustainability is created in the B2U sector and a conceptual sustainable innovation business model framework was developed. Results of this study showed that the proposed sustainable archetypes are present in the current business models of the B2U industry, proving that sustainable practices are present. In a different study, Jiao & Evans (2016) also looked at the combination of sustainable business model theory in combination with B2U. They researched four different companies and saw resemblance surrounding the need for an inter-industry partnership. Two other recurring themes that appeared to be decisive factors for the feasibility of B2U were government support and battery ownership. According to the authors, current B2U practices are not that common yet but they foresee a future in which it will become more present. This is when batteries will become more available in the future when they retire after their first application. This is also the time when more reduced EV cost hurdles will be reached.

Besides SBMs, also CBMs in relation to B2U have been discussed in recent literature. In a study by Olsson et al. (2018) new circular business models for B2U are conceptualized. These new conceptual business models range from being completely linear to fully circular. In this study, 20 EV battery experts from different stakeholders within the battery value chain were interviewed. The authors organized barriers for CBMs adoption in relation to B2U along three distinct categories, these are the cognitive, organizational and technological barriers. Cognitive barriers are the inabilities of managers to recognize new business model opportunities because they are unaware of potential opportunities or foresee potential mismatches with the current business strategy. Organizational barriers are the inabilities of the organization to adapt to new business models because of the required resources not present in the organization. The technological barriers are exogenous barriers that will be present if new battery storage systems need to be developed but there is a lack of standardization making the repurposing costly and complex. These barriers are all present with companies that want to repurpose EV batteries, however the technological barriers seem to be less prominent compared to the current practical and research focus on B2U barriers (Olsson et al., 2018). This is interesting because the current focus tends to overlook the other two barriers. The main take-away from this study is that collaborations between stakeholders along the battery value chain are necessary to set up new business models and create new business opportunities.

2.4. Research gap

The literature review has given an overview of the current literature that discus the topic of B2U and the relevant theories. The literature review also showed the research gap that is currently present in the literature. One of the research gaps is that there are few case studies that include projects that have been executed. Most studies on B2U are estimations and hypothetical cases. Olsson et al. (2018) emphasizes this need in further research. According to the authors there is a lack of knowledge about existing applications and more research is needed in this field to provide better substantiated answers. Also Martinez-Laserna et al. (2018) argue for example that stakeholders such as OEMs and BESS integrators are barely participating in the current literature. This makes it hard to concretize the estimations and potential achievable revenues. By including these stakeholders with their existing projects in further research, more reliable information can be gathered. In this study, these essential stakeholders are also included.

The second research gap is that not much research has been done on the theory of circular business model innovation in relation to the B2U value chain. Research has been conducted into the development of circular business models, but no research has been conducted into their effectiveness and cost-efficiency. Besides, Reinhardt et al. (2019) make the point that further research on the multi-stakeholder network in circular business model innovation is needed. This is needed to understand how OEMs are creating collaborative agreements and capture the full value of B2U. By looking at the multi-stakeholder network in current business model practices, this study tries to understand why certain collaborations are preferred. And whether it is indeed the case that a multi-stakeholder business model is preferable, as proposed by Reinhardt et al., compared to a more integrated business model.

3. Conceptual framework

In this section, the conceptual framework is described. A conceptual framework is an overview of what is researched in a particular study (Leshem & Trafford, 2007). It is therefore used in this research to develop a better understanding of what is researched and why. According to Miles et al. (2018), the conceptual framework has three purposes. The first purpose is to explain the limitation of who and what is being researched. The second is to delineate the relationships between the current knowledge on the topics and theory. Lastly, it is an opportunity for the researcher to create intellectual "bins" that gain insights into the topic. The conceptual framework of this research is shown in table 1 and will be explained in the running text

This study aims to create additional knowledge about the current B2U market to fill the knowledge gap and create recommendations for B2U. The optimal recommendations are where the most value for the stakeholders in the B2U value chain is created. According to Antikainen & Valkokari (2016) this is when a "win-win-win" situation occurs. In order to come to this situation, theory from the literature review is converted into a set of propositions and used to assess different stakeholders and their participation in the B2U value chain. On the left side of Table 1, the propositions are shown that are used in the conceptual framework. As mentioned, the propositions are based on the literature review and they also form the theoretical basis of what is being researched.

Proposition (expectation on what you will find out with your case study – describe expectation in terms of 'how' something happens or 'why' something might happen)	**Source (include references here: take from literature review and summarize its main statements)**
Circular Business model (CBM) innovation theory is used to form the basis of the recommendations. It is expected that CBM innovation can form the basis for the development of new B2U BMs and to manifest the opportunities of the circular	Bocken et al. (2018) describe how experimentation with CBM innovation is a driver for sustainability. Their aim of the paper was to show how CBM innovation is done in practice together with eight companies. (Chesbrough,

economy. The following propositions are based on the theory of circular business model innovation.	2010) underlines the importance of business model innovation.
1. The *Internal Adoption Factors* show how the organizational capabilities influence the process of developing a circular business model. 2. The *External Adoption Factors* will show how political, economic, sociocultural, technological, environmental and legal issues influence the process of developing a circular business model. 3. The *Take Back System* will show how the stakeholders handle the forward and reverse logistics of the raw product. It is expected that the *Adoption Factors* and *Take Back System* will influence collaboration patterns between the stakeholders from the value chain.	1./2./3. Lewandowski (2016) describes a proposed circular business model canvas based on the business model canvas introduced by Osterwalder & Pigneur (2010). It adds two additional building blocks: the *adoption factors* and the *take back system.* The added building blocks give an explanation how the businesses organize their organization in relation to the circular economy. The adoption factors have been separated into two different factors, the internal and the external factors. The building blocks are more explained in the literature review in section 1.3.3..
4. The *multi-stakeholder's network* will be used to find out whether the stakeholders have a preference for a more integrated approach to B2U or rather have a multi-stakeholder approach. The multi-stakeholder approach is expected to be preferred because of the increase in risk associated with extending product ownership	4. Reinhardt et al. (2019) discuss how their preference goes out for a multi-stakeholder approach to business model development for B2U. This means that more parties should be involved rather than integrating B2U into the business models of for example the OEMs or battery manufacturers. Explained more in section 1.3.4..

Table 1: Conceptual framework propositions

The adoption factors, are developed by Lewandowski (2016) and have been divided into the internal and external adoption factors. They are used to explain what processes influence the adoption of circular business models. The internal adoption factors provide indicators for processes that are related to the organizational capabilities. The organizational capabilities describe the organization's intangible resources such as team motivation and organizational culture, the inhouse knowledge and the transition procedures. Another part of the adoption factors are the external ones and describe the factors that are outside the organization. The external adoption factors include the political, economic, sociocultural, and technological (PEST) issues that influence the process of developing a circular business model. In The external adoption factors are closely related to the PEST analysis which is often used to analyze certain strategic risk factors (Sammut-Bonnici & Galea, 2015). Lewandowski used the PEST analysis but for this research the PESTEL analysis is preferred, including therefore also environmental and legal adoption factors.

The third proposition, also coming from Lewandowski, is the take-back system. This one is important because it explains how the return flow of resources are handled, which is one of the characteristics of the circular economy. How stakeholders take back batteries and who processes them is important to know and a major part of the circular business model. The final central concept is how the stakeholders position themselves, Reinhardt et al. (2019) distinguished two BM archetypes to this. The integrated B2U BM approach shows how certain stakeholders might want to do most of the repurposing activities themselves and keep the raw materials in their own system. The other B2U BM is more based on including other stakeholders as well. The difference in these approaches is researched and why certain preferences occur.

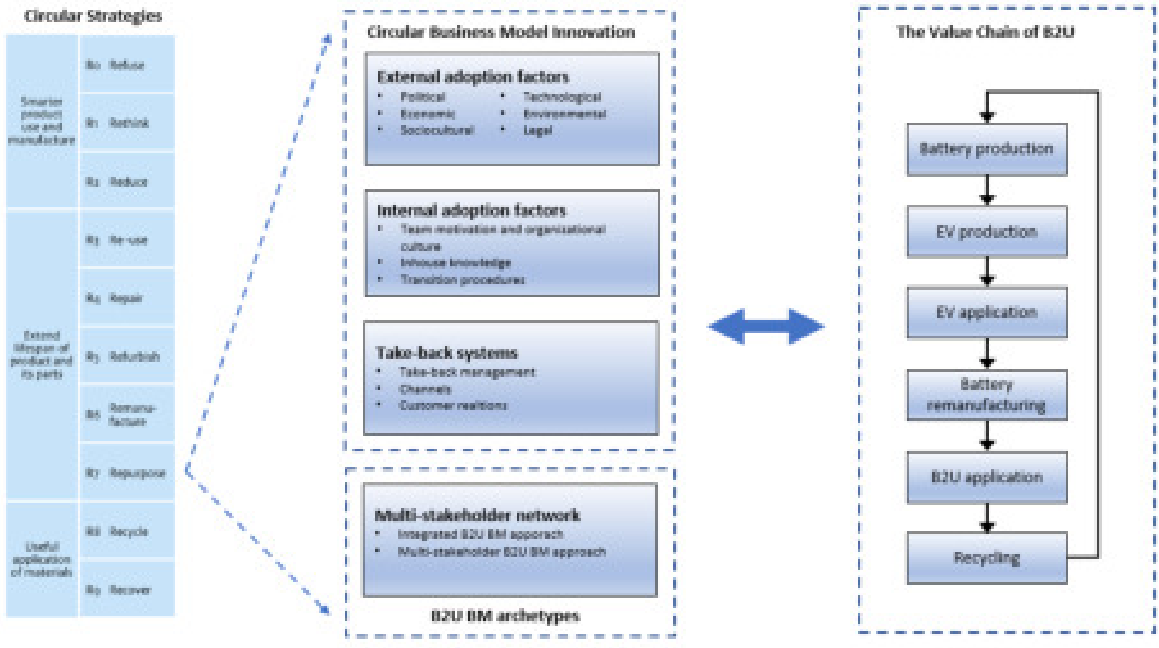

Figure 11: Conceptual Framework. Based upon: (Casals et al., 2019; Lewandowski, 2016; J. Neubauer et al., 2015; Potting et al., 2017; Reinhardt et al., 2019)

In table 1 the conceptual framework is shown. Besides the propositions, other elements in the conceptual framework are the circular strategies and the value chain of B2U. The circular strategies are based on the study by Potting et al (2017). The repurposing strategy is most relatable with B2U and is therefore highlighted in the conceptual framework. The relation with the Circular Business Model Innovation and the Multi-stakeholder propositions is then shown in the middle. On the right side the interaction of these theories together with the B2U value chain is shown. The developed value chain for B2U is based on a first life application in EVs and shows the stages involved in reaching the end product for a B2U application based on the interpretation of Casals et al. (2017), Jeremy Neubauer & Pesaran (2011) and Reinhardt et al. (2019).

4. Methodology

In this section the methodology used will be discussed. First, the practice-oriented research approach will be covered. This section explains what a practice-oriented research approach is and why it's chosen. Hereafter, an explanation is given behind the choice for doing a multiple case study and what this looks like. Also, the research framework is explained. Lastly, the methods of gathering data are explained and how the semi-structured interviews are carried out.

4.1. Practice oriented research approach

The guiding framework of this research is the practice-oriented research approach based on the design of Verschuren & Doorewaard (2010) (Figure 12). According to Verschuren & Doorewaard (2010, p45), a practice oriented approach leads to "a successful intervention in order to change an existing situation". This approach is chosen because the aim of the research is to create recommendations for an intervention and to facilitate the upscale use of B2U.

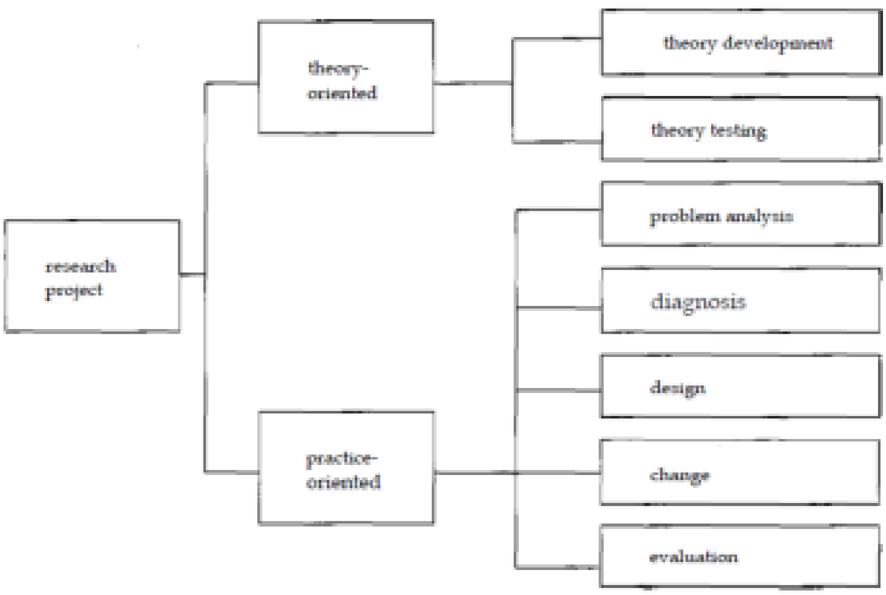

Figure 12: Overview of the theory and practice oriented research project approach. (Verschuren & Doorewaard, 2010).

The first step of the practice-oriented approach is the problem analysis, which is done with the literature review. The literature review summarizes and evaluates the research that has been done on the topic (Knopf, 2021). After the literature review, the conceptual framework was introduced, showing how circular business model innovation theory is used in this research. According to Verschuren & Doorewaard (2010), a conceptual framework will create the boundaries for the research and links these boundaries to the existing literature.

The second part of the practice-oriented approach is the diagnosis. The diagnosis is where the "background and the causes of the identified problem can be examined." (Verschuren & Doorewaard, 2010, p48). Besides in the literature review, the diagnosis is also conducted during the multiple case study. The multiple case study is explained further in the methodology section and will provide a deeper background into the current B2U market. After the diagnosis, the design of an intervention plan was established. In this research, the intervention plan is described as the recommendations. The aim of the recommendations is to facilitate the upscaling use of second-life batteries with the use of circular business model innovation theory. The recommendations come forth out of the answers from the research questions and are a result of the multiple case study that is performed.

The final stages of the practice-oriented research approach are the actual intervention and evaluation of the intervention. The intervention takes place when the intervention plan is set in motion and the recommendations are implemented. Evaluation is necessary to ensure that the proposed interventions have the desired effect. The problems that the interventions try to solve can be partially solved, but new problems can also arise (Verschuren & Doorewaard, 2010). The intervention and evaluation are outside the scope of this research and will therefore not be covered.

4.2. Case study design

In this section the rationale behind the case study design is discussed. While considering the research question, the unit of analysis (the case) should be clear (Baxter & Jack, 2008). Bhattacherjee (2012) describes the unit of analysis as the target of the research. It refers to for example a person, collective or object. The unit of analysis can also be an innovation or a process, which makes it sometimes complex to pinpoint what the exact unit of analysis is (Baxter & Jack, 2008). Because in this research the focus is to gain more clarity on the circular business model innovation in the B2U value chain by investigating stakeholders and stakeholder relationships, the unit of analysis is a process. To be exact, the unit of analysis is the process of how the stakeholders are involved in the B2U value chain in relation to the four propositions in the conceptual framework. So how do the stakeholders form their circular business model innovation, taking into account the *internal and external adoption factors, take back systems* and the *multi-stakeholder network.*

In Table 2 the central concepts/ are shown together with their indicators that will be used for conducting the multiple case study. The indicators are based upon the conceptual framework and help to recognize what is researched in empirical reality (Verschuren & Doorewaard, 2010). The indicators form the basis of the interview questions that were conducted in the multiple case study.

Central concepts/ propositions	Indicators
1. *Internal adoption factors that influence the process of developing a circular business model* (Lewandowski, 2016)	1. In what way the stakeholders recognize organizational capabilities that require intangible resources. These are separated in the following categories. 1.a. Team motivation and organizational culture 1.b. Inhouse knowledge 1.c. Transition procedures
2. *External adoption factors that influence the process of developing a circular business model* (Lewandowski, 2016)	2 How the different stakeholders approach and recognize the following external adoption factors. a. Political issues b. Economic issues c. Sociocultural issues d. Technological issues

3. *The take back system that describes the flow of the B2U supply chain* (Lewandowski, 2016)	3 How different ways of take back systems there are and how the stakeholders use them and recognize other types of take-back systems. The take back systems are identified according to the following indicators. a. Take-back management b. Channels c. Customer relations
4. *How stakeholders position themselves in the multi stakeholder network* (Reinhardt et al., 2019)	4. In what way the stakeholders recognize the pros and cons of the following two types of business model approaches. a. Integrated B2U BM approach b. Multi-stakeholder B2U BM approach

Table 2: Central concept

Case studies can be done effectively with one or multiple cases depending upon the context (Gustafsson, 2017). For this context a multiple case study is chosen which has the benefit, according to Gustafsson, to understand the similarities and differences between different situations. The data gathered from these multiple sources will ensure that the evidence is strong, reliable and complements each other (Gustafsson, 2017). Also Ridder (2017) argues that by comparing individual cases, a potential advantage is that a cross-case analysis can reveal similarities and differences between the different cases. In Figure 13, the research framework is shown. This framework is based on a design from Verschuren & Doorewaard (2010) and shows how the research will be conducted. Based on the central concepts and its indicators, question will be asked to the different stakeholders in the B2U value chain. The results from these interviews are then used to form the recommendations.

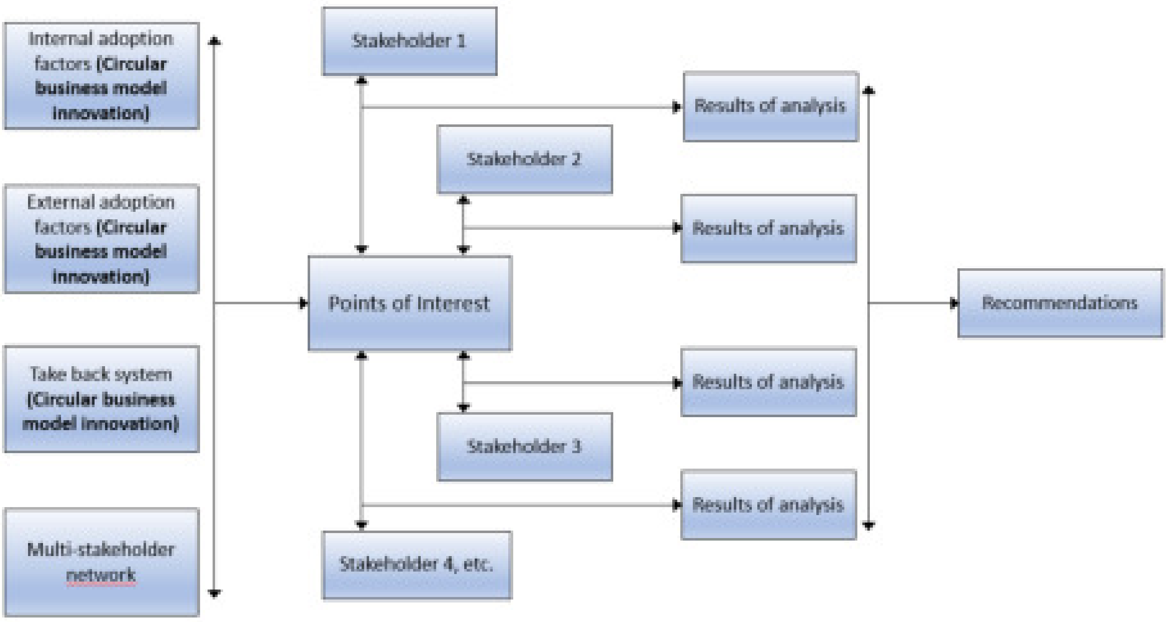

Figure 13: Research framework. Based on Verschuren & Doorewaard (2010)

4.3. Methods of gathering data

In this study different methods of gathering data are used. In table 3 an overview is given of the data collection methods and is further explained in the running text.

Primary data collection methods

- Semi-structured interviews
- Qualitative data analysis with ATLAS.ti
- Transcribed with Microsoft Word transcription
- Personal observations in meetings, discussions and interviews

Secundary data collection methods

- Scientific and governmental reports
- Google scholar search engine
- Bibliometric analysis with Web of Science and Vosviewer
- Websites

Table 3: Data collection methods

The first gathering of data is performed in the problem analysis and diagnosis that was carried out in the literature review. Methods used in this part include, but is not limited to scientific and governmental reports, websites and other forms of material on the internet. For the B2U application section of the literature review there was also a bibliometric analysis performed with the use of Web of Science (Web of Science, 2021) and VOSviewer (VOSviewer , 2021). By using these tools, a visual scientific landscape was created to discover the most recent scientific knowledge and its trends (see Appendix A).

The main method of gathering data was being done with interviews. The reason for choosing interviews as a source of gathering data was because it allows to be both versatile and flexible (Kallio et al., 2016). An interview can be done in three different ways, these are the structured, unstructured and semi-structured interview. "Structured interviews follow a predetermined and standardized list of questions. The questions are always asked in almost the same way and in the same order. At the other end of the continuum are unstructured forms of interviewing such as oral histories . . . The conversation in these interviews is actually directed by the informant rather than by the set questions. In the middle of this continuum are semi-structured interviews. This form of interviewing has some degree of predetermined order but still ensures flexibility in the way issues are addressed by the informant." (Dunn, 2000 as cited in Kallio et al., 2016, p105). Doing a semi-structured interview allows the researcher to be orderly and structured but also makes it possible to deviate from the main interview questions. This allows the researcher to go more in depth on the answer of the interviewee to create a better understanding of the researched topic. This is also why the semi-structured interview is chosen as a research method. As the researched topic includes many different variables it makes it easier to go in depth on specific topics by performing a semi-structured interview.

Added to that, another way of gathering the data was trough the company that put this research in motion called Cenex Nederland. Cenex Nederland provided much information regarding the topic and several meetings were held to introduce the topic to the researcher. Besides, discussion group session with Cenex were organized on the topic of the thesis. Cenex has a broad experience with innovation in transport and energy infrastructure and this information is very valuable as it is readily available and in abundance (Cenex Nederland, 2021). Their interest lies mainly in the gathering of knowledge on the subject. As they are a consultancy firm, they are interested in the topic of B2U and its development. Cenex Nederland has no prior work experience in the field of B2U but are interested in the topic, therefore this research was initiated by them.

To create credibility for this study the subject of validity is also discussed. One way of creating validity in the data collection is based on triangulation in which the different data gathering methods will be combined. Triangulation has been used in many qualitative case studies and will limit the problems of construct validity because multiple sources of data will provide multiple measures of the same phenomena (Ridder, 2017). Also, according to Ridder, triangulation is often coupled with qualitative data collection methods such as documents, observations and interviews. By combining documents, observation and interviews into common topics like the ones explained in the central concepts, multiple forms of data are used rather than a single source of data or incident, creating more valuable data (Creswell & Miller, 2000). In this research a secondary literature study was performed to check the information on its trustworthiness coming from the interviews. Besides the interviews, also personal observation points are mentioned within the results to create more valuable data.

4.4. Semi-structured interviews methodology

To develop the results, 14 semi-structured interviews were held with the stakeholders that were involved in the value chain of B2U. The total amount of time for the interviews combined is 604 minutes and the average time of the interviews is 43.14 minutes long. The interviews have been transcribed in Microsoft Word (*Microsoft Word*, 2021) and with the use Qualitative Data Analysis & Research Software ATLAS.ti (*ATLAS.ti*, 2021) separated into 294 different quotes that are organized into 14 different coding sections based on the literature review. In Table 4 an overview is given of the different stakeholders interviewed. In figure 14 an overview is given of the different interviews and what codes are used in the interviews. In appendix B there is also exact overview that shows which codes and how many codes have been used in each interview.

Stakeholders	**Stakeholder reference**	**Role**	**Employees**
Recycling and battery repurposing	Recycling company	Director	> 250
	Recycling facilitator	Manager	50 - 250
	B2U Entrepreneur	Owner	< 10 persons
OEM	Car Company 1	General manager	> 250
	Car Company 2	Circular lead	> 250
Utility companies	Energy Company 1	Manager	> 250
	Energy Company 2	Vice President	> 250
	Energy Company 3	Manager	> 250
Energy investment company	Investment Group	Manager strategy	10 - 50
Subject matter experts	Subject matter expert 1	General manager	50 - 250
	Subject matter expert 2	Manager	50 - 250
	Subject matter expert 3	Specialist	50 - 250
	Subject matter expert 4	Professor	> 250
	Subject matter expert 5	Senior Scientist	> 250

Table 4: Overview of the interviews that were held. Stakeholders adapted from: Olsson et al. (2018)

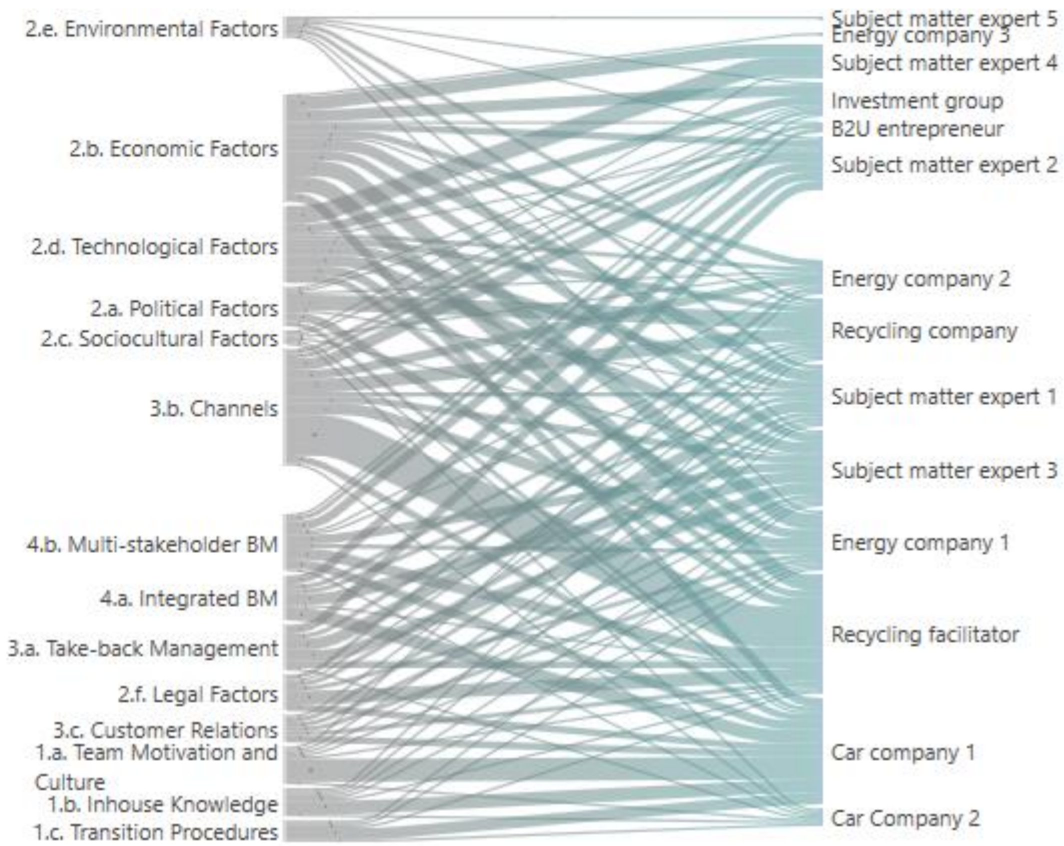

Figure 14: Flowchart of the codes in relation to the interviews

The structure of the interviews is adapted from the interview protocol by Jacob & Furgerson (2012). The protocol includes the interview questions, a script in the beginning and the end of the interview, reminds the interviewer to obtain informed consent and also reminds the interviewer of the data that he or she wants to gather. In relations to this, figure 15 shows an overview of the steps that were taken to formulate the interview questions based on the literature review.

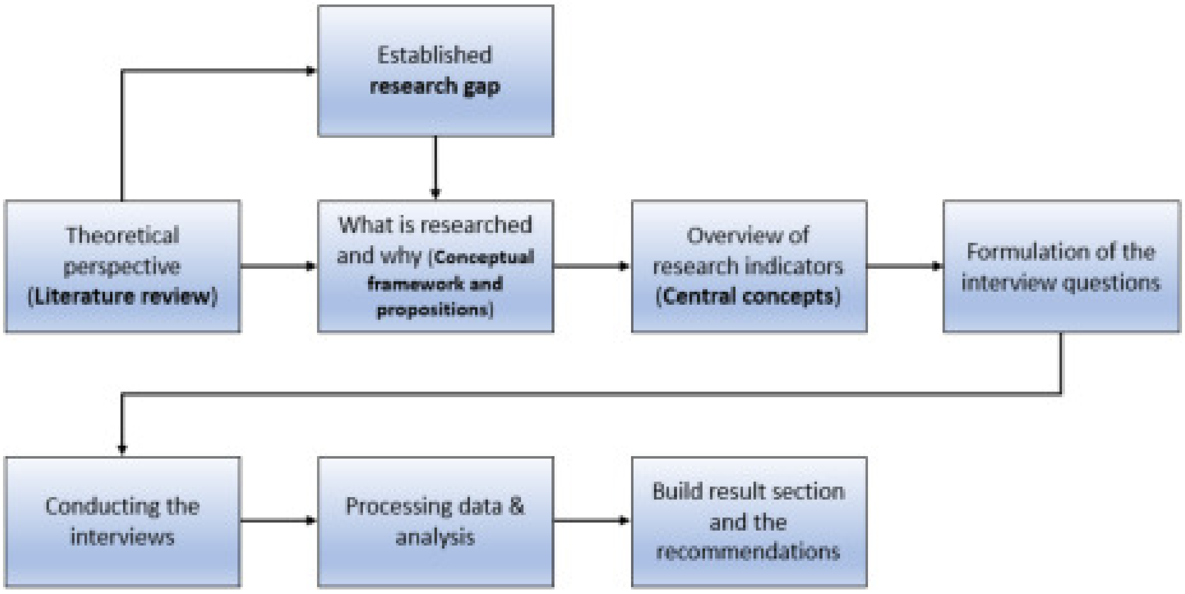

Figure 15: Steps taken to formulate the interview questions

The first part of the steps that led to the interview questions was the literature review and the research gap that formed the basis for the conceptual framework. With the conceptual framework it is shown what exactly is researched and why (Leshem & Trafford, 2007). Adding to this, the basis of the conceptual framework was built upon the propositions that combined the literature with the research aim. The next step in forming the interview questions were the central concepts which are sequentially built upon the propositions. The central concepts describe how the proposed indicators will guide the researcher and help to recognize the theory in empirical reality (Verschuren & Doorewaard, 2010). The final step in formulating the interview questions was to formulate the questions based on these indicators. By following this process, all the interview questions are linked to the literature. By grounding the literature in the interview questions, the questions are narrowed down and will result in meaningful data (Jacob & Furgerson, 2012). An overview of the main interview questions can be found in Table 5: The basic interview questions used as a framework for each interviewTable 5. These questions formed the basis of every interview in which each interview has its own unique set of questions, customized to the specific type of stakeholder.

Main interview questions for stakeholders involved in B2U (Based on which Central Concept the most)	**Main interview questions for stakeholders not involved in B2U (Based on which Central Concepts)**
• Could you tell me how you are involved in B2U? (*Take-back system*) • Can you explain the stakeholders that are involved in this process? Who are they and in what way are they involved? (*Take-back system*) • Could you tell me how the batteries are returned from their first application for reuse? (*Take-back system*) • What were the challenges you were facing when setting up B2U? (*Internal and external adoption factors*) • What are the issues you are facing currently in regards to B2U? (*Internal and external adoption factors*) • In your opinion, what would be the tradeoff between integrating B2U in your organization or letting a third party do the B2U? (*Multi stakeholder network)* • What would be the advantages of letting a third party do the B2U compared to a more integrated BM? (*Multi stakeholder network)* • What is your opinion on a mandatory take back system that makes is necessary for the OEMs to collect batteries from their first application? (*Take back system)* • How do you estimate the market for potential second life applications? (*Internal and external adoption factors)* • What do you think should be the focus if a company that would engage in battery second use? (*Internal and external adoption factors)*	• Why are you currently not engaged in B2U? (*Internal and external adoption factors*) • Can you explain the stakeholders that are involved in the process of B2U? Who are they and in what way are they involved? (*Take back system)* • What are your reasons to engage (or not engage) in B2U in the near future? (*Internal and external adoption factors*) • What would be required for your organization if you were to engage in B2U? (*Internal and external adoption factors*) • If subsidies would be available to participate in B2U, would you consider it more? (*Internal and external adoption factors*) • In your opinion, would you prefer integrating B2U in your organization or letting a third party do the B2U? (*Multi stakeholder network)* • In your opinion, how do you estimate the risks that are involved in B2U? (*Internal and external adoption factors*) • How do you estimate the market for potential second life applications? (*Multi stakeholder network)*

Table 5: The basic interview questions used as a framework for each interview

In conclusion, the topics and questions that were discussed during the interview are the ones explained in Table 5. The results of the interviews give insights into how stakeholders use circular business model innovation in the B2U value chain. Each interview has a different set of questions because each interview was addressed also as different. The stakeholders vary in knowledge on specific topics and to get the most out of each interview, individual questions based on the interviewee’s perspective were customized.

5. Results

In this section the results of the study are shown. The findings are a result of the multiple case study with the different stakeholders and their experiences in the field of battery second use (B2U). They have been interviewed on the following topics based on the propositions. The first propositions are the internal and external adoption factors that influence the adoption of business models (BM) for B2U. With these factors, more insight is gathered into what the current situation is regarding B2U and how the different stakeholders look at them. After that, the propositions regarding the take-back management systems are discussed which is followed by the multi stakeholder network. In these sections, the results of the interviews regarding the take-back systems and the preference for an integrated BM approach or a multi-stakeholder BM approach is discussed. The propositions have been put into the code structure shown in Figure 16. This figure also displays the number of quotes present in each of the codes.

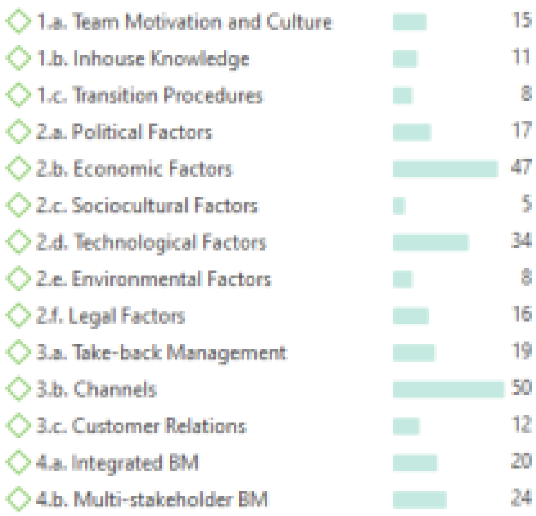

Figure 16: Code structure used based on the propositions from the literature review

5.1. Internal Adoption Factors

The internal adoption factors show how the organizational capabilities influence the process of developing a circular business model. The different indicators are described by Lewandowski (2016) and are *1) team motivation and organizational culture 2) inhouse knowledge and 3) transition procedures.* These indicators have been used as the basis for the interview questions to get to know more about how the different stakeholders position themselves in the circular economy. It proved difficult to make generalized results for the internal adoption factors because the resources are intangible and difficult to measure for each stakeholder in the battery value chain. This would require a better understanding of each unique situation of the targeted stakeholders and proved to be out of the scope of this research. This chapter is therefore not divided for each specific indicator in contrast to the other propositions but is a summary of the three indicators combined.

The first internal adoption factor found is that the market of B2U is at its first stages and requires a learning by doing attitude from the different stakeholder (Recycling facilitator, personal communication, April 12, 2021). The battery value chain is undergoing rapid changes and this requires the stakeholders to continually adapt to the changing landscape. This is also shown in the following quote from a large car company.

“There isn't a lot of plans for what we're going to do (battery second life). It's essentially an exploration of what could be done, and we're open to like any kind of ideas that we see while we are researching or by being approached by research partners to consider all of them essentially.” (Car Company 2, personal communication, June 15, 2021). The different stakeholders that are exposed to the changing market condition try to adjust their value propositions and experiment with new services. This is for example evident in the fact that car dealers and garages are changing their approach in handling car batteries (Recycling facilitator, personal communication, April 12, 2021). Electric vehicles are different in their repair and service needs because they require less maintenance compared to the combustion engine. This requires these stakeholders to adjust and for example become more knowledgeable on battery technology so that they can also provide services in that, previously unknown, area (Car company 1, personal communication, April 6, 2021).

Another example that shows this transition are the new startups that are trying to enter the battery market with B2U and recycling services. Because the car industry is changing so fast, the stakeholders are also changing and new startups appear in the battery value chain claiming to have the winning formula. With these new types of companies, new structures are being formed based on the changes within the market and will open up new collaboration patterns between the stakeholders (Recycling company, personal communication, April 22, 2021). These new structures are beneficial for the market of B2U and recycling and helps extending battery lifetime and are therefore stimulating the circular economy. An example of such a new collaboration pattern and structure is that of the Dutch Auto Recycling Nederland (ARN). This not-for-profit organization is an initiative from the car industry and facilitates car companies in their recycling responsibilities. Recently, due to the electrification of cars, an extra element is added to their services, that of battery recycling and repurposing (*ARN*, 2021). A new structure is formed that allows the processing of car batteries in collaboration with new startups that are active in recycling and repurposing.

Internal adoption factors

- The market of second life batteries is at its first stages and requires a learning by doing attitude from the different stakeholders.
- Stakeholders in the car industry that are exposed to the electrification of the market are trying to adjust their value propositions and experiment with new services.

- New innovative businesses with new value propositions are trying to enter the battery market with B2U and recycling services.

5.2. External Adoption Factors

The external adoption factors are used to create insights into how political, economic, sociocultural, technological, economic and legal factors influence the process of B2U BM adoption.

5.2.1. Political Factors

In the EU directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators (2006), also known as the ‘battery directive’, the most recent legislation regarding battery manufacturing and disposal is reviewed. This directive is an indicator for the member states of the European Union and is an authoritative instruction. It is up to the member states to make laws that achieve the goals of the directive. Recently, the European Commission proposed a new battery legislation instead of the 2006 directive. This is called the proposal for legislation (EU) No 2019/1020 concerning batteries and waste batteries (2020). Because this proposal is set out as a regulation instead of a directive, it means that all EU members must implement it in their legal system instead of sing it just as a guidance. Whilst the old directive was mainly about avoiding hazardous emissions and avoiding the waste, it's not focused on recovering resources. According to a battery recycling facilitator the big benefit of the new proposal is that there's a clear focus on the circular economy and less dependency on raw materials from outside of the EU (Recycling facilitator, personal communication, April 12, 2021). For example, in the new proposed regulation there is a specific recycling target for specific metals. So not just the overall weight based average recycling rate, but specific recycling rates for certain methods (Recycling company, personal communication, April 22, 2021). It is evident that the government is getting more responsive to the battery life cycle and the ambition are there. According to one stakeholder, who currently works for a battery recycling company, a caveat should be made that the legislation is still a proposal and the future will show how much of the proposal will be included in the final legislation when passed. Of course, this is within the EU and more needs to be done on this topic also in other parts of the world.

Another political factor for B2U adoption is part of the current 2006 battery directive. The directive states that the OEMs are responsible for the waste management of the batteries that they put on the destined market. They are responsible and should pay for "the costs of collecting, treating and recycling all collected batteries and accumulators minus the profit made by selling the materials recovered". This influences the decision what to do with the batteries for the OEMs (Recycling facilitator, personal communication, April 12, 2021). In this current situation, the OEMs benefit if less of the batteries are collected for recycling because this would mean the less they have to pay for the recycling which still costs money to do. A negative side-effect of this is that opaque battery flows going outside the EU are common both for vehicles but also electronics (Recycling company, personal communication, April 22, 2021). The government should play an important role if it has the ambition to create a circular life cycle with a focus on maintaining resources within the EU. It can do so by enforcing and monitoring their rules (Recycling company, personal communication, April 22, 2021). More on this topic will continue on the legal adoption factor section.

Whilst interviewing the stakeholders it became clear that the government has an important role in facilitating the battery value chain to maintain safe and sustainable practice. Another political factors that came across was the battery passport and the need for the recycling and repurposing industry to know what the batteries are made of (Subject matter expert 3, personal communication, March 31, 2021). The benefits of such a passport could create more transparency in the battery value chain and is something that is discussed on the

EU level for a couple of years now. With this battery passport the stakeholders know exactly what they have in front of them as many batteries are different in their size, state of health, materials and many other dynamic data types that can be incorporated in the passport (Recycling company, personal communication, April 22, 2021). Another interesting development of such a battery passport is that blockchain technology can be used for this and the EU is looking into blockchain applications for supply chains and international trade (Copigneaux et al., 2020). Blockchain can create more knowledge on material cycles and processes throughout the battery value chain and can do this in a secure environment (Recycling facilitator, personal communication, April 12, 2021)

External adoption factors: Political factors

- In the EU directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators (2006), also known as the 'battery directive', the most recent legislation regarding battery manufacturing and disposal is reviewed
- Recently, the European Commission proposed a new battery legislation instead of the 2006 directive. This is called the proposal for legislation (EU) No 2019/1020 concerning batteries and waste batteries (2020)
- Directive 2006/22/EC states that the OEMs are responsible for the waste management of the batteries that they put on the destined market
- The government has an important role in facilitating the battery value chain to maintain safe and sustainable practice

5.2.2. Economic Factors

The economic factors have by far the most cited quotes in this research. It shows that the economics behind B2U is a very emphasized topic among the stakeholders. In this section the generalized results are mentioned regarding the economic factors that influences the adoption of B2U according to the stakeholders that have been interviewed.

The first factor is related to the remanufacturing costs that are present when batteries are picked for repurposing. They first have to be dismantled out of the car and perhaps also out of the battery pack if that's required. The individual cells are then measured to make sure that the state of health is still good enough for a secondary application. Then the cells need to be remanufactured into a new solution that can be sold to a customer. All these steps are adding costs and effort, lowering the already low margin (B2U entrepreneur, personal communication, April 16, 2021). Lowering the cost of remanufacturing is therefore also one of the challenges for B2U to become viable (Energy company 1, personal communication, April 12, 2021). All the steps needed for remanufacturing are shown in figure 17.

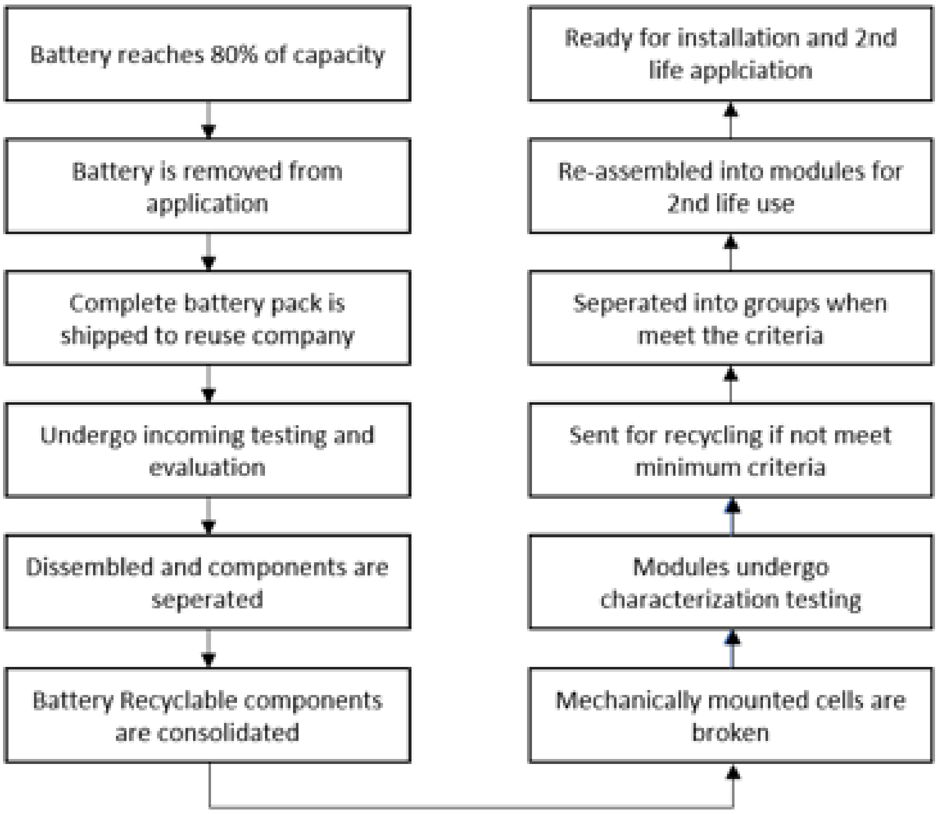

Figure 17:Remanufacturing process for B2U. Adapted from (Hossain et al., 2019).

A second economic factor is that new batteries are getting cheaper per storage unit and will compete with second life batteries (Energy company 1, personal communication, April

12, 2021). For the last years, the price of battery cells has decreased steadily and are expected to decrease even further in the coming future (Figure 18).

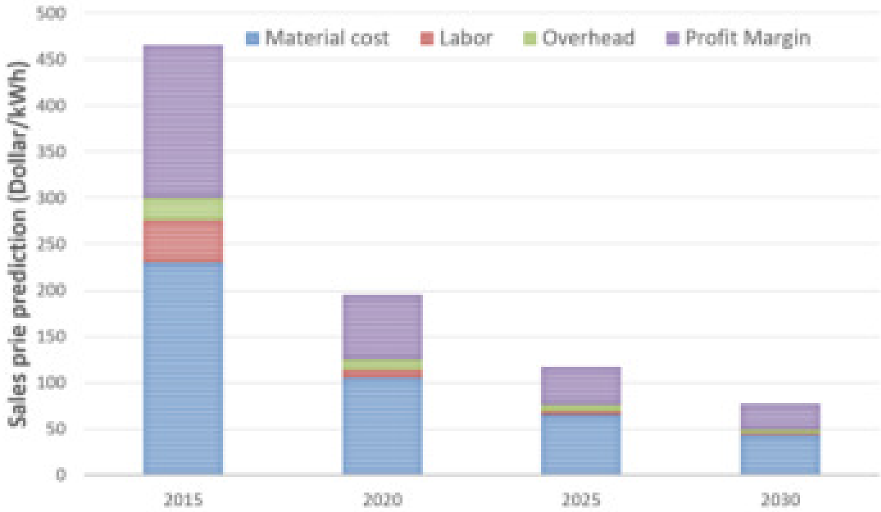

Figure 18: Prediction of sales price of the lithium-ion battery up to 2030 (Berckmans et al., 2017)

For B2U to be successful, the price of a second life battery energy storage system (BESS) should compete with the price of new BESS. The price of these second life BESS are difficult to estimate as there is not much data available. Another problem with this is that to this day, the number of batteries coming from EVs is still too low for large scale second life battery adoption (Subject matter expert 4, personal communication, April 8, 2021). But when this amount will increase it will also become more feasible to create large systems that perhaps can compete pricewise with new battery storage systems.

A third economic factor influencing the adoption of B2U is that recycling is not commercially viable at the moment but is shifting towards becoming profitable (Recycling facilitator, personal communication, April 12, 2021). Making it economically more interesting to start earlier with recycling in the battery life cycle. Recycling should be at the end of the life cycle but this trend will make it more interesting for recyclers to choose to fully recycle instead of first repurposing or reusing. There are two trends that influence this process. Firstly, the demand for raw materials will increase and therefore the price of these raw materials will increase (Recycling facilitator, personal communication, April 12, 2021). This will make it more interesting to recycle the batteries instead of a second life because there is a high demand for the materials coming from old batteries. The second reason why recycling is becoming more viable is that the cost of recycling is getting cheaper also due to technological advancements (Recycling facilitator, personal communication, April 12, 2021).

Another important economic factor that needs to be taken into account is the potential market for battery storage systems coming from EV. In recent literature, scientists make the connection between the market of B2U coming from EVs and the energy market. Therefore, two energy market operators have been interviewed to get an idea if this is a possibility for them. As of now, the results from these stakeholders came back negative for this intersectoral collaboration. The main reason for this is because the utility companies are at the end of the value chain. They need BESS and they'll look for the best price and highest quality but this cannot be done with the batteries coming from used EVs (Energy company 2, personal communication, May 5, 2021). The economic factors explained before are the reasons for this. Other reasons come from the technological factors and the legal factors and will be explained more in those sections.

External adoption factors: Economic factors

- The remanufacturing costs are high because manual labor is required in the dismantling, measuring and repacking processes.
- New batteries are getting cheaper per storage unit and will compete with B2U solutions.
- Recycling is not commercially viable at the moment but is shifting towards becoming profitable and will also compete with B2U.

- Potential markets for BESS coming from B2U are still uncertain and requires further research on current practices.

5.2.3. Sociocultural Factors

The sociocultural factors give representation to the population trends that are present for B2U and those that might influence the adoption of B2U. In general, there is a trend for the importance of sustainable solutions and the different stakeholders interviewed also mention the relevancy of this topic and what it means for them. “We really think that the market is going to really grow … Because I feel the world is really changing towards sustainability issues. There's lots of programs. Some are still a bit fickle and we need to see how they will turn out” (Energy company 2, personal communication, May 5, 2021). Companies are looking for sustainable solutions for their businesses but these are sometimes difficult to find especially if the system is focused towards earning money. There is however a transition going also between the different stakeholders that is related to the energy transition. Both a result from political factors but also economic factors. EVs are getting more attractive also for customers, changing the car industry into a more sustainable market. One car company explained the following reason for their sustainable outlook. “It's definitely the social human factor. That we can guarantee it's fully social compliant minerals that were getting and that there is no slave labor and unfair wages and unnecessary environmental destruction happening.” (Car Company 2, personal communication, June 15, 2021). New sustainable structures in the market need to be build and without collaboration between the different stakeholders this will become difficult to achieve (Recycling company, personal communication, April 22, 2021).

External adoption factors: Sociocultural factors

- There is a trend for the importance of sustainable solutions and the different stakeholders interviewed also mention the relevancy of this topic and what it means for them.

5.2.4. Technological Factors

In this section the technological factors will be explained that have to do with the adoption of B2U. These factors will explain more about the technical properties of the batteries coming from EVs and what this means for manufacturing and also the end product.

The first technological adoption factor regards the degradation of the Li-ion cell used in EVs. The more stress the cell has withgone, the more it will impact the cell chemistry. Which will result in a lower capacity and a state of health. This battery degradation is very inconsistent among batteries of even the same manufacturer and makes it difficult to estimate how well a specific cell will perform in the long run (Subject matter expert 4, personal communication, April 8, 2021). When the battery comes out of its first life in the EV, it has been cycled through for some time. The first thing to do then is to measure its state of health to make an estimation on how long the battery will perform with the right specifications. Also literature states that it hard to estimate the lifetime of batteries coming from EVs (Martinez-Laserna, Gandiaga, et al., 2018). The authors of this study showed that there is a lack of knowledge on this topic which make it difficult to have a lifetime estimation for retired EV batteries because of the lack of experimental data. This is a problem because if BESS are made from EV batteries it is important to know how long they last due to warranties and performance expectancies for potential customers.

The second technology adoption factor explains how the battery cells coming from EVs are far from ready to be installed in a new BESS and require different techniques to make them run smoothly. In figure 19 an illustration is shown that puts this in perspective.

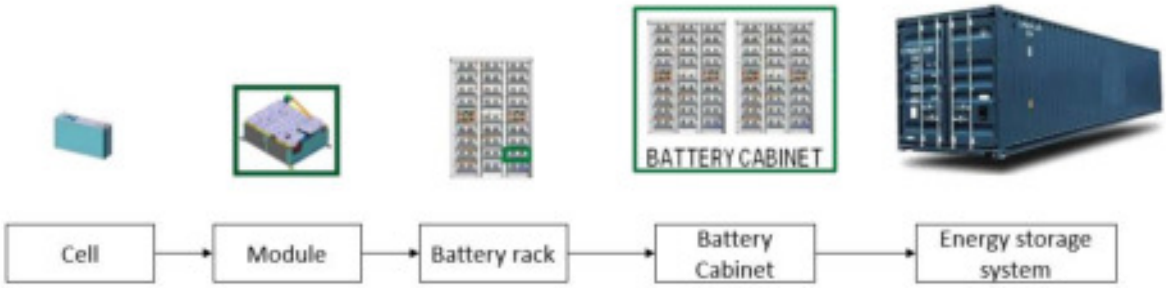

Figure 19: Steps from individual cell towards a BESS. Adapted from (Bowler, 2014).

For example, balancing the capacity from old battery cells give problems when operating in a BESS coming from recycled EV batteries (Energy company 1, personal communication, April 12, 2021). It is important to group cells together based on their condition for the performance of the new battery solution. This can be done on cell level but also on the higher levels within a pack or the battery module depending on interconnectivity and state of health. Balancing is necessary because the state of health of each individual cell will determine how good the entire battery solution will perform. By grouping the cells on their state of health, the best performance can be achieved. One downside of this, and this is also explained in economic factors, is that it takes manual labor to perform these steps which cost money. For some batteries coming from EVs it's hard to disassemble them because of the frame it's build in (Recycling facilitator, personal communication, April 12, 2021). As mentioned before it is technically possible to also keep the cells within the battery modules and this is also preferred by one of the energy companies interviewed that have tried doing battery second use (Energy company 1, personal communication, April 12, 2021). It requires less labor, you don't need to compromise the battery management system and also, the battery packs are sometimes airtight, watertight, have standard plugs and integrated fuses. According to their experience there are also some downsides to this as well. Combining packs together and making them work simultaneously requires collaboration with the OEMs or battery manufacturers because getting access to the software cannot be done without them. But if this collaboration is in place, it would provide a smoother transition in creating a second life for the batteries. In this experimental project conducted by an energy company, an OEM and a technological service company, the technical problems proved to be an important reason why the result of B2U came back negative. The disassembling and refitting had major constraints in the project and required lots of effort to conduct.

A third technological factor is that new battery storage technologies are undertaking rapid development. Li-ion technology is for example improving and new li-ion batteries will have a longer life span (Recycling company, personal communication, April 22, 2021). But besides the development of batteries that are used within EV, there are also other battery technologies that are improving and are perhaps more suitable for stationary applications (Investment group, personal communication, April 14, 2021). These technologies could be become superior compared to li-ion technology because of for example better safety specifications. With stationary storage systems, the size of the battery is also less important compared to when it’s used within a car. Where the amount of weight of the battery will influence the performance of the car it will not affect the performance of a stationary storage system.

External adoption factors: Technological factors

- The degradation of the Li-ion cell used in EVs have a unique degradation curve that influences the capacity of the battery in relation to the number of cycles done together with other factors.
- Battery cells coming from EVs are far from ready to be installed in a new BESS and require different techniques to make them run smoothly.

- New BESS technology is undertaking rapid development. Li-ion technology is for example improving and other technologies are also on the rise.

5.2.5. Environmental Factors

The environmental factors influencing the adoption of battery second use are of importance to understand how the environment is influenced by battery second use. Climate change is a major concern that impacts many industries. The growing awareness of the potential impacts on the climate is changing the way businesses conduct their operations. This is also discussed in the sociocultural factors section and was measured among the stakeholders from the interviews. The circular economy also has its pillars focused on the environment and tries to minimize the impact the economy has. Part of the circular approach is the strategy to recycle but before that, repurposing is a way to extend a product lifetime and make optimal use out of the resources and raw materials (Subject matter expert 1, personal communication, March 31, 2021). As mentioned before, one of the problems now occurring is that products are exported to countries where recycling has not yet become mature. Therefore, if the lifecycle of a product is extended it is important that recycling must be ensured also in places where this is less viable (Recycling company, personal communication, April 22, 2021). The battery passport is explained before and is something that can help with this problem. A battery passport can create insights as to where the raw materials are coming from to ensure its not coming from illegal mines for example but also where the product is heading (Recycling company, personal communication, April 22, 2021).

External adoption factors: Environmental factors

- The growing awareness of the potential impacts on the climate is changing the way businesses conduct their operations.
- Part of the circular approach is the strategy to recycle but before that, repurposing is a way to extend a product lifetime and make optimal use out of the resources and raw materials.

5.2.6. Legal Factors

The first legal adoption factor that will be discussed is that of the producer responsibility which ensures that car manufacturers are responsible for the waste-management of the batteries that are put on the market. The EU directive that is currently in place is the 2006/66/EC on batteries and accumulators and waste batteries and accumulators (2006). The car manufacturers are in a position to do either the recycling themselves or to give the responsibility of recycling to an external party and pay for their services. In general, investments in second life batteries are seen as something that is needed but does not have the economic incentive to support it (Car company 1, personal communication, April 6, 2021). The main stakeholder, the OEMs, in most cases do not have their core business aligned with B2U endeavors mainly because it requires additional investments (Car company 1, personal communication, April 6, 2021). One example that gives an indication of the OEMs preference in this regard is that in the Netherlands 30-40% of the OEMs invests in a takeback system that allows the OEMs to carry out the manufacturing responsibility themselves and integrate the battery recycling in their own BM such as Tesla and most of the French brands do (Recycling facilitator, personal communication, April 12, 2021). The other 60-70% lets a third party take over the responsibility and pays a fee to take care of it. Because B2U requires an initial investment, OEMs with large capital funds are expected to be more likely to differentiate from their core business and also include B2U in their value propositions (Car company 1, personal communication, April 6, 2021).

Another legal adoption factor comes from the potential end user that is present in the battery value chain. In the energy market, BESS are needed due to the transition to smart grids, which will become more important in the future (Energy company 3, personal communication, April 22, 2021). However, there are strict checklist that the utility companies use when buying BESS (Energy company 2, personal communication, May 5, 2021). In a different project for battery second life this was an issue that was faced and couldn't be solve in collaboration with the different stakeholders (Subject matter expert 1, personal communication, March 31, 2021). Energy companies want to have a reliable BESSs that can operate when it needs to operate and has warranty for a certain amount of time. Therefore, energy companies do not see potential for B2U for their services because of the inability of B2U to give the right warranty on second life systems. "We are interested in business case calculations for 10 to 20 years. And then we want to know what is the cost? What's the warranty? What can we expect out of the battery for in terms of lifetime and cycles? And if we cannot get these answers from Second Life then we don't go for Second Life." (Energy company 1, personal communication, April 12, 2021) Technological factors such as the state of health degradation curve make it very difficult to estimate how long a second life BESS will last. It is also difficult for second life BESS to guarantee the right performance over time. Another factor in this is that the economics need to be good for utility companies to buy a second life BESS compared to the increasingly cheaper new storage solutions. The new storage solutions would have a better warranty, longer lifetime, better performance and is more cost-effective. For the utility companies a new BESS is therefore a better choice compared to a second life BESS.

External adoption factors: Legal factors

- The producer responsibility ensures that car manufacturers are responsible for the waste-management of the batteries that are put on the market.
- The OEMs are in a position to do either the recycling themselves or to give the responsibility of recycling to an external party and pay for their services.
- Utility companies have strict checklist when buying BESS and require a high level of legal warranty

5.3. Take-back Systems

In this section, take-back systems are evaluated in relation to the take-back management, channels and customer relationships.

5.3.1. Take-back Management

There are a couple of ways in which batteries can be taken back from their first life in EVs. The first way is from the car recycling companies where they dismantle the cars if they are at the end of their life cycle (Recycling facilitator, personal communication, April 12, 2021). This route is not particularly large right now because most of the electric vehicles are recently new and are still in use. The cars that end up here are from either accidents or cars that reach their end of life. This will however rise simultaneously with the increase of electric cars on the road as is happening right now. Another way in which batteries can be retrieved is in co-operation with garages and car dealers (Recycling facilitator, personal communication, April 12, 2021). This stakeholder replaces batteries for their customer and supplies them with new ones. This stakeholder sometimes has close relationships with the car manufacturers and in case of the car dealers are part of their supply network. Collaboration with the recyclers/dismantlers and car dealers/ garages is how currently B2U take-back management takes place for the companies that work on B2U. Another route where batteries end up can be outside of the official dealer channels. At this point the batteries have a high chance to be sold from consumer to consumer (Recycling facilitator, personal communication, April 12, 2021).

5.3.2. Channels

As said before, the OEMs have two options to handle the waste-management of the batteries that they put on the market. Either do it via the channels of car recyclers or create their own take-back management. In the first case this means that the responsibility will be transferred to a third party that will carry out the responsibility in exchange of a fee that will cover the costs of the waste-management. Via this route, the third party can be an organization of multiple car dismantlers or car recycling companies that work together (Recycling facilitator, personal communication, April 12, 2021). In the Netherlands for example there is a consortium of companies from the car industry that created an organization that takes on the waste-management responsibility called ARN (*ARN*, n.d.). This organization will then choose to either directly recycle the battery or to also transfer the responsibility to another party that will engage in B2U activities.

In the Netherlands about 30 to 40% of the OEMs chose to do it themselves. This means that the OEM will take care of the waste management themselves in their own network. One easy take-back system is that of leasing the car or leasing just the battery. Making them the owner of the product that they sell to the customer and also make the OEMs more willing to take it back as the battery remains some value also at the end of its first use lifecycle (Subject matter expert 3, personal communication, March 31, 2021). If car companies choose this route, it will make it easier to have large quantities of the same type of batteries. This is preferable because this makes it easier to either repurpose on battery module level. Also, recycling is done easier if the batteries are of the same type and have similar chemistries (Subject matter expert 3, personal communication, March 31, 2021).

5.3.3. Customer Relations

Current customer relationships are mostly based on selling private owned cars and it will probably remain like this unless there will be fundamental changes in the business models of the OEMs (Recycling company, personal communication, April 22, 2021). Making it more difficult to create channels in which the batteries are taken back in a structured manner. One of the ways this can become more streamlined if the customer would be approached more as someone who receives a service rather than the end product. This can be done either by leasing the car or with shared mobility. A lease model for example can create a take-back loop for the OEMS and car dealers. This would make it easier for them to collect for repurposing or recycling activities for the batteries (Car company 1, personal communication, April 6, 2021). A similar construction is also being carried out by only leasing the battery instead of the entire car. The car would be bought on its own but the battery remains in the possession of the OEM/car dealer. With this construction, the car would have a lower initial price, making it also more interesting for the customer. These types of constructions have the potential to also increase customer relationship (Subject matter expert 1, personal communication, March 31, 2021).

5.4. Multi Stakeholder Network

In this section the differentiation will be made of the business models that are present in the current B2U value chain. The integrated B2U BM approach will discuss the advantages and disadvantages when the OEMs have a more integrated approach of their producer responsibility and have take-back systems in place for them to do repurposing and/or recycling themselves. The multi-stakeholder B2U BM approach also includes external parties that will take on the producer responsibility and take care of the repurposing or recycling. An example of the multi stakeholder B2U BM approach is shown in figure 20.

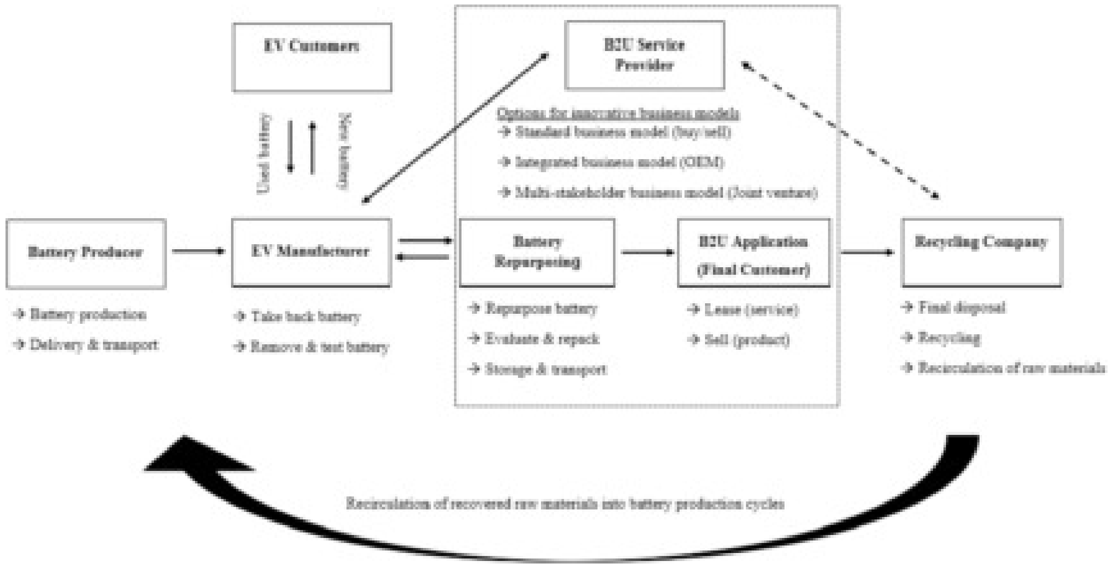

Figure 20: Example of the Multi stakeholder B2U BM by Reinhardt et al. (2019)

5.4.1. Integrated B2U BM Approach

The integrated BM approach would be advantageous for different reasons but also have some downfalls for the car companies. The most important stakeholder in this approach are the OEMs and the network of the OEMs with for example the car dealers and other players. The OEMs have a strong position when it comes to participating in B2U because of their inhouse knowledge and experience with the car battery (Recycling company, personal communication, April 22, 2021). Another advantage for the OEM is that the raw materials coming from the reversed take-back loops can be reused for their own material supply in the manufacturing of new batteries (Car company 1, personal communication, April 6, 2021). In this way the price of the raw material can be controlled, making them less reliable on price fluctuations in the market and supply uncertainties. This would mean a better control over the supply chain of raw materials needed for the manufacturing processes. Structures need to be put in place for the OEMs that are willing to participate in B2U and recycling to make this approach work. These structures have been explained in previous section and could be different types of leasing structures in combination with other services (Car company 1, personal communication, April 6, 2021).

There are however also some negative associations with B2U for the OEMs. It first of all requires a large financial investment to start with B2U especially if there is no system in place for taking back batteries. Secondly, it requires inhouse knowledge on what to do with the batteries (Car company 1, personal communication, April 6, 2021). It is outside of their core business and requires an entrepreneurial vision on what the potential benefits would be (Subject matter expert 3, personal communication, March 31, 2021). An estimate from one of the interviewed car companies is that companies with more capital will become more involved in battery second life and recycling because of this first initial investment (Car company 1, personal communication, April 6, 2021). Because these investments add up to the changing regulations for car companies to transition faster into the electric vehicle market, it would require some effort to take this on as well. A gap will exist between large companies that have the money to invest in these types of innovation whom therefore will have a better control of the market and its resources.

5.4.2. Multi-stakeholder B2U BM Approach

The multi stakeholder B2U BM approach is focused on the participation of different types of stakeholders outside the OEMs network that participate in partnerships. For the OEM it could also be economically interesting to not integrate B2U and recycling in their BM. In this way, the OEM does not need to take care of its recycling responsibility and transfers it to an external company that is willing to take it on for a fee (Car company 1, personal communication, April 6, 2021). Therefore, the total investment costs will be lower and making additional investments for waste-management not necessary. The focus of the company can remain in this case more on the core business of the company and other challenges such as the electrification of the industry batteries (Car company 1, personal communication, April 6, 2021). The participation grade of a particular OEM in the B2U market will also depend on how much expertise and knowledge there is within the stakeholders and their participation in the entire battery value chain (Car company 1, personal communication, April 6, 2021).

The disadvantages of a multiple stakeholder BM approach are that the OEM loses their control over the batteries and lose an asset that still contains financial value. For them, this could also become an issue if the battery ends up in a secondary application outside of the car without their knowledge. They don't want to be responsible for whatever application the batteries will be used in (Recycling facilitator, personal communication, April 12, 2021). This makes it also legally some extra work to make sure that all references towards the OEM are removed and that the responsibility of the battery lies with the external companies. Another negative side effect is that sometimes it is not clear where the batteries will end up. Opaque flows of old batteries will exist in which sometimes the batteries are exported outside of countries with developed recycling facilities (Recycling company, personal communication, April 22, 2021). This is also explained in the political adoption factor section. This will have a negative circular effect whereby countries do not recycle the batteries with the appropriate measures. These unsustainable practices could have a negative effect on the OEMs themselves as there is a general transition of the public towards more sustainable practices (Subject matter expert 4, personal communication, April 8, 2021).

6. Discussion and contribution

The features of the circular economy are becoming increasingly apparent in the emerging EV market. As the landscape of the car industry is changing from combustion engines to the more sustainable battery technologies, actors within the industry are noticing the economic potentials and are trying out new business models to make the transition. In this research it is shown that external factors are one of the important reasons why new business models are developed as the car industry is forced into a new type of market. As the batteries coming from retired EVs will become more available within the coming years, the expectation is that the B2U market will develop itself even more. New circular practices have been found on the topics of reusing, repurposing and recycling and have uncovered a learning by doing attitude from the different stakeholders interviewed. Interviewing the relevant stakeholders active in the market of B2U provided a new perspective on the B2U market and its development. This market oriented approach was missing in the current literature (Olsson et al., 2018). According to Martinez-Laserna et al. (2018) there is also a lack of the contribution coming from the OEMS and BESS integrators in current research. Whilst in this research, these stakeholders have their fair share of contribution. Therefore, the research gap in which there is a lack of literature on market development and stakeholder positions has thus been addressed with interviewing the relevant players in the B2U value chain.

The perspectives of circular business models have been used to create insights into the current market development of specifically B2U practices. The propositions and assumptions made in the beginning of this research created a structure to evaluate the B2U market and proved effective in finding its current state and development. Because there are many different relational constants that also affect the adoption of a circular business model by the different stakeholders, it proved almost impossible to create the perfect picture of the B2U market. The economic and technological factors have resulted in the most quoted responses from the interviewees. This may be due to the specific type of questions during the interviews but the results also showed the importance and relevancy of these factors. The stakeholders represent the market of B2U and their main concerns were either technical or economic of origin.

6.1. Current B2U market development

Neubauer et al. (2015) expected B2U to be a low margin market and also Martinez-Laserna et al. (2018) expects the economic viability and market potential of B2U uncertain. However, the emergence of new companies that have their core business on B2U activities show that the market is profitable and marks a new stage in the market development of B2U. It is unclear however whether these relatively small companies have the potential to grow further in size and provide a sufficient output for the number of batteries coming from the increasingly retired vehicles. Interviewing the different stakeholders created a better picture into the development of the B2U market and added to the current literature.

Most notable, it was unearthed that the collaboration between energy providers/utility companies and B2U providers is not something that will happen in the near future. According to Neubauer et al. (2015) the only identified market that has potential to cope with the increasing supply of batteries coming from EVs is that of BESS services to the grid. Viswanathan & Kintner-Meyer (2011) also make the assumption that batteries coming from EVs can provide a solution for BESS for the grid. But interviews that were held at the energy companies give a different picture of the situation. Energy/utility companies are at the end of the value chain in the case of battery second use. This results in that the energy companies are basing their decision on the specifications and price of the product coming from B2U. In their experience, B2U does not have the potential to live up to their product specifications economically, technically and also legally. They have not yet seen a price and performance competitive system compared to a BESS with new batteries and are not looking in this direction for any future solutions. With the decreasing cost of new BESS, it will be very difficult to provide a cheaper solution made from old EV batteries. Technically it would also be very difficult to create a system that is reliable in its performance due to the aging cells. In BESS coming from EV batteries, it is uncertain how long the lifetime of such a system will be and how it will perform over time. Cell degradation is a constant process and because of its previous life in EV it is uncertain when the cells will reach their end of life. This is also related to the legal factor that influences the adoption of B2U in the utility market. Because the utility companies require a high standard of energy storage it is very difficult for B2U provider to provide the right level of warranties. If the BESS cannot give the guarantees to deliver the needed performance, utility companies will not engage in partnerships for B2U. Other market opportunities are still in place nevertheless but focus more on storage solutions for remote areas with no electricity or backup systems with a need for energy supply. How BESS coming from B2U will perform in these area's is still unclear and would require further research.

Another interesting result that was found is that in the current market there is a preference for the multi-stakeholder network BM configuration. According to Reinhardt et al. (2019) it is expected that there is a preference for the multi-stakeholder network BM configuration. This is also what was found to be the case in the current B2U market in the Netherlands. In the Netherlands, 60 to 70% of the OEMs choose to collaborate with a partner that will take over the producer responsibility. This adds to the literature by confirming there is a preference for the multi-stakeholder network BM approach.

6.2. Future B2U market development

Future market development is difficult to predict as there are many different factors influencing the process of B2U. However, there are some factors that are more important than others and these can be predicted with some accuracy. Because companies have the tendency to first look at the cost picture, the economic factors are of importance and there are some cost related trends happening that will probably continue in the future as well. One of those trends is the costs of recycling which is going down. This trend can result in the effect that recycling will become a strong competitor to B2U because why not immediately recycle your product if this is the most economically sensible thing to do? This goes against the circular approach of the circular economy because repurposing should not be a competitor to recycling but an addition for extending the full life cycle of a product. As of now, in the current situation, the recycling companies ask money to do the recycling of batteries. This can still happen because of the producer responsibility whereby the OEMs have to pay their fair share and pay the recycling companies to take care of the batteries that they put on the market. Repurposing companies however are glad to receive the batteries for free together with the producer responsibility. The economic gains in repurposing EV batteries will reduce when the point of profitable recycling is reached. When this point is reached, batteries coming from take-back systems will have to compete between recycling companies and B2U companies, outbidding each other and raising the price of EOL EV batteries. This will diminish the already low margins made with B2U.

This will also influence the decision of the OEM in carrying out their producer responsibility. The batteries will have a higher residual value because there is a market for the retired batteries coming from their car fleet. The OEMs now have the preference to outsource their producer responsibility and let other parties take care of it but this requires them to pay for these processes. Whenever the batteries are increasing in residual value, it would be logical to expect that the OEMs will try to keep the batteries in their system. If this is the case it’s expected that the OEMs will chose to have a more integrated BM approach in the future and that the decision will shift in that direction instead of the now multi-stakeholder BM approach. OEMs have the incentive to create more focus on take-back systems that will make sure that the batteries are owned by the OEM during its life-cycle. This can be done with for example leasing structures or car sharing services. Another side-effect of this process would be that B2U for retired EV batteries is a temporary market and will be unable to compete with recycling. However, it is expected that B2U will not completely be discarded and that support from the government could provide the necessary aid to extend the life-time of EV batteries.

6.3. Recommendations

The aim of this study is creating clarity on the circular business model innovation in the B2U value chain by investigating stakeholders and stakeholder relationships. Another step that is taken is to also facilitate the circular economy and to provide recommendations based on sound research and information. The recommendations in this section are created based on the results and discussion section of this research which represent the views and opinion of the different stakeholders within the battery value chain. They are developed to help achieve the optimal circular development goals and to provide the market with insights to develop new or strengthen existing circular business models. This section is divided into recommendations for businesses and for politics as they are the main target groups.

6.3.1. Recommendations for Businesses

Businesses that are working on B2U applications have opportunities in developing circular business models and should have a focus of decreasing the costs of remanufacturing. The following recommendations are focussed towards these stakeholders.

- Secure a high-level battery supply coming from EVs. This can be done in close collaboration with OEMs and securing exclusive access to their end-of-life EV batteries.

- Improve remanufacturing processes to keep costs at the minimum. If these processes are optimized, the economy of scale will also have greater effect and will decrease the remanufacturing costs.
  - Design processes and techniques that result in good time-management and minimum labour.
  - If possible, try to keep the EV batteries at full battery module or pack level to decrease labour and problems with the extra remanufacturing processes.

    - Standardize product groups to maximize the economy of scale so that the development of standardized modular BESS technology can be a high priority.

- Experiment with different business models to keep the advantage compared to competitors. Experimenting with business models can uncover new possibilities in the market.
    - Business models focused on providing services rather than one-time sales will increase customer retention and has the option to generate more and reliable income streams.
    - Trying out new business models will also ensure differentiation from competitors and could provide a competitive advantage.

The following recommendation are focussed towards the OEMs to participate in circular business models surrounding the battery life cycle coming from their EVs.

- The OEMs should collaborate with third parties in order to have a multi-stakeholder BM approach and to more efficiently handle circular initiatives.
    - Invest in take-back systems and initiative to handle batteries coming from retired EVs.
    - Seek collaboration with partners if the knowledge of B2U is not readily available within the company.

- Increase inhouse knowledge surrounding circular topics that will help the company in developing new business models and have a better understanding of what is possible with battery second use.
    - This can be done with for example training existing personal or hire new employees that have experience in this field.

- Improve design for circularity. This means developing new standards for circular batteries that will make it easier to conduct circular activities.
    - Design batteries that are easy in for example repairing, dismantling and remanufacturing activities.
    - Focus on extending the life cycle of first use in maintaining good health for the batteries during its application in the car. Also provide repair services to extend the life cycle.

- Experiment with different business models to keep the advantage compared to competitors. Experimenting with business models can uncover new possibilities in the market.
    - Expand service offerings besides cars and introduce service packages that will for example lease the car and solar panels needed for charging.

6.3.2. Recommendations for Politics

This section will go into the recommendation that are aimed at politics and governmental organizations that have a strong position in changing the circular value chain.

- Develop clear definitions and standards that will help the industry understand what it needs to do and in what activities it can invest with support from the government.
    - This includes clearer legal definitions surrounding the producer responsibility to make the system watertight and remove any opaque flows of products that goes to countries with less recycling capabilities.
    - Make clear definitions on reporting obligations and how they are performed so misinterpretation and misleading numbers is less likely.
    - Also create standards for the calculation of external costs outside the economic factors such as environmental impact or other sustainable impacts. This can be for example life cycle assessments or CO2 footprint studies.

- Support industry by creating incentive and sanctions systems that will help shape the industry in the right circular direction.
    - Invest in the circular value chain by creating financial incentives for companies to become more circular. These incentives need to be chosen carefully based on experimental results and scientific research.
    - Regulate and enforce rules to maintain safe and legal practices.
    - Introduce initiative that will help steer the industry into collaboration with the different stakeholders, an example can be the battery passport that will provide transparent data on where batteries are located and what they made of.

- Increase inhouse knowledge surrounding circular topics. This will help governments in developing creating a better understanding of the circular battery value chain.
    - This can be done with for example training existing personal or hire new employees that have experience in this field.

- Invest in science and research infrastructure that are committed to develop more knowledge on circular battery topics.

7. Limitations and future research

This study is based on interviewing the relevant stakeholders which implies some limitations to the acquired results. The first limitation is that the use of interviews as the main source of data can influence the data collected, as people can have significant differences of opinion. This can be either due to their ability for them to express themselves in the correct manner but also in their willingness to share certain information (Verschuren & Doorewaard, 2010). Also, strategic answers can be a limitation to the acquired data. If a certain stakeholder has a desired situation, he or she may be biased in their answer. Another limitation was the absence of specific stakeholders within the B2U value chain. It proved for example difficult to talk to the right people from businesses that are working solely on B2U activities. As they are the stakeholders that are directly related to the multi-stakeholder BM approach, it would be very interesting to also hear their point of view. However, it proved difficult to establish contact with these stakeholders and therefore only one B2U entrepreneur has been interviewed. Their absence might be due to the fact that these stakeholders are relatively new to the market and do not want to give away much information away about their practices and results. The study also showed that the market for B2U is not one with high margins so reluctance towards giving too much information away seemed to be the case.

For further research, more cooperation with B2U business can be established to find out what their success factors are and how they approach the circular business of EV batteries. By including the companies that are currently working on B2U, it would provide interesting information regarding their practices and their approach towards finding the right customers. For these types of businesses, it is a constant process to find new market opportunities and their experience in this field could create new insights as to where their BESS coming from EV batteries could be profitable. The assumption made in this research that utility companies are not interested in B2U storage systems can also be further investigated. This study showed that the interviewed stakeholders in the utility sector have a negative association with B2U, but the limitations of this study could have influenced this result. A more qualitative study on this topic could create more clarification whether energy companies are interested in B2U.

The last avenue for further research regards following the expected trends mentioned in this research. In the discussion section for example it is mentioned that it is expected that the B2U market will not grow considerably in size because of its competition with recycling. An analysis and further research on the market trends mentioned in this research could create a better picture in to what extent B2U is feasible and will evolve. This can also be seen as another limitations of this study as the trends are expectations of the future market development but do not give any certainty as to what will happen. The cost reduction of new batteries or the increasing profitability of recycling is expected to happen but maybe these trends will end up very different due to unforeseen circumstances. By further researching these trends over time, more knowledge is created on the effects it has on the B2U market.

8. Conclusion

In this study, the main research question is answered and opportunities for the upscaling use of 2nd life batteries are investigated. Besides, recommendations are formulated that give businesses and policymakers a foothold for participating in the B2U value chain. This was done by interviewing 14 different stakeholders that are currently present in the B2U market. These interviews resulted in a dataset which was coded into different topics based on the literature review to understand the current market perspectives and the expectations on the future market development. By having a practice-oriented approach in this research, new perspectives were uncovered directly from these market practices. This approach, according to Olsson et al. (2018), fills the lack of literature on the current B2U market development. Also including OEMS and BESS integrators as sources of information addresses another lack of knowledge in the current literature as these stakeholders have a lower participation rate according to Martinez-Laserna et al. (2018). The main conclusion is that the current B2U market requires a learning-by-doing attitude from the various stakeholders, as many of their projects are the first of their kind. To make B2U work it would require an innovative approach as there are high costs involved with relatively low margins.

To answer the first sub-question regarding the processes that influence the creation of new business models in repurposing end-of-life EV batteries, research has been done on circular business model innovation theory regarding its unique properties. Out of this literature review, four different propositions surfaced and were used as the basis for a market analysis. Each proposition identified new insights based on a different perspective. According to the stakeholders, the main processes influencing the creation of new business models for B2U are based upon either economic or technical factors. The data illustrates how these factors were the main concern among the different stakeholders in the B2U market. As of now, B2U is not economically attractive and different reasons play a role in this. The first reason is that the remanufacturing costs are high due to the required manual labor for dismantling, measuring and repacking processes. Another important economic factor is that new batteries are getting cheaper per storage unit and will compete with the salvaged batteries coming from retired vehicles. Besides, potential markets for BESS coming from B2U are still uncertain and require further research on current practices. For the technical factors, the battery degradation was mentioned by the different stakeholders as an important factor to be overcome. Total battery lifetime predictions remain uncertain after a first application and performance decreases based on the number of charge-cycles the battery has completed, together with other factors that influence the batteries lifetime. This also creates difficulties when warranties need to be given to potential customers that require a reliable system for a long period of time.

The second sub-question regards the evaluation of the current market of B2U and its recent developments. It was yet unknown what preference the OEMS have in their approach to battery second use. They have the option to do it either themselves in their own supply chain (integrated BM) or do it with different partners that take on the responsibility of the 'waste' management (multi-stakeholder network BM). Reinhardt et al. (2019) expected that the OEMS will have a preference for the multi-stakeholder network BM and that more research is needed to prove this. Data from this research showed that in the Netherlands there is a stronger preference for OEMs to choose the multi-stakeholder network BM. The data shows that an estimated at least 60-70% percent of the OEMs operating in the Netherlands collaborate with third parties to handle their producer responsibility. This confirms the expectations by Reinhardt et al. in the Netherlands, but does not confirm this is also the overall consensus outside the Netherlands. Further research in other parts of the world can prove this assumption further.

Another noticeable result from this study regarding the current market was that cross-sectoral collaboration with utility companies proved very difficult. According to Neubauer et al. (2015) the utility sector is the only identified market for BESS that is large enough to fully adopt all the batteries coming from retired EVs. However, in this research the data showed that collaboration between the different sectors proved difficult due to economic, technical and legal constrictions. The utility companies have not yet seen a price and performance competitive BESS in comparison to a BESS coming from completely new batteries. Besides, the interviewed utility companies are also not looking in this direction for any solutions. The main reason for utility companies to not participate in B2U is that they require high performance and long lifetime stability which is currently difficult for B2U BESS to provide sufficient guarantees for due to uncertain lifetime and performance predictions of the batteries. This makes it difficult to apply certain warranties on the BESS and therefore considered riskier to implement. Other sectoral collaborations however have been researched to a lesser extent in this research and have not been included in this study. Further market research on other sectors could provide more insights into the current B2U market.

The third sub question explores the expectations of the future development of the B2U market. The expectations are based on the assumptions of the interviewed stakeholders and proved difficult to predict. However, there are certain trends surfacing that might be able to give more insight into the future development of the B2U market. One major trend that could influence the adoption of B2U BMs is that the prospect of profitability of recycling is improving. The current situation is one where batteries coming from take-back systems still require further investment to recycle them as recycling is still not yet profitable. But the business case for recycling has increased over time and according to the market insights of stakeholders, a point will soon be reached where recycling will become profitable. At this point EOL batteries will have a higher residual value making recycling companies compete for these batteries together with B2U providers. This trend is expected to make B2U less viable as it will increase costs and reduce the already low margins made with B2U. Another expectation is that the BM preference of the OEMS will be influenced by this trend and will shift more towards an integrated B2U BM. For the OEMs it would be more interesting to keep the batteries under their own control and engineer their takeback systems in order to keep ownership of and access to the raw materials. The increasing residual value would be for example beneficial for their supply of raw materials for new batteries and will help support the negative effects of fluctuations in market prices.

In the final stages of this study, recommendations are made and are separated to address both businesses and politics. The key takeaways for businesses are that they have the potential to create new business models based on the circular strategy of repurposing but face a difficult market. High remanufacturing costs are to be overcome and will require innovative business model implementations to keep competitive advantage. A secure and reliable stream of EV batteries need to be established with preferably close collaboration with the OEMs directly. This would lower the risk regarding battery supply and would allow to focus more on improving the remanufacturing processes to keep costs at a minimum and to benefit from economy of scale. Also, recommendations for OEMs have been established and focus on collaborating with third parties in a multi-stakeholder network approach. Collaborating with partners that already have a certain knowledge about B2U will help to reduce the needed in house knowledge and will allow the OEMs to keep the focus on the transition towards electrification. Besides, inhouse knowledge surrounding circular initiatives should be generated and can be done by training existing employees or hire experience. OEMs should also improve design for circularity by developing new standards that will make it easier to participate in circular initiatives.

The recommendations for politics focus on governmental organizations that have a position in changing the circular value chain. It is of importance that clear definitions and standards need to be developed to help the industry in choosing what activities it can invest in with support from the government. Industries can be stimulated with different types of incentives and sanctions that will help to further shape the circular value chain for EV batteries in the right circular direction. This is needed because the industry mostly focuses on the economic aspects. However, sustainable practices should also be involved to a larger extent and politics have the power to include this. Also, governmental organizations should continually increase their inhouse knowledge on topics such as the circular economy to help create a better understanding of the market practices and to provide well founded changes. Another recommendation, related to the previous one, would be to invest in science and research infrastructure that are committed to develop more knowledge on circular battery topics.

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Appendix A: Vosviewer result on B2U applications

Web of Science settings:

TS = (("electrical vehicle battery" OR "EV battery" OR "li-ion battery") AND ("second life" OR "second-use" OR repurposing OR recycling OR refurbishing))

Exported as: tab-delimited (Win),

VOSviewer settings:

Type of analysis: Citations

Unit of analysis: Documents

Minimum number of citations of a document: 5, 71 meet the threshold

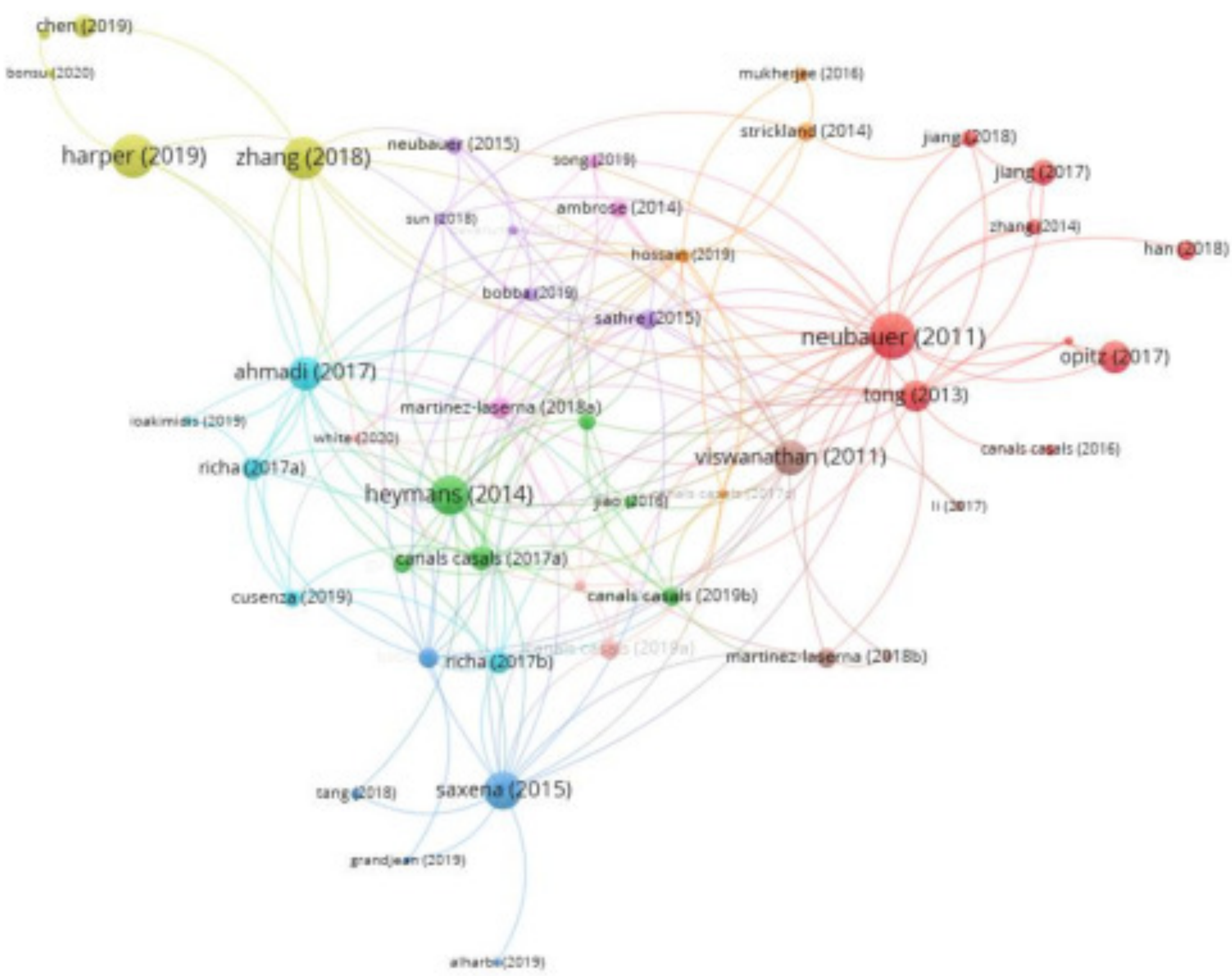

Figure 21: VOSviewer of the B2U research landscape

Appendix B: Overview of the codes in relation to the interviews

	1: Subject matter expert 2 (12)	2: Subject matter expert 3 (15)	3: Subject matter expert 1 (19)	4: Car company 1 (21)	5: Subject matter expert 4 (14)	9: Recycling facilitator (32)	10: Recycling company (16)	11: Energy company 3 (1)	12: Investment group (11)	14: B2U entrepreneur (3)
1.a. Team Motivation and Culture (16)		1	1	10		1				
1.b. Inhouse Knowledge (12)		1	1	6		1	1			
1.c. Transition Procedures (9)		1		5		1				
2.a. Political Factors (17)	1		1	2		4	7		1	
2.b. Economic Factors (47)	3	4	5	4	6	7	1	1	5	1
2.c. Sociocultural Factors (6)		1		1	1				1	
2.d. Technological Factors (34)	1	5	4		8	3	3		4	
2.e. Environmental Factors (9)	1	1	2				2		1	
2.f. Legal Factors (16)			2	3		6	1			
3.a. Take-back Management (20)	4	5	5			3	2			
3.b. Channels (51)	5	3	2	3		18	6		2	2
3.c. Customer Relations (12)		2	2	3		2	1			
4.a. Integrated BM (20)	4	5	2	6		1	2			
4.b. Multi-stakeholder BM (25)	4	4		4		5	1		1	2
Totals	23	33	27	47	15	52	27	1	15	5

	15: Energy company 1 (16)	16: Energy company 2 (10)	17: Subject matter expert 5 (1)	18: Car Company 2 (4)	Totals
1.a. Team Motivation and Culture (16)	1	1		1	16
1.b. Inhouse Knowledge (12)	1			1	12
1.c. Transition Procedures (9)	1			1	9
2.a. Political Factors (17)		1			17
2.b. Economic Factors (47)	7	3			47
2.c. Sociocultural Factors (6)		1		1	6
2.d. Technological Factors (34)	4	2			34
2.e. Environmental Factors (9)	1		1		9
2.f. Legal Factors (16)	2	2			16
3.a. Take-back Management (20)				1	20
3.b. Channels (51)	5	4		1	51
3.c. Customer Relations (12)	2				12
4.a. Integrated BM (20)					20
4.b. Multi-stakeholder BM (25)	2	1		1	25
Totals	26	15	1	7	294

Appendix C: Examples LinkedIn Interview invites

Coen Smits van Oyen • 21:30

Dear Ms [redacted]

I'm doing my thesis on the topic of EV battery second use and was wondering if you would be available for a short conversation about this topic? Your experiences with microgrid solutions could provide me with valuable information for my research.

Sincerely,
Coen Smits van Oyen

Coen Smits van Oyen • 11:34

Dear Mr [redacted]

I got your contact via [redacted] and he told me that your working in the field of EV battery second use. I'm doing my thesis on this topic and was wondering if you would be available for a short conversation?

Sincerely,
Coen Smits van Oyen

Coen Smits van Oyen • 11:11

Beste meneer [redacted]

Op dit moment ben ik bezig met mijn master thesis over het hergebruik van EV batterijen. Zou u eventueel beschikbaar zijn voor een kort gesprek hierover? Uw ervaring en inzichten zouden mij kunnen helpen in het onderzoek.

Met vriendelijke groet,
Coen Smits van Oyen

Appendix D: Results table

Proposition from the Conceptual Framework (Expectation on what you will find out with your case study – describe expectation in terms of 'how' something happens or 'why' something might happen)	Results (Summarize results per proposition – describe them as 'dry' as possible. Also mention empirical source (APA style).)
1. The *Internal Adoption Factors* show how the organizational capabilities influence the process of developing a circular business model.	1. In what way the stakeholders recognize organizational capabilities that require intangible resources. These are separated in the following categories.
	a. Team motivation and organizational culture Second life batteries endeavors are not the core business for car manufacturers and requires additional innovation/investment 2:11, 4:1, 4:6, 4:7, 4:9, 4:20 Investment in second life batteries is more a sustainable investment rather than an economic investment 3:19, 4:14, Car companies with large capital funds are more likely to differentiate from their core business. 4:16, 4:19, 4:21 The market of second life batteries is at its first stages and requires learning by doing from the different stakeholder. 9:3, 15:5, 16:5
	b. Inhouse knowledge **THESE ARE NOT USED**

	The participation grade in new market developments will also depend on how much expertise and knowledge there is within the stakeholders of battery second use. 3:16, 4:8, 4:19, 15:7 The OEMs have a stronger position to participate in battery second use because of their inhouse knowledge and dependency on raw materials. 3:16, 4:9, 10:10, - Economic 3:10, more customer engagement when take-back system is in place
	c. Transition procedures No result has been found in this adoption factor
2. The *External Adoption Factors* will show how political, economic, sociocultural, and technological issues influence the process of developing a circular business model.	2 How the different stakeholders approach and recognize the following external adoption factors.
	a. Political factors The OEM is responsible for the batteries that they put on the destined market and this responsibility can be transferred to other parties. This influences the decision what to do with the batteries **1:8**, 9:10, 10:14, - the less is collected, the less they have to pay into the systems, and this is one of the reasons which also drives all kind of I would say opaque flows out of Europe for electronics for vehicles, and this of course can also. Happen for batteries. The OEM has a bigger need to change if the political situation in the operating market has a large share in total car sales. 4:24 The government can play an important role in the battery value chain to maintain safety and sustainable practices. 3:20 4:15, 9:10, 10:4 - Government can create market for recycled raw material. (This is being done right now?) 9:10 9:11 - enforcement, monitoring and so on. 10:4 10:13 - Only with government money can it be viable. 12:7 Battery passport for dynamic data exchange, loading cycles, state of health, location, recycling result 10:5, 9:4, 9:9

- There is also a need coming from the recycling industry so they know how much material they can get recycled 2:9 9:4
- More transparency 2:8
- Blockchain technology 9:9

New draft battery directive. 9:8 10:2
- The new battery directive is a direct regulation on all EU members instead of guidance (regulation 2006) so no own interpretation. 9:8 10:2
- More focus sustainable and smart mobility 9:8
- More focus on circular economy 9:8
- Less dependence on raw materials outside EU 9:8

The old battery directive is still mainly about avoiding hazardous emissions and avoiding the waste, but it's not really about recovering resources. The big benefit of the new proposal is that there's a clear focus on**10:2**
- specific recycling targets for specific metals, so not just the overall weight based average recycling rate, but specific recycling rate for certain methods. T
- they have a recycled content approach 10:2
- They have a life cycle approach 10:2

b. Economic factors

To this day, the number of batteries coming from EVs is still too low for large scale second life battery adoption. 1:1, 3:1, 5:10
- Arena project did not have enough
-

Repurposed batteries can provide cheaper stationary solutions compared to new batteries. 1:11
- if there is a a quick way to identify what the state of health of the battery and its suitability for reuse and perhaps you mix them with the new batteries. 1:11
- only if made possible by government money 12:7

Large scale implementations might have lower labor costs because of economy of scale 2:10, 3:18

- Full battery packs are easier to connect together. Removing a lot of obstacles if disassembly is necessary. (Only possible for car manufacturer) 2:10
- Uniformity 3:18

Labor cost for remanufacturing EV batteries is too high. 14:3, 15:7, 15:8

- Then the price has to be really, really low that you accept those downsides. Limited. Usability in terms of years or cycles. 15:8

New batteries are getting cheaper per storage unit and will compete with second life batteries. 2:15, 3:15, 5:11, 5:15 9:15, 12:2, 15:7, 16:4

Raw materials are getting scarcer and prices are rising, underlining the need for recycling. 2:14, 3:13, 5:11, 5:13

Recycling is not commercially viable at the moment but this will shift and become commercially viable. 5:1 5:13 9:10, 9:12, 15:10

- This will also shift repurpose to recycling 5:13
- Market for recycled material can and will become larger due to policy 9:10
- Because of the demand of raw material will increase 9:12
- Cost of recycling is getting cheaper 9:13
- Current recycling can only be viable with government money 12:7

Smart grids will become more important in the future and could provide potential business cases for battery storage systems. 2:13, 11:1

Second life batteries endeavors are not the core business for car manufacturers and requires additional innovation/investment. (**ALSO, MOTIVATION**) 4:11, 4:13

- A "smaller" car manufacturer says that the focus is now somewhere else and to create a second life channel for batteries, more capital is needed. 4:11
- The step to electrification is now more important and already requires a major shift/investment of the car companies 4:13 4:21, 4:22

Second life batteries have been a topic for a longer period of time but does not seem to be picked up. 5:10

Car companies will try to make it viable because they want to shift the responsibility and therefore also the cost. 12:4 10:15

- the less is collected, the less they have to pay into the systems, and this is one of the reasons which also drives all kind of I would say opaque flows out of Europe for electronics for vehicles, 10:14

There is an economic need from the market to know what's inside the battery. 2:9

- Recyclers need it to know where the batteries are and what materials can be recovered. 9:4, 9:9

Utility companies at the end of the value chain are not interested in second life batteries because of better alternatives (**ALSO CHANNELS)** 15:12, 16:8

-

Value stacking is a market in which the battery storage system operates and can provide a solution. 12:10 12:11

- Different type of markets can be addressed 12:10
- Not peak shaving for renewables 15:15, 15:16
- Politics are in favor because of increase renewables
- More decentralized solutions going forward 16:11
-

Another application are home storage systems that require high safety standards. 9:20

- Not achievable

c. Sociocultural factors

In general, there is a trend going that renewable are becoming more important, driving the need for energy storage.

- The world is changing towards sustainability issues 16:11, 5: 11?

There is a transition in the market that is focused on the energy transition.

- Dealers are changing 9:16
- These new structures need to build also with the OEMs 10:11
- Learning by doing 9:3

d. Technological factors

Cell technology

Balancing the capacity from old battery cells gives major issues when operating in a battery storage system coming from recycled EV batteries. 2:1, 15:7, 16:2

- It is important to group cells together based on their condition 5:5, 15:7
- Different battery types give even more problems. 5:7

The degradation curve is very inconsistent making it difficult to estimate how long the system will work. 16:3, many others?

- The batteries coming from EVs already have a reduced capacity due to the fact that they are built with outdated technology, but also because of degradation from its first life use. 3:6, 9:15

Safety is an important issue when looking at battery second use. 10:7

- To maintain safety standards, it is necessary to operate the cells in a more cautious manner. If you stress the cells to much more safety concerns arise 5:8, 5:9
- Every cell needs to be tested and removed if necessary 12:3
- Another application are home storage systems that require high safety standards. 9:20 **(LEGAL?)**

New battery storage technologies outside Li-ion technologies are also undertaking rapid development and are more suitable for stationary application because of for example better safety specifications. 12:6, 12:8

- New batteries will also have a longer life span. 9:15, 10:8
- Battery technology is improving rapidly both on car battery technology but also for energy storage battery technology. 10:8 12:6

Manufacturing

It is technically possible to repurposing of EV batteries 5:3, 5:5

Some batteries coming from EVs are hard to disassemble because of the frame its build in. 9:29, 12:3

- Piece on BNR about this

With Battery second life it is better to keep the cells inside the modules and inside the battery pack. 2:10, 5:2 12:3, 15:3, 15:4

- Less labor 2:10
- Compromising the BMS and you need a new one 5:2, 12:3,15:4, 16:2
- Also, pack is airtight, watertight, standard plugs, integrated fuse. No reprogram, only update 15:4
- Cons: it is difficult to connect the different BMS systems together and requires collaboration with car company

It is easier to do repurposing with large quantities of the same EV batteries. 3:18

- Economy of scale

The ratio of raw materials in batteries from EVs is changing. And less are materials is used. Making the rare materials in the old batteries more important because they can provide for more batteries. 10:9

Electricity grid operators have strict rules for the performance of energy storage systems 2:2 9:18

- In a project for battery second life this was an issue they faced and couldn't provide 3:2, 3:5

e. Environmental factors

Second life use is necessary and always goes hand in hand with recycling. 1:10 3:11 3:14

It is a problem that recycling cannot be done in all places of the world. Therefore, recycling must be ensured also in places where this is less viable. 1:10 3:11 10:1 10:13,10:14, 12:5

A battery passport can create insights as to where the raw materials are coming from to ensure its not coming from illegal mines for example. 2:8, 10:13

	e. Legal factors Energy provider have a strict checklist that they use when buying storage systems and want guarantees 3:5 9:30 15:7 16:3 16:4 Certified dealers can be ensured to create a safe environment for repurposing. 3:12 Car manufacturers have difficulties insuring batteries for lease. 4:16 Due to legal constrictions, car manufacturers have their main focus on electrifying their fleet. 4:24 There is a producer responsibility that ensures that car manufacturers are responsible for the product they put on the market including batteries. 9:1 9:25 The battery regulation includes a piece on recycled material in new batteries. 9:11 Car manufacturers don't want their brand associated with the battery cells if they are used in a different application outside of the car. This is legally settled so there is also a new producer responsibility. 9:23, 9:24
3. The *Take Back System* will show how the stakeholders handle the forward and reverse logistics of the raw product.	3 How different ways of take back systems there are and how the stakeholders use them and recognize other types of take-back systems. The take back systems are identified according to the following indicators. **a. Take-back management** Cars coming from the market will be brought to a vehicle recycler or back to the manufacturer 1:3, Also, car dealers will have batteries that need to be replaced and choose where the old batteries go to. 9:5

	- Car dealers are changing attitude in also repairing batteries 9:5 OEMs can take back the batteries and keep them in their own loop. 1:5, 1:6, 2:5 - Makes it easier to recycle/repurpose large number 1:6, 2:4 - A lease model can create a takeback loop for OEMs/ car dealers. 2:3, 2:6, 3:4, **10:11** - CUSTOMER RELATION. Positive eigen chap 3:10 - Customer viewpoint for leasing should be made attractive also from government. 2:7 - Negative: There is no open market 3:7 3:8 3:9 The vehicle recycler will then choose to either recycle or repurpose the batteries. 1:4
	b. Channels **Battery repurposing companies** Do not have a strong motive to start recycling the batteries after their end of life and sometimes export second life stationary applications to countries without proper recycling facilities. Want preferably the same type of batteries to make it easier 9:30 Exporting products result in waste streams 10:1 **Car recycling companies** Work together with dismantling companies 9:6 Sometimes have exclusive blanket orders (recontact) with OEMs 9:7 Collect the batteries and send it too either - Battery recycling company, Cost's money 9:26 - Repurposing companies, does not cost money 9:26 **Energy storage suppliers involved in repurposing for second life** Get their batteries from:

- OEMs/car dealers 1:6
- Car dismantling companies - private owners 1:6 10:11

OEMs/ car dealers

Around 60 to 70% of the OEMs choose to pass the responsibility to a third party. The others integrate it in their own BM such as Tesla and most of the French brands. 9:32

OEMs have different interests to start a take back system
- Need the resources for new batteries 1:12 3:13
- A take-back system will cost money 10:14
- Want to transfer the end-of-life responsibility 12:4

Have a better position in collecting batteries from their fleet
- Also easier for recycling companies with same type of batch. 1:7
- With leasing constructions 2:6

Car dealers are transitioning towards refurbishing batteries 9:16, 10:6

Energy/grid operators

Have strict criteria for energy storage systems because they want reliability. 3:5 15:9

Governmental agencies
- Governance over market 10:15
- Should promote the market development (see politics)

Private owners
Sell their batteries to third parties resulting in waste streams 9:19

c. Customer relations

	A lease model can create a takeback loop for OEMs/ car dealers. 2:3, 2:6, 3: 4, 4:10, 4:23 **10:11** Car manufacturers have difficulties insuring batteries for lease. 4:16 4:17 Increased customer relationship 3:10
4. The *multi-stakeholder's network* will be used to find out whether the stakeholders have a preference for a more integrated approach to B2U or rather have a multi-stakeholder approach. The multi-stakeholder approach is expected to be preferred because of the increase in risk associated with extending product ownership	4. In what way the stakeholders recognize the pros and cons of the following two types of business model approaches. **a. Integrated B2U BM approach** Pro's: - **Check inhouse knowledge section** - The raw materials van de reused for their own batteries 1:12, 3:16 - The knowledge of how to handle the batteries for repurposing is in house. 1:13 - There is a market for second life use - With a leasing plan an increased customer relation is achievable (see also customer relation) 3:10 - Easy to combine also with other value propositions 4:10 - You want to make it circular to keep the resources under own control. Then you can control the price and have no surprises 4:25 - As a service 4:25 Cons: - It requires a large initial investment 4:11, 4:13 - A gap will exist between large companies with money 4:21 - It is outside of their core business 2:11
	b. Multi-stakeholder B2U BM approach Pro's - The producer responsibility is shifted 4:4 - Less direct costs only to shift the responsibility 4:4 - Focus can remain on the core business of the company. 2:11 4:7

Con's

- Unsure where the batteries will end up. This could be an issue especially if it's within a secondary application outside of the car. They don't want to be responsible. 9:7 9:24

Appendix E: Discussion table

1. Conceptual investment 4:11/model	2. Conceptual investment 4:11/model	3. Discussion	4. Discussion	5. Discussion	6. Avenues For further research
Proposition [expectation on what you will find out with your case study – describe expectation in terms of ‘how’ something happens or ‘why’ something might happen)	Source (reference here: take from literature review and summarize its main statements)	Findings on propositions: Did things happen as you thought they would happen; did you point out the reasons why something happens as it happens correctly?	Theoretical/empirical contribution. How do findings relate to existing literature?	What can you NOT know/conclude from your study? Limitations on your data and data gathering.	1.Which propositions couldn’t be falsified? How could they be researched in a follow-up research project, using which research questions and methods? 2.Which new propositions can you formulate based on your findings?
1. The *Internal Adoption Factors* show how the organizational capabilities influence the process of developing a circular business model.	1./2. /3. Lewandowski (2016) describes a proposed circular business model canvas based on the business model canvas introduced by Osterwalder & Pigneur (2010). It adds two additional building blocks: the adoption factors and the take back system. The added building blocks give an explanation how the businesses organize their organization in relation to the circular economy. The adoption factors have been separated into two different factors, the internal and the external factors. The building blocks are more explained in the	1. market of second life batteries is at its first stages and requires learning by doing from the different stakeholder 2. Industry is forced into a new market and need to improve their value propositions	1. synergistic, it contributes to the literature as the debate is still present where second life is going and if it’s feasible	1. It proved difficult to make generalized results for the internal adoption factors because the resources are intangible and difficult to measure for each stakeholder in the battery value chain. This would require a better understanding of each unique situation of the targeted stakeholders and proved to be out of the scope of this research. This chapter is therefore not divided for each specific indicator in contrast to the other propositions but is a summary of the three indicators combined.	1. Further research can be done on the stakeholders and their specific organizational approach to the changing condition of the market. To what extend are they changing and what these organizational changes do to the internal adoption factors
2. The *External Adoption Factors* will show how		3. It shows that the stakeholders for	3. Antagonistic, it falsifies the assumption that the	3. The utility companies have indicated that they do	3. What type of markets are available

political, economic, sociocultural, and technological issues influence the process of developing a circular business model.	literature review in section 1.3. 3..	B2U in collaboration with energy storage systems for renewables is not going to happen. Legal, economic, technological reasons 4. Shift is going on to adjust to the electric vehicle market and new collaboration patterns are emerging. 5. Producer responsibility needs a high enforcement level to also minimize opaque flows	battery energy storage systems can be used for the energy market 4. synergistic, it contributes to the literature as the debate is still present where second life is going and if it's feasible 5. synergistic, it contributes to the literature as the debate is still present where second life is going and if it's feasible	not foresee any collaboration in the near future. The perspective from the B2U companies might also be interesting but have not been interviewed probably due to not wanting to share much information. 4. 5. It is unsure what the exact impact is of these opaque flows	for B2U as there are some options. 4. Research on the new collaboration patterns. 5. Research on how the producer responsibility is carried out and how to improve it.
3. The *Take Back System* will show how the stakeholders handle the forward and reverse logistics of the raw product		6. Take back systems need to be put in place to optimize the flow of battery handling into repurposing and recycling	6. synergistic, it contributes to the literature as the debate is still present where second life is going and if it's feasible	6. Not much information has been gathered on current practices and current experiences regarding different takeback systems currently in place from OEMs. Could provide better insights if these systems are achievable.	6. Different take back management systems and its results
4. The *multi-stakeholder's network* will be used to find out whether the stakeholders have a preference for a more integrated approach to B2U or rather have a	4. 4. Reinhardt et al. (2019) discuss how their preference goes out for a multi-stakeholder approach to business model development for B2U. This means that more parties	7. For now the multi stakeholder approach is more popular but if recycling becomes positive the suggestion is that	7. synergistic, it contributes to the literature as the debate is still present where second life is going and if it's feasible	7. Not much information has been gathered on current practices and current experiences regarding different business model approaches for OEMs. It looks like there's a trend	7. Further research on the trend of what the OEMs choses to recycle and repurpose its vehicles.

multi-stakeholder approach. The multi-stakeholder approach is expected to be preferred because of the increase in risk associated with extending product ownership	should be involved rather than integrating B2U into the business models of for example the OEMs or battery manufacturers. Explained more in section 1.3. 4..	car companies want to maintain control and have a more integrated BM.		going towards integrated BMs but this can be researched more on what the exact reasons would be for the OEMs to do this.	