Thomas Guggenberger, BSc

Analysis of the Influence of Evolving Energy Storage Technologies on Business Models in the Automotive Industry

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Chair: Univ.-Prof. Dipl.-Ing. Dr. techn. Stefan Vorbach

Adviser 1: Dipl.-Ing. Ines Korajman BSc

Adviser 2: Dipl.-Ing. Dipl.-Ing. Michael Rachinger BSc BSc

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Statutory Declaration

I declare that I have authored this thesis independently, that I have not used other than the declared sources/resources, and that I have explicitly marked all material which has been quoted either literally or by content from used sources.

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Abstract

The aim of this thesis is to deconstruct the potential impact of alternative energy storage solutions on the prevailing automotive business models. Due to factors such as sustainability policies, an accelerating pace in technological innovation and changing customer behaviour companies face an increasing imperative to put their traditional business models into question. As a response to the current technological development in the range of electric mobility the aftermath of the battery as an alternative to the dominating internal combustion engine on the automotive business models will be explored. Therefore, a qualitative study is conducted where expert interviews with industrial firms are evaluated to show possible directions where the automotive industry is heading due to technological changes. Furthermore, the major players in the industry regarding electric vehicles are analysed. The outcome of the qualitative study were six core dimensions in which the statements of the individuals have been aggregated. The categories indicated a trend for the regarded companies towards business model innovation as a response to the indecisiveness of actors in the Automotive Ecosystem. Furthermore, interview data suggested that the introduction of new technologies led to an increasing importance of collaboration and sharing within the business ecosystem to diversify and get access to technologies from actors within that Ecosystem. Most importantly, the qualitative study showed that the main actors are only just in the middle of a profound transformation and that initiatives of the regarded companies disclose a certain reservation in facing the technological changes.

Ziel dieser Arbeit ist es, den Einfluss von alternativen Energiespeicherlösungen auf die vorherrschenden Geschäftsmodelle in der Automobilindustrie zu analysieren. Durch Faktoren wie Nachhaltigkeitspolitik, zunehmend schnellere technologische Neuerungen und ein verändertes Kund_innenverhalten sehen sich Unternehmen vermehrt gezwungen ihre bisherigen Geschäftsmodelle zu hinterfragen. Aufgrund der derzeitigen technologische Entwicklung im Bereich der Elektromobilität soll die Auswirkung der Batterie als Alternative zum – nach wie vor – dominierenden Verbrennungsmotor erforscht werden. Zu diesem Zweck wird eine qualitative Studie durchgeführt, bei der mittels leitfadengestützter Expert_inneninterviews mit industriellen Unternehmen die mögliche Entwicklungsrichtung der Automobilindustrie herausgearbeitet werden soll. Des weiteren werden die Hauptakteure in besagter Industrie recherchiert. Die einzelnen Aussagen der Interviewpartner_innen konnten in sechs Kerndimensionen unterteilt und zusammengeführt werden, auf welchen die Ergebnisse der qualitativen Studie basieren. Die qualitative Analyse weist darauf hin, dass vermehrt Geschäftsmodellinnovationen als Antwort auf die derzeitige Unentschlossenheit der Akteure im Business Ökosystem vorgenommen werden. Darüber hinaus wird in den betrachteten Unternehmen im Zuge der Einführung neuer Technologien vermehrt auf Kooperation mit anderen Unternehmen gesetzt um Zugriff auf die Technologien der anderen Akteure im Business Ökosytem zu erhalten. In erster Linie zeigte die qualitative Studie jedoch, dass sich die Hauptakteure gerade erst mitten in einer tiefgreifenden Transformation befinden und die Initiativen der betrachteten Unternehmen eine gewisse Zurückhaltung gegenüber den technologischen Veränderungen zeigen.

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Abbreviations

BEV	Battery Electric Vehicle
BM	Business Model
BE	Business Ecosystem
BMF	Business Model Framework
BMI	Business Model Innovation
CAES	Compressed Air Energy Storage
CVT	Continuous Variable Transmission
EC	Electrochemical Capacitor
EDLC	Electric Double-Layer Capacitor
EMBATT	Chassis Embedded Battery
ESP	Engineering Service Provider
ESS	Energy Storage Solution
EV	Electric Vehicle
FC	Fuel Cell
GM	General Motors
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
ISG	Integrated Starter Generator
KERS	Kinetic Energy Recovery System
Li-ion	Lithium-ion

OEM	Original Equipment Manufacturer
OII	Open Innovation Information
MENA	Middle East and North Africa
NEV	New Electric Vehicle
R&D	Research & Development
UC	Ultracapacitor
NiMH	Nickel Metal Hydride
PbA	Lead-Acid
PHEV	Plug-in Hybrid Electric Vehicle
PHS	Pumped Hydro Storage
RQ	Research Question
SMES	Superconducting Magnetic Energy Storage
WLTP	Worldwide Harmonized Light Vehicles Test Procedure
WTW	Well-to-Wheel

1 Introduction

As the thesis introduction, section 1.1 states the general topic and motivation for the study. Subsequently section 1.2 identifies the research aims and objectives of the thesis. The limitations of the study are defined in section 1.3 whereas the research method is provided in section 1.4. Finally, section 1.5 presents the structure of the thesis.

1.1 Topic Description and Problem Definition

The global automotive industry is facing radical changes: Rising costs, changes in customer behaviour and tighter regulations. Furthermore, innovations in technology threaten existing revenue streams and blur the once clear dividing lines between car manufacturers (also referred to as Original Equipment Manufacturers or OEMs) and Tier 1 & 2 suppliers as well as between OEMs and technology companies. As it is stated by Sakkers (2016), the automotive business model (BM) hasn't changed significantly in the past century. The current automotive supply chain has the shape of a pyramid with the auto manufacturers on the top, leveraging their position by pitting the suppliers against each other and thereby exerting pressure on their margins. However, as the business environment has become more erratic and uncertain due to changing geopolitical circumstances and recent developments such as shared mobility and connected vehicles, companies have to dissociate themselves from the perseveration of formerly enduring BMs in order to stay competitive and to enable sustainable growth (Wells, 2013). Furthermore, air pollution and global warming issues as well as insecurity of energy supplies have given impetus to a worldwide quest for alternatives to the combustion motor, as stated by Jacobson (2009). The electrification of vehicles has become a discernible trend, manifesting itself through global shifts in regulations, changing customer needs and progressive technology. The question arises how the traditional car industry will respond to this imminent disruptive force.

1.2 Research Objectives and Research Question

Against the above background the aim of this master thesis is to first of all elaborate on the current BM of the automotive industry and analyse the driving forces of change that postulate business model innovation (BMI) with respect to alternative energy storage systems (ESS). Second, it should give an overview of available alternative ESS for vehicle application and, taking the battery as an example, explain the effects of the battery on the value chain in particular due to their current significance as a middle-term means to reduce environmental pollutions. To dive deeper into the problem, major players in the Electric Vehicle Revolution are identified and a qualitative study is conducted on selected companies. Thus, the following research question (RQ), divided into three sub-questions, can be derived:

RQ: How has the value creation aspect of business models in the automotive supply chain changed due to the development of Energy Storage Solutions?

- RQ-Sub1: Who are the leading actors in the automotive supply chain with regard to ESS?
- RQ-Sub2: What initiatives do firms (identified in RQ-Sub1) undertake towards technologies for ESS?
- RQ-Sub3: How do initiatives towards ESS influence the value creation aspect of investigated firms?

1.3 Scope of Study and Limitations

This study will place emphasis on how batteries influence the value-creation facet of the automotive BM using literature analysis and quantitative content analysis.

The restriction of this thesis to the battery has been made considering the current electrification trend of the automotive industry and the fact that it is a relatively advanced technology compared to other promising alternatives such as ultracapacitors or fuel cells. Moreover, due to their reference to actuality and their disruption potential it facilitates the opportunity to see behind the curtain of companies' real time progressive adaption of their BMs in prospect of a potential global tipping point for electric cars. Finally, it allows this single energy storage system to be discussed in greater depth.

The dissection of the major players in the supply chain is limited to publicly available content and company data. Since this topic is highly subject to change it is necessary to set a time frame that shall be covered by this research. No public documents are considered after 2018. Three of the interviews that create the basis for the qualitative analysis have been conducted in person across Styria, Austria and one has been conducted by phone. Finally, the scope of this study has been restricted to the value creation considering the vast scope that is summarized under the term business model.

It needs to be criticized that results of qualitative research such as interviews are often subject to subjectiveness of the interviewees. (Flick, 2009) Of course, the chosen method tries to counteract any subjectivities in the best possible way to come up with generally applicable bottom lines from all statements made. Nonetheless one should keep the limitations of qualitative study in mind, especially when they are held anonymous.

What hasn't been dealt with sufficiently in the theoretical part of this thesis is the fact that evidently there are a lot of new entries that completely change and challenge the approach for companies. Reportedly, a differentiation in client types becomes essential as new entries with different expectations and an increased agility appear on the scene.

1.4 Research Method

To answer the research question, two main research approaches were chosen. For the theoretical part of the thesis the analysis of relevant literature served as a basis to get a general understanding of the status quo. For the empirical part, experts from eligible companies located in Styria and Upper Austria were chosen as representatives of the respective organisation to conduct interviews. The methodology of an expert interview has been chosen to collect the required data. With this method the focus does not lie on the respondent itself but rather on his knowledge in relation to the research question (Gläser & Laudel, 2010). In this context, an expert can be defined as someone who has specific knowledge relevant for the examination (Bogner & Menz, 2005). A semi-standardized interview guide is used which includes topic blocks with open questions on the research question. All qualitative interviews will be digitally recorded, anonymised and transcribed according to fixed rules (Hussy et al., 2010). The data was analysed by conducting a qualitative content analysis with a technique called "inductive category formation" as described by Mayring (2014). In opposition to the quantitative method, the quantitative content analysis does not only focus on primary content but also on latent content (Mayring, 2012).

1.5 Structure and Content of the Thesis

This thesis is divided into four different parts and 9 chapters as shown in figure 1 below.

Chapter 1 depicts the motivation for the study as well as the research aims, objectives, limitations and structure of the thesis.

Chapter 2 comprises a review of the status quo as well as accruing trends in the automotive industry with a major focus on electrification.

Chapter 3 deals with the business model concept which involves disambiguation of the term business model in general and business model innovation. This is followed by an analysis of the contemporary automotive business model and the pressures for change as well as prospects of future business model innovation.

Chapter 4 is devoted to alternative energy storage systems which are of relevance for the automotive industry in one way or another. It comprises a classification as well as a subchapter on their effects on the value chain. Part four includes a summary and a discussion of the key findings as well as the limitations of this paper.

Chapter 5 highlights the major players in the automotive industry that will most likely sustain their key role in electrification over the next few years. They are subdivided into the three categories of OEMs, Suppliers and Engineering Service Providers.

Chapter 6 elucidates the methodology of the empirical data collection whereas Chapter 7 shows the results obtained from the content analysis.

Lastly, Chapter 8 provides the discussion of the results whereas Chapter 9 ends the thesis with a final conclusion where the key points are represented.

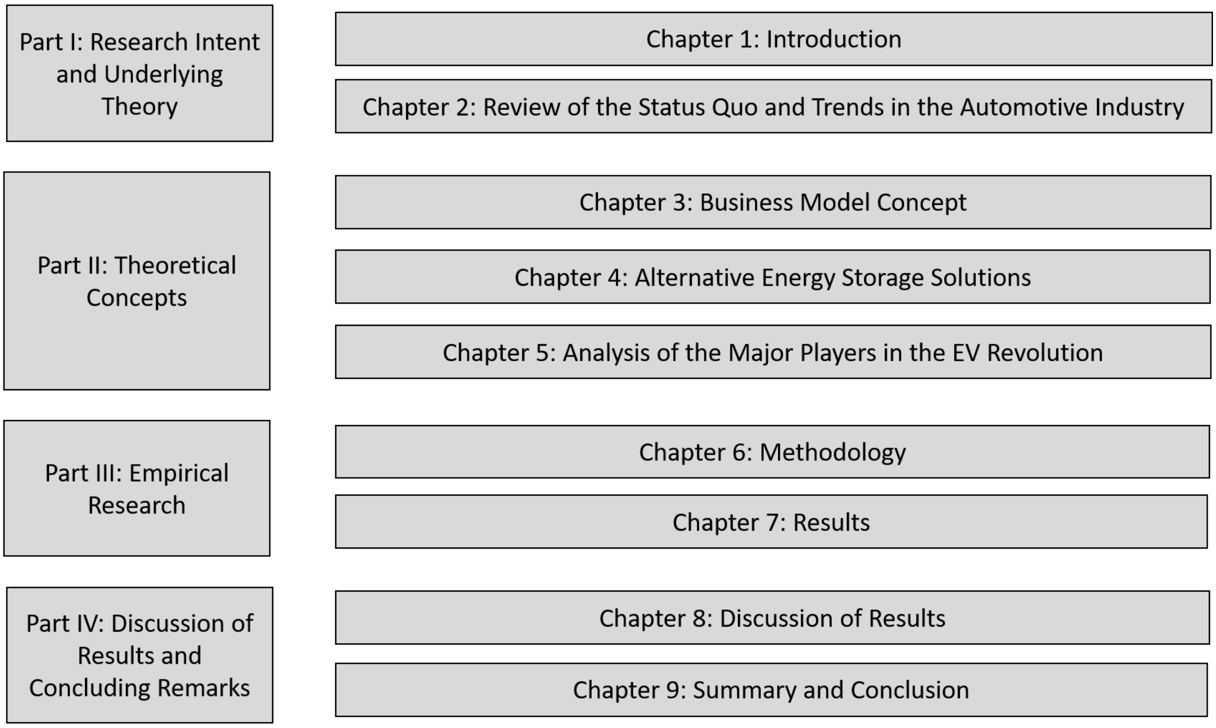

Figure 1: Outline of the Study

2 Review of the Status Quo and Trends in the Automotive Industry

Worldwide, the transport sector consumed about 28 % of the total energy in 2016 whereof over 90 % stem from oil products (International Energy Agency, 2017). According to a forecast of Dudenhöffer (2018), the number of passenger cars sold worldwide by the end of 2018 will reach 87.3 million, the main growth driver being Asia, whereof China alone accounts for an estimated 25.75 million new cars. Statistics like these suggest that improvements in vehicle efficiency can crucially reduce emissions of greenhouse gases and pollutants.

Internal Combustion Engines (ICE) have been the primary way of power generation for vehicles for more than a century due to its high energy density and the low cost of petroleum. Nowadays, however, increasing customer awareness, ever-declining oil reserves, legislation calling for lower emissions and better fuel economy lead to pathbreaking changes in the automotive industry. (Lukic et al., 2008) Therefore, car manufacturers need to make some fundamental decisions regarding the distribution of their resources. The automotive industry in Germany for example has the option to further expand their technical lead in propulsion concepts with fossil fuels to continuously reduce the fuel consumption of vehicles evolutionary. This would surely enable them to secure attractive short-term market opportunities. However, if they beyond that neglect the development of alternative drive concepts, producers who focus their resources on new revolutionary concepts will gain a long-term competitive advantage. (Müller et al., 2011)

Recently, vehicle electrification has rapidly gained momentum in the automotive sector. As reported by Zubi et al. (2018), it is expected that 1.5 million EVs are going to be sold worldwide by 2020. However, current statistics of the International Energy Agency (2018) show that the number of sold EVs worldwide already crossed the threshold of 1 Mio. cars in 2017, leading to the assumption that the number of EV sales by 2020 will be much higher. With the growing commitment of policy makers and nearly all OEMs for a reinforced deployment of EVs this trend will most likely not cease for the next decade as is evident from Figure 2. Sure enough, a rise in sales volumes combined with increasing competition in new technologies will rather contribute to an ongoing reduction in battery costs.

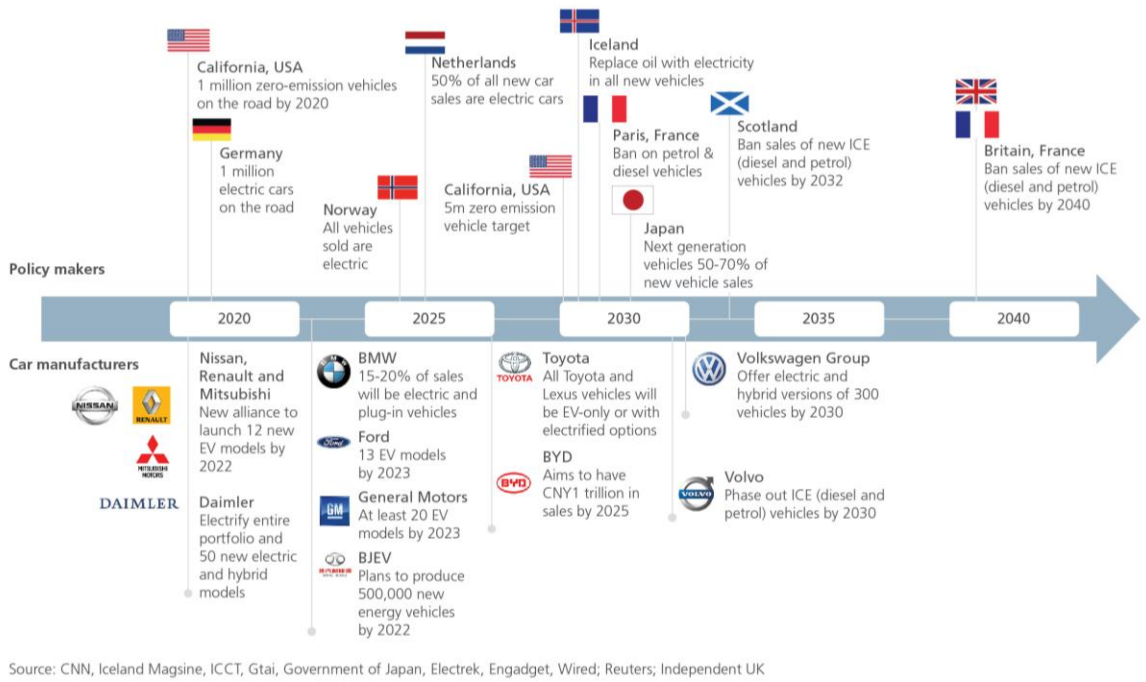

Figure 2: Electric Vehicle Technology Future Milestones - Policy Makers and Car Manufacturers (Ryu et al., 2018)

A large portfolio of both short-term and long-term solutions is currently offered and constantly enlarged by manufacturers, ranging from drivetrain electrification to advanced vehicles using different sources of energy like battery electric vehicles and hydrogen fuel cell vehicles (Lukic et al., 2008).

At this point a clear distinction has to be made between “electrified” and “electric” vehicles. Due to the fact that those two words are often misleadingly substituted for one another for the sake of simplicity the definitions will be set as follows:

“Electrified vehicles” are also called hybrid electric vehicles and can be divided into subgroups such as micro hybrid, mild hybrid, full hybrid and plug-in hybrid pertinent to their degree of electrification, whereas the term “electric vehicle” refers to fully electric cars that are exclusively powered by an electric motor, without an internal combustion engine. (Chau & Li, 2014) Figure 3 below illustrates the different stages.

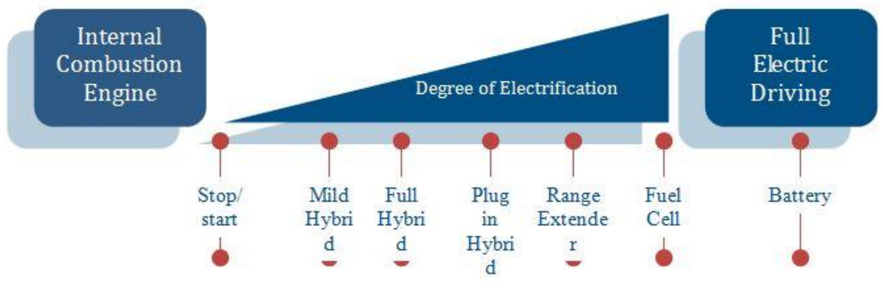

Figure 3: Schematization of the Degree of Electrification in Vehicles (Gruosso, 2015)

A micro HEV possesses an integrated starter generator (ISG) that employs start/stop technology where the vehicle shuts down the engine at standstill and restarts it when the driver releases the brake pedal. The vehicle is only propelled by the ICE. A mild HEV is akin to a micro HEV except that the starter is enhanced by stronger electric components that support vehicle propulsion. Hence the battery pack, alternator and electric motor are bigger and play a more central role in vehicle operation. A full HEV is again similar to a mild HEV, using the same electric components but in much larger size. On the contrary they typically use a smaller ICE and have the ability to be driven purely by the electric motor. What's more, they use a more elaborate control system to tweak efficiency. A plug-in HEV or PHEV only differs from a full HEV in that its engine is even more downsized and the electrical components are even larger. Furthermore, a PHEV can be charged by plugging into an outlet, therefore substituting electricity from the grid for gasoline. They are perfect for urban commuting but may also be used for longer trips. It is noteworthy that most mild and all full HEVs have regenerative braking systems (Kinetic Energy Recovery Systems or KERS) integrated. (Macomb Community College, 2018) An overview of the mentioned Hybrid levels and their specifications is given in Figure 4 below.

Hybrids	Micro Hybrids		Mild Hybrid	Full Hybrid
	ISG, Start/Stop	ISG Hybrid		
Engine	Conventional	Conventional	Downsized	Downsized
Electric Motor	Belt Drive	Belt/Crankshaft	Belt/Crankshaft	Crankshaft
Electric Power	2–5 kW	3-10 kW	10-20 kW	15-100 kW
Operating Voltage	12 V	12-42 V	60-200V	200-600V
Fuel Economy Gain	3–5 %	5-10 %	15-20 %	20-30%

Figure 4: Comparison of Hybrid Levels (Macomb Community College, 2018)

This differentiation is particularly important because, as Lukic et al. (2008) insinuate, drivetrain electrification can merely be seen as an interim solution on the path to petroleum waiving.

Hybrid electric vehicles have a combined propulsion composed of an ICE and an electric motor. The electric motor gets its electric energy from sources such as batteries, flywheels, ultracapacitors (UCs) or fuel cells (FCs). Improvements in fuel efficiency are achieved using smaller engines combined with regenerative braking technology. A classification of HEVs can be done according to their mechanical connection as parallel, series, or a blend of both. In hybrids with a parallel drivetrain the electric motor and the ICE can provide the power simultaneously whereas in a serial drivetrain it only receives propulsion power from the electric motor alone and the engine only acts as a recharger for the energy storage unit. (Lukic et al., 2008)

Battery electric vehicles solely use the stored energy of the battery to drive the vehicle. A common issue is the low energy density and the hence resulting low range of those types of vehicles as well as long recharging times and the lack of charging infrastructure. Further drawbacks include a lack of standardization of connectors, a limited choice of electric vehicles and the fact that they are still costly, even with governmental subsidies. (Lukic et al., 2008)

Yet, despite these disadvantages, a shift of consumer demand is becoming noticeable towards electric vehicles which has a powerful potential to disrupt the status quo. As McKinsey (2017) stated in their report, between 30 % and 45 % of vehicle buyers in Germany and the US consider an electric vehicle purchase though very few eventually buy an electric vehicle, deterred by driving range and higher initial costs. (McKinsey, 2017)

However, this will presumably change drastically with advances in storage capacity and decreasing electric vehicle costs due to economies of scale in battery production. According to a battery price survey conducted by Bloomberg New Energy Finance the price of Li-ion batteries in 2016 amounted to $273/kWh which corresponds to a drop of 73 % compared to 2010. Arguably, fierce competition among the major manufacturers also has been and will further be contributive to cutting the prices. (Curry, 2017)

It should be noted that electric mobility is not limited to cars alone. Other modes of transportation are also developing quickly, buses and two-wheelers in particular. In 2017 there were approximately 100,000 electric buses and an estimated 30 million two-wheelers sold worldwide. The lion’s share of which came about in China. (International Energy Agency, 2018)

Another aspect that is closely related to the widespread adoption of electric vehicles is the growth of the charging infrastructure. Private chargers (both at residences and workplaces) were the most widely used in 2017. Publicly accessible chargers should be seen as an important component on the path to an EV supply infrastructure. In 2017 there were almost 320,000 public chargers available worldwide. However, most of them were slow charging stations (Level 1 or 2 chargers), only 110,000 of them were fast chargers (Level 3) compared to an estimated 3 million private chargers at residences and workplaces. (International Energy Agency, 2018)

In general, chargers can be classified into three main groups, from Level 1 to Level 3 according to their power levels. The lowest charging level receives the current from a standard (US) household power socket, delivering 120 VAC (alternating current voltage). This is the slowest way of charging an EV, producing the least amount of stress on the battery with charging rates up to 1.92 kW. Level 1 is therefore mainly meant to be used over night at low off-peak rates. Level 2 chargers allow for a wide range of charging speeds up to 19.2 kW due to its higher voltage of 240 VAC. Contrariwise, Level 3 chargers use advanced DC (direct current) charging techniques and can deliver power over 20 kW. They are also the most expensive to deploy. (Yilmaz & Krein, 2013)

Figure 5 provides a general conspectus of the number of chargers deployed in the observed period 2010-17 for all charger types and exemplifies the ongoing upward trend of charging infrastructure. It is noteworthy that market uptake is closely reflected by the expansion of charging infrastructure (International Energy Agency, 2018). In the given illustration slow chargers allude to Level 2 chargers whereas fast chargers refer to Level 3 chargers. It can be seen from this illustration that private charging (home and workplace) is the most common form of powering EVs owned by private persons.

Further developments in electric cars are often limited by the efficiency of the ESS (Lukic et al., 2008) which will be explored further in a subsequent chapter.

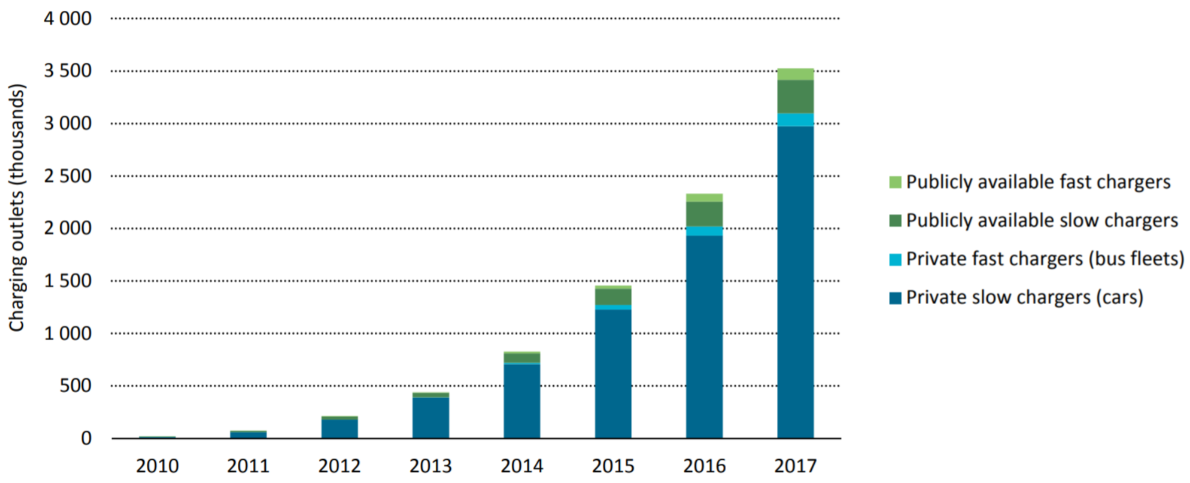

Figure 5: Global EV Charging Outlets, 2010-17 (International Energy Agency, 2018)

3 The Business Model Concept

Since the main objective of this thesis is to discover influences of alternative energy storage systems, the battery in particular, on the BM it is necessary to discuss what this term actually means and why it is vital for automotive manufacturers to think about their BM. The following subchapter will depict the general conception of a BM as well as the framework that will be used for this paper.

3.1 What Is a Business Model?

BMs have increasingly received attention over the past 20 years due to industry growth, emerging markets and advanced technologies (Zott et al., 2011). Not without a reason: They are currently perceived to be more valuable for a company's competitive edge than novel products or services. (The Economist Intelligence Unit, 2005)

Literature has many depictions on how to design and describe the elements of a BM and yet academics do not reach a consensus on what a BM actually is. (Zott et al.,2011)

In general, a BM can be described as having three constituent elements that can be deduced from existing frameworks: The value proposition which defines the product- and service content respectively (i.e. how to capture value), the value network that determines how the business is linked internally and with other businesses (i.e. how to create value), and the revenue & cost model that describes the types of revenue that the organisation will seek. It is generally understood, that BMs are dynamic objects that are subject to change, especially in view of the emergence of new markets and technologies. (Nieuwenhuis & Wells, 2015)

A successful BM according to Chesbrough & Rosenbloom (2002) identifies and exploits the hidden value of a technology but also confines the later search for a new model for prospective technologies, a cognitive constraint that is often neglected when this subject matter is discussed.

For this work the St. Gallen magic triangle concept by Gassmann, Frankenberger & Csik will be used as a guideline. As shown in Figure 6: St. Gallen Magic Triangle Concept (adapted from Gassmann et al., 2014)the concept consists of a mere 4 interdependent dimensions which on the one hand make it easy to use while on the other hand offer sufficient depth to describe the BM architecture as such. The 4 dimensions will be explained briefly now according to Gassmann et al (2014):

Who: Not knowing your target customer is a strategic key factor often leading to business failure. This dimension should identify the target customer and is crucial for the design of a new BM.

What: This dimension relates to the value capture or the value proposition respectively. It describes the products or services offered to the customer. In other words, which problems does the product/service bundle solve and what benefits does it bring to the final customers?

How: The third dimension is made up of the company's activities, processes, capabilities as well as the resources to form the value proposition. In short, by what means the offering is created.

Value: The last dimension relates to the revenue model or profit mechanism. It provides the essential question of any company, how to be financially viable.

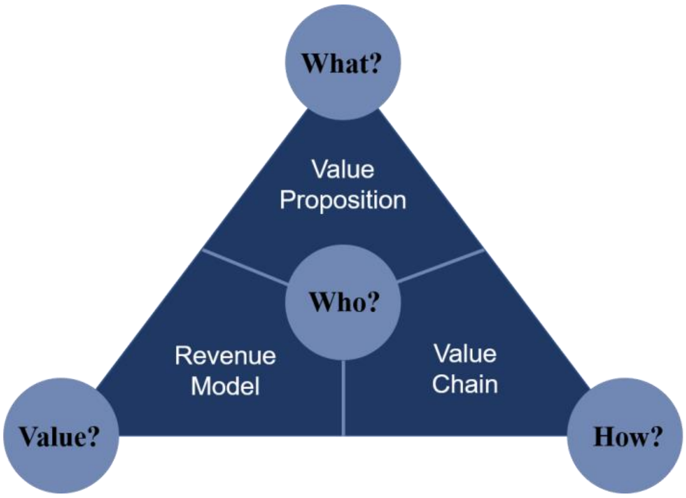

Figure 6: St. Gallen Magic Triangle Concept (adapted from Gassmann et al., 2014)

This paper will focus on the third dimension, also commonly referred to as value chain ("How to create the value proposition") which will now be explained in more detail.

The value chain dimension shall provide answers to essential questions pertaining to key resources that are needed for the realisation of the value proposition and the capabilities and key activities that are needed to acquire them. Furthermore, it is important to know who the most influential partners and suppliers are and what they contribute to the value chain. Lastly, it is vital to grasp if the internal value chain of the company matches their core competencies. (Gassmann et al., 2013)

However, it should be taken into consideration that competition today doesn't happen between individual companies anymore. Instead, in consonance with Peppard & Rylander (2006), networks of interconnected organisations have formed where the performance of one company is heavily influenced by the behaviour of every single partner (stakeholders, distributors, suppliers etc.). Due to this shift to co-operative behaviour it makes sense to substitute the eroded linear supply chain model with its company focus by a contrasting network approach in which organisations concentrate on the value-creating ecologies where customers, suppliers and partners co-produce value by deliberately working together. The battle has shifted from individual companies battling against each other to a warfare between networks of interdependent enterprises. While each unit remains relatively autonomous the firms operate in a framework consisting of common principles. Despite that, the question of how value is created remains the same. The answer however gets much more complex when the analysis extends from the perspective of an isolated organisation to a network of relationships. The outcome of one relationship influences the others – positively or negatively. In their paper the authors give the example of the company Intel whose success in developing a new microprocessor very much depends on a multitude of contributing factors, one need only think of software developers that have to write applications to that take advantage of the new processing capacities or hardware developers that must design systems that can contain the new chip. It is vital to understand the dynamic nature of such network economies. Companies are no longer to be thought of a unit in a closed system submit to non-controllable change but rather precipitates its own change. Consequently, a thorough analysis of the network comprises all aspects including suppliers, competitors, customers, allies, regulators as well as any other participant in the network that can influence the organization's value creation. (Peppard & Rylander, 2006)

3.2 Business Model Innovation

There are several reasons why BMI should be utilized by companies. On the one hand it constitutes an often-underutilised source for future value, especially in times of economic change. On the other hand, it adds a lot of difficulty for competitors to imitate an entirely new set of activities instead of just a single new product, process or service. (Amit & Zott, 2012) BMI entails benefits that decidedly surpass that of any other form of innovation. (Schallmo & Brecht, 2010; Snihur & Zott, 2013) This is consistent with a recent study by Bashir & Verma (2017) which concludes that BMI can yield four times higher returns than product innovation and therefore always outpaces product and process innovation. This is due to the fact that companies may also benefit from BMI by cost savings and reduced risk linked with their businesses, the authors point out.

This leads to an important question: How do incumbent firms innovate their BM which is currently still yielding profits, but whose effectiveness will probably be subverted by external changes? (Sosna et al., 2010)

Chesbrough (2006) brings forward the argument that BMI does not simply involve the search for a new technology. To flourish, firms must adapt their BMs so that they are more receptive to external ideas and routes to market. To help companies identify at which position they are currently standing in relation to their potential Chesbrough (2006) introduced the business model framework (BMF). This tool can be used to articulate steps for the further advancement of the model and will be used in this thesis to classify the different results in the discussion. The BMF offers 6 types of BMs, transitioning from closed to open:

- Type 1: The company has no differentiation in its BM
    - most of the companies don't have a distinct business model and therefore don't have a process in place to manage it. They mainly compete on price and availability, selling commodities, following the conventional approach of a red ocean strategy which often leads to a downward spiral.
- Type 2: The company has created differentiation in its BM to a certain extent
    - This differentiation allows to target customers other than those who simple buy upon price and availability and serve a different market segment. However, they may not have the required resources to sustain their differentiated position.
- Type 3: The company has developed a segmented BM
    - The advantage lies in different segments that the company can compete in simultaneously which results in a greater market share. Cost leadership, differentiation and niche markets can be addressed at the same time to cover a wide range. However, vulnerability remains with major market or technical shifts.
- Type 4: The company has an open innovation BM
    - Key aspect of this model is to be open to external ideas and technologies which involves a broader set of assets for the company to accelerate internal innovation. Besides the acceleration of internal developments other benefits include risk sharing, reduced cost and reduced time-to-market.
- Type 5: The innovation process gets integrated with its BM
    - The company integrates even further with external parties.
- Type 6: The company's BM is an adaptive platform, able to change and be changed by the market
    - The management of Intellectual Property is embedded in every business unit.

When exploring BMs, a differentiation needs to be drawn between incumbents who already have a well-established BM and entrepreneurial firms who may try to get involved in the competitive market with the help of BMI – especially when it is hard to compete with incumbents pertaining to their current BM. (Bohnsack et al., 2014)

In literature there are two opposing views on how firms react when they face disruptive innovations and other critical threats. One view takes the position where organizations respond to critical threats with an increased proclivity to engage with change whereas another cherishes the threat-rigidity phenomenon where the resistance to change gets reinforced by focusing on day-to-day routines (Osiyevskyy &

Dewald, 2017). As shown in the paper by Osiyevskyy & Dewald (2017) cognitive barriers such as (perceived) unpredictability and time pressure hinder managers in their ability to seize opportunities and make them blind to alternative solutions.

3.3 Analysis of the Contemporary Automotive Business Model

In agreement with Wells (2015) the typical OEM exerts an established and well-defined BM. The value proposition is constituted of product/service bundles that comprise steel vehicle bodies in combination with gasoline or diesel engines (they may or may not feature an assisting hybrid electric drive) that are sold to final consumers accompanied by warranties and provision of services. As a means to reach various customer types market segmentation is done by different types and classes of vehicles.

As stated by Williander & Stålstad (2015), by sticking to this conventional “sell-and-disengage” BM potential customers for an electric vehicle will be instigated to compare it to a traditional ICE vehicle leading to an unnecessary emphasis on the three common issues of higher price, shorter range and the uncertain battery lifetime. What’s more, behavioural economics suggest that people perceive high costs of purchase but low prospective operating expenses less attractive than the other way around, even if there is no change in the overall economic impact.

Value creation is realised through interlacing of in-house capabilities with global supply chain management (Wells, 2015). However, Frigant (2011) reports that automobile manufacturers have been increasing outsourcing, nowadays attributing 75-80 % of the total value of finished cars to external suppliers. According to the author, this can be explained by a shift of carmakers to their core competencies, namely designing cars and selling mobility solutions. What’s more, the role of suppliers has changed considerably from mere producers of parts to worldwide companies that possess extensive expertise enabling them to provide technical off-the-shelf solutions for the auto manufacturers. It is noteworthy at this point that most new patents in the automotive industry are in fact filed by suppliers. Hence, firms will benefit from integrating innovative suppliers into cooperative development projects if they want to compete in the industry's race for innovation. However, Schiele (2010) states that the availability of highly innovative suppliers is rather low. Therefore, attaining preferred customer status can offer a real competitive advantage for firms. This compels OEMs to ponder how they could become more attractive as customers. This counterintuitive comprehension of the buyer-supplier relation suggests a shift in supply chain management from a mere pursuit of the lowest possible purchasing price to a more strategic approach when dealing with key suppliers. According to Steinle and Schiele (2008, p.11) a company is a preferred customer "if the supplier offers the buyer preferential resource allocation".

There is a noticeable trend towards delegating greater responsibilities to the suppliers. That trend can go to such lengths that a product line's complete development and fabrication gets sub-contracted to them. Suppliers become innovation partners, blurring the once clear dividing lines between OEMs and Suppliers. This led to the emergence of so-called "Tier 0.5" suppliers in the new automotive supply chain. This has already happened in niche segments where Daimler and BMW outsourced to Magna Steyr and Porsche to Valmet, for instance. (Legner et al., 2009)

Pursuant to Niewenhuis & Wells (2003), contemporary automobile manufacturers predominantly depend on financial services and aftersales (spare parts, services etc.) as revenue where replacement parts alone account for about 18 % of the total revenue. In fact, in western Europe only 37 % of the total profit derives from the disposition of the new car, the remaining lion's share is covered by the aftersales market as stated in the report by Gebauer et al. (2010). These percentages considered a representative 13-year vehicle lifetime according to the automotive passenger car lifecycle model. As stated in the report, the Western European aftermarket already reached maturity stage hence major annual rates of growth are rather expected in developing markets like Eastern Europe, India, Russia and China.

Perhaps the biggest changes occurred in the value context when local and national governments started to support EVs on a grand scale with regulations, incentives and other actions. Then again administrations are also to a considerable extent unwilling to abandon the automotive industry as it exists today, given their major contributions to wealth creation, advances in technology, occupation and taxation etc. (Wells, 2015)

3.4 Analysis on the Pressures for Change in the Automotive Industry

Conforming to Wells & Nieuwenhuis (2015), the main stimuli for change are maturing markets, shifts in demand that require the shutdown of some plants and the installation of new plants in other locations, an increase in market volatility and fragmentation as well as shorter product life cycles which necessitates much greater product portfolios.

In addition, the authors mention the exigency of a set of new technologies that is certainly not limited to EVs and indistinct but nonetheless significant concerns about evident culture shifts in mature markets that causes the so-called 'peak car' phenomenon which describes the observed trend of recession in car use and possession by younger people in developed cities. This incipient market saturation leads to the conclusion that profitability can only be sustained with a higher capture of value per car. This will by no means be an easy task that will certainly not be achieved by all vehicle manufacturers. The only way out is to bundle the resources effectively and focus on expanding to emerging markets. (Wells & Nieuwenhuis (2015)

Then again Oliver Wyman, a global consulting firm, argues that there exist seven underlying trends that will significantly shape the automotive industry till 2030, mainly driven by Artificial Intelligence (AI), Machine Learning and Digitization. Those trends are characterized by a change in customer structure, new control concepts of Human-Machine-Interfaces, Pay-per-use distribution channels, electrification of powertrains, an advance to fully autonomous and connected vehicles as well as an increase in the digitization of processes. Those seven trends will potentially influence the three major aspects, the product itself as well as its consumption and creation, to a high extent. (Wyman, 2018)

Sharing cars particularly poses a threat to the automotive industry. It increases the utilization of cars that already exist while lowering the cost per kilometre, rendering car ownership obsolete for an incremental number of people. Together with an increasing market presence of low-maintenance electric vehicles this development will be pushed even further, the proven automotive BM, in its current form, will be jeopardized. (Vieser, 2017)

There's an increasing awareness among automotive companies that they are going to need help conquering the radical changes that will define the next decade. This argument is substantiated by the high number of joint forces between carmakers and tech companies that have been entered in 2016 alone: General Motors invested $500M in *Lyft*, Volkswagen invested $300M in *Gett*, a European Taxi Service, Toyota invested an undisclosed amount in *Uber* as a "strategic partnership" whereas Apple invested in a Chinese ride-hailing service and BMW started working together with *Intel* and *Mobileye* to develop self-driving cars, only to name a few. (Lee, 2016)

3.5 Prospects of Future Business Model Innovation

Some indicators suggest that perchance automobility has reached its climax in mature industrial countries and that the possession and utilization of a car will no longer be regarded as a status symbol by several people. The usefulness that a car ownership once entailed diminished slightly with increasing financial costs (i.e. fuel, insurance, taxes, maintenance), traffic congestion and limited parking spaces. It remains unclear, however, if this implies an imminent disastrous tipping point of the current BM or if it rather evolves incrementally of the conventional model. As per Wells (2015), the most probable scenario is the progressive expansion and growing importance of alternative BMs that are currently somewhat circumstantial. A parallel development is also imaginable although it is unclear to what extent it is possible to uphold more than one BM especially when there are conflicting issues. (Wells, 2015)

For the automotive industry, diversification is key in order to stay competitive these days. Car manufacturers are now faced with miscellaneous competition from the IT sector, energy and logistics sector as well as young startups like the U.S. company Uber or the French car rental company Drivy. As it is argued in the article by Vieser, no automobile manufacturer is big enough to tackle the market power of digital companies such as Google or Facebook. The willingness to cooperate is therefore a necessity for OEMs to gain a competitive edge. (Vieser, 2017)

Where once high investments were put into internal Research & Development (R&D) capabilities the ever-increasing complexity and expenses made effective innovation unbearable to achieve single-handedly (Ili et al., 2010). This mindset is reflected in the so-called open innovation concept, a term coined by H. Chesbrough, professor and faculty director of the Center for Open Innovation at the University of California. (Altmann & Li, 2011)

A fundamental change happened in the way companies come up with new ideas and how they bring them to the market. In the old paradigm it was believed that firms must have full control over the whole innovation process, from the idea generation to its development and commercialisation. There was this unwritten rule that to be successful a company has to outdo competitors in the extent of R&D expenses and by hiring the smartest people in the industry. This allowed to spot the best ideas and bring them to the market first. To prevent others from stealing their ideas, intellectual property rights where aggressively controlled. However, this model that worked so well for a good deal of the 20th century started to erode due to several factors including, but not limited to the massive increase of knowledge workers and their accretive mobility which gives companies a hard time in controlling their proprietary ideas. What’s more, the increasing presence of private venture capital supports new firms in commercialising ideas that have leaked from corporate research. In the novel open innovation model companies commercialise both external ideas from other firms as well as its own ideas and try to bring them to the market by taking advantage of pathways outside of their current BM. The open innovation principles are characterised by the notion that one doesn't have to be the originator of an idea to benefit from it and that a better BM is superior to being the first to market. (Chesbrough, 2003)

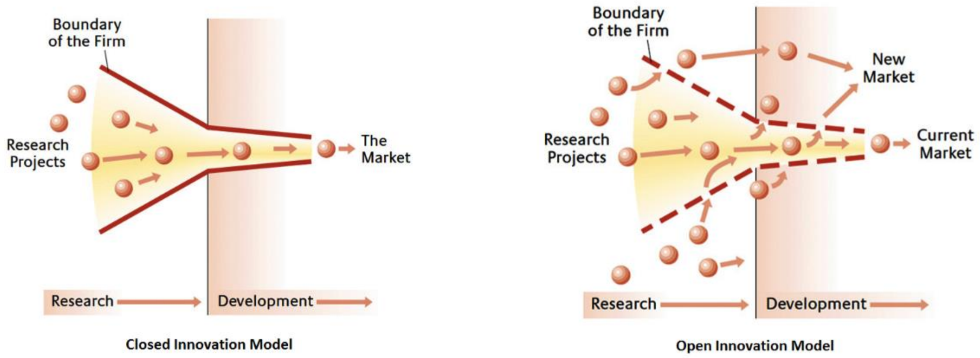

Figure 7: Closed Innovation Model vs Open Innovation Model (Chesbrough, 2003)

As is evident from Figure 7 the closed innovation model on the left that prevailed for a good portion of the 20th century for numerous leading industrial enterprises was characterized by a doctrine of selfcontainedness concerning R&D operations. On the other hand, the new open innovation model to the right symbolises the openness to innovations and external ideas from other companies, illustrated by a dashed line. This porous boundary enables innovation to move easily between the company and its surrounding environment. (Chesbrough, 2003)

With the transition from fossil-fueled cars to EVs the opportunity arises in both the energy and the vehicle sector to come up with pioneering new BMs and energy management solutions to accommodate developing market demand, according to Edwards & Mashhadi (2018), experts in energy sector innovation. Incumbents are adjusting their BMs and forging joint ventures to consolidate expertise while new entrants are also entering the picture, capable of disrupting the status quo with their new products or services.

4 Alternative Energy Storage Solutions

4.1 What is an Energy Storage?

Energy Storage Systems (ESS) are of ever-increasing importance in energy markets to boost the utilization of renewable energies, cut down on carbon dioxide emissions and are a main component of a smart grid standard. (Olabi, 2017, deSisternes et al., 2016)

To describe and classify the different energy storage systems a clear distinction in terminology is essential.

An energy storage is an energy-technical system to accumulate energy in the form of internal, potential or kinetic energy. It comprises the three primary processes charging, storing and discharging within one cycle. They get physically implemented in the form of an energy converter (charge, discharge), a storage unit and ancillary units. (Sterner & Stadler, 2014)

Furthermore, a distinction must be made between energy storages that can only be charged and discharged once versus those that can be charged and discharged repeatedly. The latter will be the focus of this thesis.

When it comes to metrics and performance evaluation, the most significant characteristic of any energy storage is the quantity of energy that can be stored per unit of mass also known as specific or gravimetric energy, and the speed at which this energy can be stored or retrieved, also referred to as power density. If it’s a matter of space constraints, said characteristics may also be expressed in terms of volume, commonly referred to as energy density or volumetric density. (Schougaard & Bélanger, 2014)

A diligent evaluation of future fuel system options necessitates the analysis of the entire vehicle fuel cycle which is commonly referred to as a well-to-wheel (WTW) analysis. This can help to better understand the environmental impact that different powertrain technologies, electricity generation technologies as well as fuel sources will have and allows for a holistic approach. The process for a conventional ICE vehicle for example mainly consists of two primary steps. In the first one which is called well-to-tank, the energy source gets mined, transported and then eventually stored in the vehicle. The second step consists of driving the car consuming the stored energy, referred to as tank-to-wheel. (Woo et al., 2017)

4.2 Different types of energy storage systems

In this section an overview of common energy storages is given. The energy storage systems will be classified pursuant to the energy type being used. (International Electrotechnical Commission, 2011)

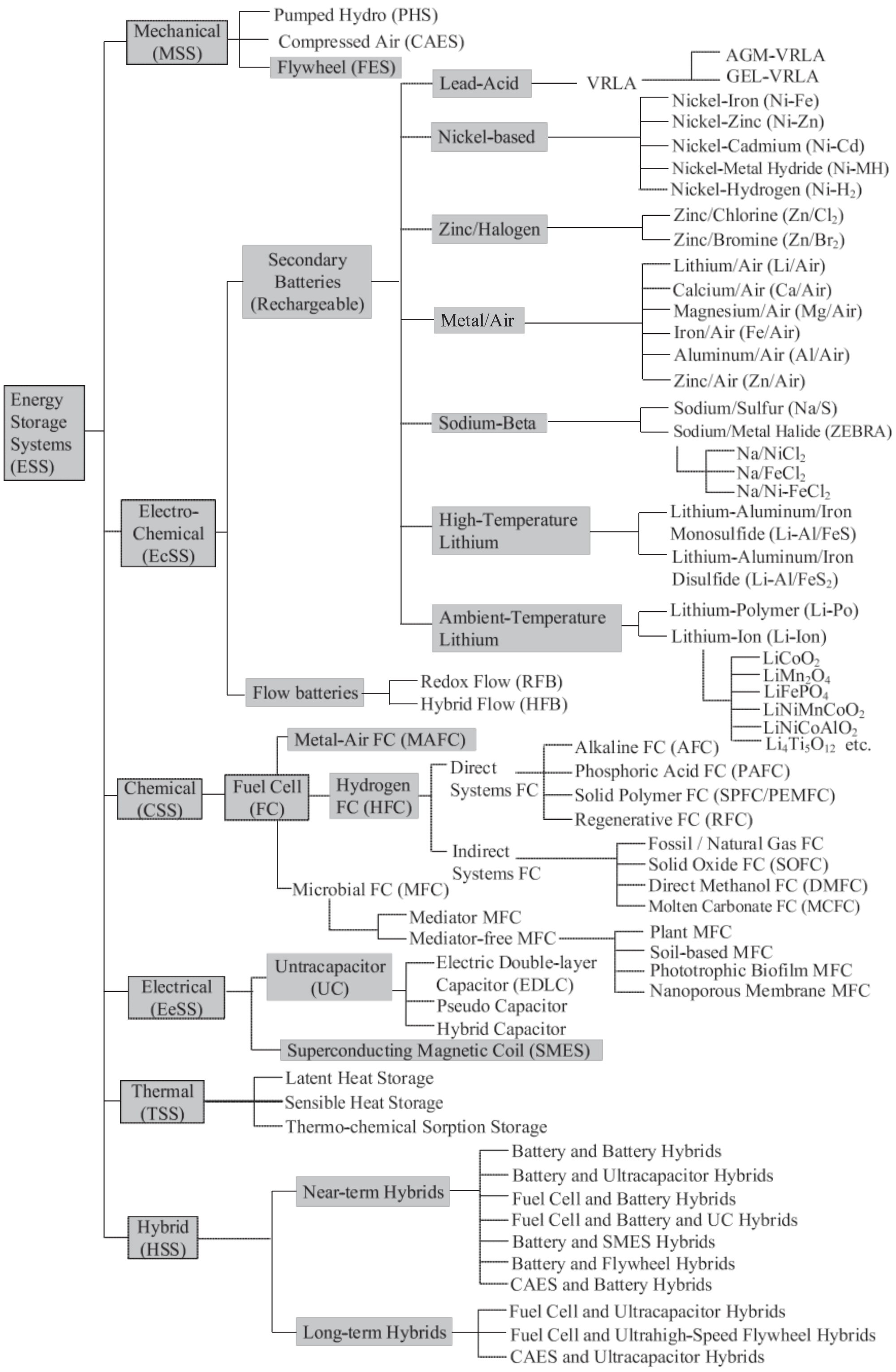

Figure 8: Classification of Energy Storage Systems (Hannan et al., 2017)

Figure 8 shows the different ESS systems subdivided into chemical, electrochemical, electrical, thermal and mechanical energy storage systems. ESS systems that are commonly used for EV applications are highlighted in grey.

4.2.1 Mechanical Storage Systems

These include the pumped hydroelectric storage (PHS), the compressed air energy storage (CAES) and the flywheel energy storage (FES). They are predominantly used to produce electricity globally with the PHS being the most popular one. In pumped hydroelectric power plants water is being pumped to a higher level using excess energy. This water is then later released and drives a turbine on the way down that is shafted with a generator that produces electricity. This storage type is characterized by a high efficiency, a lengthy period of storage and comparatively low investment costs per energy unit. (Amirante et al., 2017)

In CAES air gets compressed with the help of electrical power which then gets stored in an airproof tank. When needed, the high pressure gets adjacently released when the air is fed to a gas turbine to recuperate the electrical energy. The output can be optimised by burning natural gas in the highly pressurized air before it passes into the turbine. However, this adds undesirable carbon dioxide emissions to the process compared the genuine storage. Oftentimes the chambers to store the pressurized air are located underground or underwater, especially for large-scale facilities due to the low storage density. (Breeze, 2018)

The basic concept of a flywheel to store kinetic energy using a rotating mass has been around for thousands of years. In the 18th century this technique got adopted to smooth the strokes of the steam engine piston and is still in use today as a means to add smoothness to the engine rotations. A flywheel consists of a large massive or composite disc on an axle that is embedded in frictionless bearings. The higher the torque of inertia or the rotational speed respectively, the higher the storage capacity will be. It should be noted though that increasing speed is the more efficient way of boosting capacity. For energy storage purposes, energy will be supplied to the flywheel by means of a reversible motor generator. Besides the requirement of special bearings, the rotor usually operates in a vacuum box to diminish aerodynamic losses. (Breeze, 2018)

In the automotive sector, flywheels are often being used in hybrid electric vehicles to overcome the deficiencies of batteries such as low regeneration efficiency and thermal issues. Their advantage over the more obvious solution, the ultracapacitor, is clearly the higher energy density, the unnecessity of dedicated power electronics and the overall simpler and cheaper solution. An often-mentioned concern addresses the safety of the flywheel as the surface speeds may approach sonic or even supersonic for some configurations which frequently leads to disaffirmation of this technology. However, this containment issue shall not be seen as an intractable problem. (Pullen & Dhand, 2014)

Another utilization of flywheels intervenes where the highest amount of energy is lost in a vehicle – during deceleration or braking. The so-called Kinetic Energy Recover System (KERS) acts like a regenerative braking system and is able to store and reuse the otherwise lost energy. The primary components of a flywheel hybrid are a continuously variable transmission (CVT), a step-up gear that connects said CVT with the flywheel and a clutch that links the whole system with the primary shaft of the transmission. During braking or decelerating, the flywheel system gets connected to the driveline and energy can flow to the flywheel which then gets stored as rotational energy. Whenever needed, this stored energy can be transmitted back to the vehicle. Power of up to 60 kW can be provided by the flywheel. (Matthews, 2013)

A lot of effort is put into the optimization of flywheels to get them to a lasting operation period up to several hours to use them as a power storage device for vehicular application. (International Electrotechnical Commission, 2011)

4.2.2 Electrochemical Storage Systems

Systems that fall under this category are, for example, redox flow batteries, electrochemical capacitors and secondary rechargeable batteries. The fundamental principle is a reversible transformation process from chemical to electrical energy and vice versa. (Hannan et al., 2017)

Batteries are the predominant energy storage system on the market for portable energy storage. They store electricity within chemical components that differ in their electrochemical potential. This difference determines the voltage of the battery. They can be divided into three categories: Primary batteries that can’t be recharged and have to be discarded when depleted. Secondary batteries that can be restored to their initial state after they have been drained by reversing the electrical current flow through the electrochemical cell. The third category is related to specialty batteries that are configured for a specific purpose, mostly medical or military use with little to no commercialized applications due to a variety of reasons. Usually, batteries don’t need time to start-up, operate over a wide temperature range, operate regardless of the orientation and are characterized by an availability of up to 95 % at low drains. (Winter & Brodd, 2004)

Due to reasonable costs and advances in technologies battery energy storages have become the most prevalent energy storage technology in electric vehicles. The main types are Lead-Acid (PbA), Nickel-based (Ni-Cd, Ni-Zn, Ni-MH), Lithium-Ion (Li-Ion) and Sodium-Sulfur (Na-S) batteries. (Joseph & Shahidehpour, 2006; International Electrotechnical Commission, 2011)

The most crucial characteristics when it comes to batteries are its specific power and energy, safety and robustness. From a consumer's point of view, the most important indicator is the battery's cycle life, that translates to the number of full cycles that a battery can accomplish under normal working conditions before the performance drops below 80 % of its initial values. (Zubi et al., 2018) It is noteworthy that in the development of every battery there is a trade-off between power and energy. They can be either high in power or high in energy, but they can't be both. A common scale to describe the charge and discharge rates of batteries are expressed as a C-rate. The C-rate refers to the discharging rate of a battery proportional to its maximum capacity. A 1C rate implies that the discharge current will drain the whole battery in 1 hour. For a battery that holds a capacity of 100Ah this would correspond to a discharge current of 100A. There are high-performance batteries that can be charged and discharged at rates above 1C with reasonable stress. For example, a 5C rate for the same battery would equate to 500A for 12 minutes. (MIT Electric Vehicle Team, 2008)

According to these metrics an overview will be given on the following pages of the most relevant battery types that are currently in use.

4.2.3 Lead Acid Battery (PbA)

They are the most widely used battery type worldwide with a commercial use dating back to the late 19th century. Their typical applications include renewable energy storages, emergency power supply and as starter batteries in almost every ICE. They are used in both stationary and mobile applications with a typical service life of 6 to 15 years and efficiency levels of about 80 % to 90 %. They facilitate a mature technology, safe operation, temperature tolerance and ruggedness at low cost. Drawbacks are the capacity decrease during high loads, lower energy density and toxicity of lead. Its established recycling processes and the simple charging technology together with the above-mentioned benefits gives reason for further R&D as it is the case in current research on lead-acid technology improving micro- and mild-HEVs. (Hannan et al., 2017; International Electrotechnical Commission, 2011)

4.2.4 Nickel-Cadmium and Nickel Metal Hydride (NiCd, NiMH)

Nickel-Cadmium batteries have been commercially introduced in the beginning of the 20th century. In comparison with PbA batteries, nickel-based batteries offered several advantages such as higher power and energy density as well as a higher number of cycles. They have been a very successful battery system from a technical perspective as they are the only batteries capable of operating well at low temperatures ranging from -20 °C to -40 °C. However, the toxicity of cadmium remained a major problem and led to the prohibition of Ni-Cd for consumer use in the European union in 2006. Another drawback, the high self-discharge rate, is also worth mentioning. (International Electrotechnical Commission, 2011; Tariq et al., 2017)

Nickel Metal Hydride batteries were initially developed as a substitution for the Ni-Cd batteries. According to a paper of Young (2017) that summarized the outcome of recent research activities on this technology, NiMH batteries continue to play an important role as an energy storage source in 2017.

In mobile applications NiMH batteries have widely been replaced by Li-Ion batteries whereas current hybrid vehicles largely operate with NiMH batteries due to their robustness and safety compared to lithium ion energy storages. (International Electrotechnical Commission, 2011)

These batteries have a limited operation period of about 200 to 300 cycles assuming a repeated discharge at high load currents which establishes the best operation of this kind of battery to be achieved at load currents of one fifth to one-half of the nominal capacity. They also have a high discharge rate which can be enhanced by chemical additives at the expense of downgraded energy density. (Prabhakar & Ferdowsi, 2008)

4.2.5 Li-ion Batteries

Since around 2000 Lithium-ion batteries have become the most significant energy storage technology for mobile applications. With its high cell voltage level reaching up to 3.7 nominal Volts a significant reduction of connections and electronics can be achieved due to a smaller number of cells in series necessary. Consequently, one single Li-ion cell has the ability to replace three NiMH or NiCd cells which only have a nominal voltage of 1.2. Further benefits include a high specific energy density, a high number of cycles, low self-discharge and long lifetimes. (International Electrotechnical Commission, 2011; Hannan et al., 2017)

The gravimetric energy density of a Li-ion battery largely depends on the type of cathode, the anode material and its micro- and nano-structures. Current Li-ion technologies cover a broad range of specific energy ranging from 90 to 250 Wh/kg. (Zubi et al., 2018)

Further benefits of this technology are the use of non-toxic materials that feature low heat generation and can be recycled as well. However, there is the eventuality that the battery gets overdischarged which can at worst lead to catastrophic events such as ignition because it contains flammable electrolyte solutions, lithium and oxygen. (Prabhakar & Ferdowsi, 2008; Perner & Vetter, 2015) What's more, Li-ion batteries are fragile, relatively expensive in comparison with other batteries and they require an overcharge protection circuit to assure safe operation. (International Electrotechnical Commission, 2011)

Nonetheless this technology is on the rise with the main markets being road-transport, electronics and – at some indefinite future date – power supply systems. The demand of Li-ion batteries for road-transport currently outperforms portable electronics and is becoming the main market. (Zubi et al., 2018)

In view of recent evaluations of battery technologies, the IEA argues that Li-ion is anticipated to continue to be the dominating technology for the next decade. Different technology options are anticipated to become available past 2030. Figure 9 shows the probable dates of commercialisation of given developments in cell technology. The main trends that are likely to be launched during the coming years include for instance the reduction of cobalt content for the cathode to cut back costs and enhance energy density (shift from NMC111 to NMC622 by 2020) or further improvements to the anode graphite structure to facilitate more rapid charging rates. Regarding the electrolyte the focus will be on developing a gel-like electrolyte material. (International Energy Agency, 2018)

According to Zubi et al. (2018), the massive demand growth for Lithium-Ion batteries could reach 220 GWh in 2025 compared to only 45 GWh in 2015 and a predicted energy of 125 GWh in 2020.

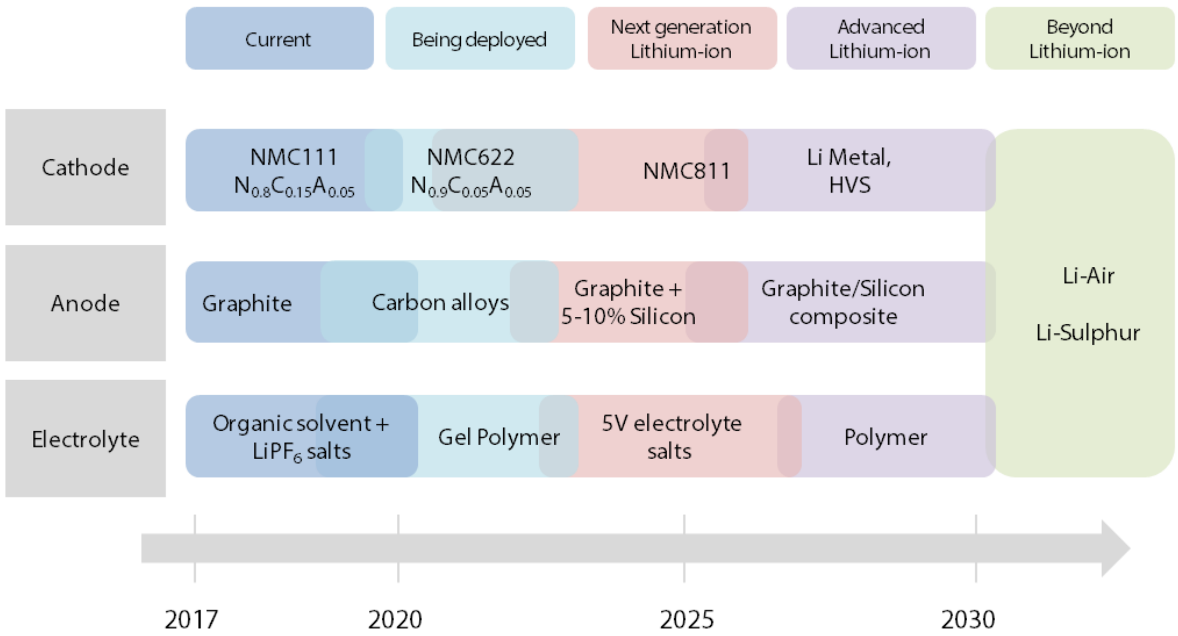

Figure 9: Expected Battery Technology Commercialisation Timeline (International Energy Agency, 2018)

4.2.6 Electrochemical Capacitors

Electrochemical Capacitors (ECs), also referred to as supercapacitors (SCs) or ultracapacitors (UCs) differ from the battery primarily in the process that takes place at the electrodes. The capacitor stores the energy electrostatically on the surfaces of the electrode in contrast to the battery where there's the chemical process of electron transfer e.g. oxidation/reduction. (Schougaard & Bélanger, 2014)

An electrochemical capacitor is similar to a conventional capacitor, structure- and function-wise. Because the energy that can be stored is commensurate with the electrode's surface area typically both anode and cathode are made of carbon due the porosity of the material with surface areas reaching beyond 1000m²/g. With the discovery of new types of carbon materials even higher surface areas and hence capacity is possible. Due to their fast charge/discharge rates they are particularly suited for high power applications, i.e. for the recuperation of deceleration and braking energy for heavy vehicles or as a power assist to hybrid vehicles. (Abruña et al., 2008; Semadeni, 2003)

ECs can deliver both power (over 1kW/kg) and energy (more than 5 Wh/kg) with at the same time thousands of recharge cycles. They can be coupled with batteries to reduce peak power requirements to extend battery life and reduce the battery size. (Semadeni, 2003)

However, the low energy density of traditional ECs compared to the ten-fold higher storage energy density of current Li-ion batteries has restricted them for most commercial applications. (Chiam et al., 2018)

EC's can be classified into three groups based on their energy storage principle: Electric Double-Layer Capacitors (EDLCs), which is the most common type and also the most prevalent technology on the market. EDLCs use a liquid electrolyte and accumulate energy via electrostatic interaction. The second group is called pseudocapacitors which is much less frequently in use than EDLCs. From the operating principle they are closer related to batteries than to capacitors. The fundamental benefit of the pseudocapacitor lies in its greater capacity due to fast and overly reversible faradaic reactions. The drawback is a shorter lifetime due to the degradation of electrodes during charging and discharging. Further disadvantages are a lower charging efficiency, a lower discharge rate and a lower cyclability compared to EDLCs. The third and newest type is called a hybrid capacitor and as the name suggests is a combination of the previous two storage principles. The major advantage lies in a higher energy density (both gravimetric and volumetric) combined with the ability to provide high currents. However, they are not commercially available yet and are still subject to laboratory investigations. (Libich et al., 2018)

In Superconducting magnetic ESSs (SMES) electrical energy is stored in a superconducting electromagnetic coil in the form of a magnetic field. This technology which is characterised by a high power, high-energy conversion efficiency and a quick response of milliseconds is only in the early commercial phase. Although lower than that of EDLC the initial cost is high for a typical SMES. They require a power converter for AC/DC supply as well as a refrigeration system to constantly keep the low temperature. They are generally used in UPSs, grid systems and introduced in HEV applications with batteries. However, the widespread deployment of this technology has been hindered by problems regarding the complexity, efficiency, environmental impact and the cost of the system. (Hannan et al., 2017, Chatzivasileiadi et al., 2013)

4.2.7 Redox Flow Batteries

Redox flow batteries are rechargeable batteries whose fuel consists of two different electrolytes that exchange ions through a membrane. The liquids are stored in external tanks and are pumped into the cell when needed. According to Kurzweil (2015) this technology will not conquer the EV market anytime soon due to the large volumes that are required and will currently mainly serve stationary applications.

4.2.8 Chemical Storage Systems

Energy in CCS can be stored and released through chemical reactions of one or more chemical compounds with each other, thereby forming other compounds. (Dincer & Rosen, 2011)

One very common chemical storage[1] system is the fuel cell (FC) which differs from the battery mainly in terms of energy source supply. For a FC, fuel and oxidant are supplied externally which brings the advantage that the FC can generate electricity for as long as active material is supplied to it. They offer a fuel efficiency of 40 to 85 %. Liquid or gaseous fuel is used for the anode whereas chlorine, air and oxygen are used as the oxidant for the cathode. One very popular type of FC that is already on the market uses hydrogen to produce electricity. (Hannan et al., 2017)

Hydrogen, a flammable gas, not only possesses a high energy potential (3 to 5 times the calorific energy of coal), it is also the most abundant element in the universe. Hydrogen can either be utilized for catalytical combustion or for conversion to electrical energy with the aid of a FC. (Gurz et al., 2017)

According to Hoffmann & Dorgan (2012), hydrogen fuel cells could be 2.5 times more efficient than internal combustion engines. They offer the advantages of BEV but also distinguish from them through way quicker refuelling and their ability to travel longer distances between it (Speers, 2018).

ULEMCo, a UK-based company and a pioneer in hydrogen fuel technology took a different approach: They developed a truck with an ICE that is purely running on hydrogen fuel to showcase the efficiency and cost effectiveness of hydrogen fuel in decarbonizing heavy goods vehicles. It is claimed, that contrary to the common FC and electric motor approach, the target of zero carbon emissions can be reached considerably faster because there is no need for a full transformation and electrification of conventional engines or change in truck design for that matter. (Petters, 2018)

[1] Strictly speaking, a fuel cell is an energy conversion device and can therefore only be a component of an ESS

4.2.9 Regenerative Fuels

For the sake of completeness regenerative fuels from renewable resources such as Hydrogen, Hydrocarbons, Ethanol or oil from biomass shall also be regarded due to their future significance in reaching climate targets. Given the fact that for example in Germany only 5 % of the car fleet are renewed annually thinking about alternatives or additives to conventional fuel becomes an evident and necessary step to further reduce CO_2 emissions (Burkert, 2018). But even the short-term potential of alternative fuels — a widespread accentuation from E10 to E20 (synthetically produced with renewable electricity) would cut down 10 % on CO_2 emissions for gasoline engines — is quite remarkable. Necessary changes to the engine would be already technically feasible today. In the long term, regeneratively produced synthetic fuels can enable a complete carbon-neutral private transport. This is due to the fact that during production they absorb as much CO_2 from the atmosphere as they emit later on during combustion. (Scharrer, 2018)

Particularly noteworthy in this regard is the R33 Blue Diesel developed by Volkswagen. It constitutes a renewable, residual fuel that can be combusted in a conventional engine with little NOx emissions and a reduction in CO_2 emissions of at least 20 % (WTW). This fuel is currently being field tested at the company-internal petrol station in Wolfsburg, Germany. (Burkert, 2018)

In the following Table 1 by Chatzivasileiadi et al. (2013) a comprehensive overview is given on the most important characteristics of the above described EES technologies to easily compare them and depict their peculiarities. The environmental impact, recyclability and maintenance are classified from 1 to 5. For environmental impact and maintenance 1 = **high**, 2 = **medium**, 3 = **low**, 4 = **very low**, 5 = **no** whereas recyclability ranges from 1 = **poor** to 5 = **excellent**. The abbreviations **N/A** and **not appl.** stand for **not available in the literature** and **not applicable** respectively. Furthermore, the recharge time of each technology is proportional to the size of the system. Bold text with bigger font stands for the **most favourable(s)**, bold for the **second most favourable(s)** and italic for the **least favourable(s)** related to the characteristic described in each column. As is evident from Table 1 it is not possible to state unambiguously that a certain energy storage technology is superior to the others as it clearly depends on the application and corresponding parameters and every ESS necessitates compromises.

Table 1: Characteristics of EES technologies (Chatzivasileiadi et al., 2013)

		Power rating MW	Energy rating kWh	Specific power W/kg	Specific energy Wh/kg	Power density kW/m^3	Energy density kWh/m^3	Round-trip eff. %	Critical voltage V	Discharge time	Response time	Lifetime (years)	Lifetime (cycles)	Operating temp. °C	Self-discharge %/day	Spatial requirement m^2/kWh [f]	Recharge time [i]	Investment power cost €/kW	Investment energy cost €/kWh	Com-mercial use since	Technical maturity	Envir. impact [e]	Recy-clability [e,f]	Main-tenance [e]	Memory effect	Trans-port-ability	Cumulative en. demand MJ/kWh [k]
	PHS	**100-5000**	**$2x10^5$-$5x10^6$**	Not appl.	*0.5-1.5*	0.1-0.2	*0.2-2*	75-85	Not appl.	**h-days**	s-min	**50-100**	$>5x10^5$	Ambient	0	0.02	min-h	*500-3,600*	60-150	1929	**mature**	*1*	Not appl.	3	N/A	no	N/A
	CAES	**100-300**	**$2x10^5$-10^6**	Not appl.	30-60	0.2-0.6	12	≤55	Not appl.	**h-days**	*1-15min*	**25-40**	**No limit**	Ambient	0	0.10-0.28 [g]	min-h	400-1,150	**10-40**	N/A	medium [j]	*1*	Not appl.	3	N/A	no	N/A
	Hydrogen	<50	$>10^5$	>500	33,330	0.2-20	600 [b]	*29-49*	Not appl.	**s-days**	ms-min	5-15	$>10^3$	+80 to +100 [a]	0.5-2	**0.005-0.06** [g]	**Instant.**	550-1,600 [d]	**1-15**	2010	*Early*	3	2-3?	*1*	N/A	yes	5,501
	Flywheel	<20	$10-5x10^3$	**400-1600**	5-130	**5,000**	20-80	85-95	Not appl.	15s-15min	ms-s	≥20	**10^5-10^7**	-20 to +40	*20-100*	0.28-0.61 [g]	<15min	**100-300**	1,000-3,500	2008	mature	**5**	4	3	no	yes	*30,449*
	SMES	0.01-10	10^{-1}-10^2	**500-2000**	0.5-5	2,600	6	**≥95**	Not appl.	ms-5min	ms	≥20	10^4	*-270 to -140*	10-15	*0.93-26* [g]	min	100-400	*700-7,000*	2000's	*early*	3	N/A	2	N/A	yes	N/A
	EDLC	0.01-1	10^{-3}-10	*0.1-10*	0.1-15	**40,000-120,000**	10-20	85-98	0.5	ms-1h	ms	≥20	$>5x10^5$	**-40 to +85**	2-40	0.43	**s-min**	100-400	300-4,000	1980's	medium	3	4	**4**	no	yes	N/A
Conventional batteries	**Pb-acid**	<70	10^2-10^5	75-300	30-50	90-700	75	80-90	1.75	s-3h	ms	*3-15*	$2x10^3$	+25	0.1-0.3	0.06	*8h-16h*	200-650	50-300	1870	**mature**	2	5	3	no	yes	**652**
	NiCd	<40	10^{-2}-$1.5x10^3$	150-300	45-80	75-700	<200	70-75	1.0	s-h	ms	15-20	$1.5x10^3$	**-40 to +45**	0.2-0.6	0.03	1h	350-1,000	200-1,000	1915	mature (portable)	2	4-5	*1*	*yes*	yes	1,372
	NiMH	*10^{-6}-0.2*	*10^{-2}-500*	700-756	60-120	500-3,000	<350	70-75	1.0	h	ms	*5-10*	*$3x10^2$-$5x10^2$*	-20 to +45	0.4-1.2	0.02?	2h-4h	120%xNiCd	120%xNiCd	1995	mature (mobile)	3	4-5?	*1*	*yes*	yes	N/A
Advanced batteries	**Li-ion**	0.1-5	10^{-2}-10^5	230-340	**100-250**	**1,300-10,000**	**250-620**	**90-98**	*3.0*	min-h	ms-s	8-15	$>4x10^3$	-10 to +50	0.1-0.3	0.01? [h]	min-h	*700-3,000*	200-1,800	1991	mature (mobile)	**4**	4	**5**	no	yes	1,156
	NaS	0.5-50	$6x10^3$-$6x10^5$	90-230	**150-240**	120-160	<400	85-90	1.75-1.9	s-h	ms	12-20	$2x10^3$-$4.5x10^3$	*+300*	20	0.019	*9h*	700-2,000	200-900	1998	Medium	**4**	5	3	no	yes	N/A
	NaNiCl	<1	$120-5x10^3$	130-160	125	250-270	150-200	90	1.8-2.5	min-h	ms	12-20	10^3-$2.5x10^3$	*+270 to +350*	15	0.03?	6h-8h	**100-200**	70-150	1995	mature (mobile)	N/A	5	**5**	no	yes	N/A
Flow batteries	**V-Redox**	0.03-7	$10-10^4$	N/A	75	0.5-2	20-35	75	**0.7-0.8**	s-10h	**< 1ms**	10-20	$>13x10^3$	0 to +40	0-10	0.04	min	2,500	100-1,000	1998	medium	3	5	3	no	no	774
	ZnBr	0.05-2	$50-4x10^3$	50-150	60-80	1-25	20-35	70-75	**0.17-0.3**	s-10h	**< 1ms**	*5-10*	$>2x10^3$	+20 to +50	0-1	0.02	3h-4h	500-1,800	100-700	2009	medium	3	5	*1*	no	yes	[illegible]
	Zn-air [c]	several	$x10^3$	1350	**400**	50-100	**800**	60	0.9	6h	ms	**30**	$>2x10^3$ ($>10^4$)	0 to +50	N/A	**<0.005?**	N/A	785	126	2013/14	*early*	3	3	3	no	yes	**710**

4.3 Effects on the Value Chain

One of the most important questions when it comes to the reshaping of the EV supply chain is about the vehicle design. According to Klug (2013), there exist two opposed concepts, namely the conversion and the purpose design. For the conversion model, simply a conventional ICE vehicle is taken, and the powertrain components get replaced with the major advantage of keeping the development costs down and perpetuating economies of scale which is ideal for new entrants to the EV market. Purpose design, on the other hand, goes along with reconstructing the EV architecture from scratch with the alternative power train in mind which allows for a more radical innovation and new possibilities. This is also the approach that Tesla uses as does BMW with its i-series vehicles. (Ward, 2017)

This perspective applies to the supply chain as well: Whilst the supply chain for a conversion EV very much resembles traditional ones besides some additional elements, the supply chain for a purpose design EV often appears fundamentally different. Klug argues that the impacts that EVs have on the automotive supply chain will create value potential for the supplier industry and logistics respectively and will go along with an increase in freight volume. However, this very much depends on what the car manufacturers buy in contrast with what they are willing to make themselves. While the powertrain traditionally was a key part of in-house development, many automotive firms typically have not so much expertise with electric components. (Ward, 2017)

Pertaining to a scenario by Deloitte, the increasing share of electric cars together with progress in automation will furthermore result in a workforce depletion in production. In fact, 20 % of blue-collar workers are to be dismissed due to automation of technical processes and electric vehicle production. Yet future OEMs will remain attractive working places for R&D and digital talents with mobility management services and hi-tech peculiarities asserting themselves at the core of the firm’s value proposition. (Deloitte, 2017)

For EVs, the battery is the single most important component and has been the main obstacle for a large-scale introduction of electric powertrains. As of right now it is the most expensive and heaviest element in an electric car with far-reaching impacts on the automotive value chain as well as logistic costs. A couple of different approaches are conceivable to strike the right balance between access to know-how and adequate control of the value chain. Automotive manufacturers may decide to source batteries and motors from third party suppliers, gain expertise through buying battery producers or joint-venture with them for vertical integration. (Ward, 2017)

There are, however, some good reasons to locate the battery production near the vehicle assembly sites. Besides high costs and risks due to the transportation of heavy and potentially dangerous goods the supply chain flexibility also gets reduced. Therefore, a scenario is plausible where the final assembly of the batteries takes place somewhere near the assembly locations whilst the cells and other necessary components are produced elsewhere. It is important to note that this development will not be driven solely by incumbent firms, quite the contrary: The electric vehicle industry offers a wide range of opportunities for start-ups as well as expansions from other industrial sectors due to its different nature. (Ward, 2017)

With the disadvantage of the complexity, the heavy weight and the high cost of the battery on the one hand, other EV components on the other hand tend to be simpler and smaller than their ICE vehicle counterparts which impacts the supply chain as well. For example, EV motors are more prone to be commoditised than internal combustion engines which thereby limits the ability of manufacturers to leverage their motor technology as a kind of competitive differentiation. (Ward, 2017)

Conforming to the International Energy Agency (2018), a global forecaster, the Republic of China is leading the electric car market by a huge margin. Nearly 580,000 EV were sold there in 2017 which corresponds to more than half of the global EV sales in that year.

As stated in an interview with Dr. Klug, a Professor of Logistics Management at the Munich University of Applied Sciences, heavy government support and the enormous Asian market are turning China into a global production hub. They have established a complete automotive value chain, composed of components that are predominantly produced locally. Controlling important raw materials will presumably become strategically important for firms pursuing a leading role in the production of EV. While Lithium for example is highly recyclable and available in great quantities in sea water, other materials may be more arduous. Cobalt for instance (to a great degree a by-product of copper and nickel mining) is mainly supplied by mines in the DR Congo, a country that is known for its innerpolitical instabilities which may threaten supply security. (Ward, 2017)

Another factor that puts the Cobalt supply chain at risk is the fact that beyond 80 % of the world's refined cobalt is produced in China (Sanderson, H./Financial Times, 2018). Furthermore, a continued trend in mark-up – the price for Cobalt has tripled between 2015 and 2018 – could gravely stunt battery manufacturing. Currently, Cobalt is a critical element in Li-ion batteries as it basically extends the life cycle of the battery cell. While substituting it with cheaper and more widely available Nickel is possible this may lead to a fire hazard since Cobalt decreases the propensity of cells to overheat. (Goldsmith, C./World Finance, 2018) Using the example of Tesla one can gain a better sense how much Cobalt is currently needed in an EV: In 2018 the company's average cobalt usage in their nickel-cobalt-aluminium (NCA) battery was 4.5kg per vehicle compared to 11kg in 2012 which equals to a 60 % reduction in 6 years (Benchmark Mineral Intelligence, 2018). For comparison, the respective quantities in nickel-manganese-cobalt (NMC) batteries (the technology that most competitors focus on) have approximately twice the cobalt content relative to NCA batteries which can be seen from Figure 10 below. A typical

EV with a 55kWh battery pack and a NMC622 cathode will contain approximately 12 kg of refined Cobalt. Furthermore, lithium-cobalt-oxide (LCO) batteries have been added to the illustration which are used extensively in portable electronics due to their good performance and safety. However, they are unprofitable for EV applications due to its high cobalt usage which makes them expensive. (McKinsey&Company, 2018) In spite of Lithium being essential in all three cathode compositions, the illustration shows that it constitutes only a small percentage of the total cathode. In fact, each one of those Li-ion batteries contains more Cobalt than Lithium.

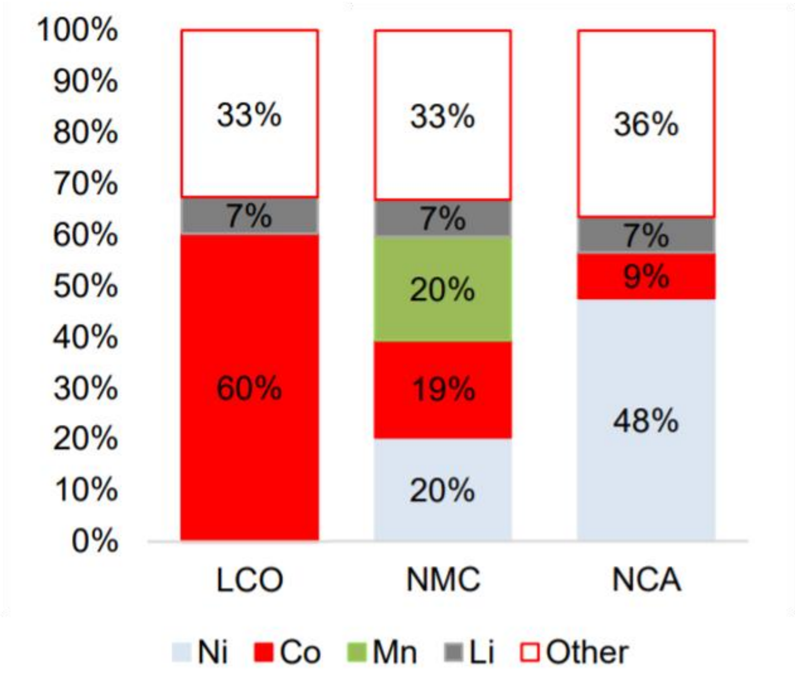

Figure 10: Battery Cathode Composition in Selected Li-ion Batteries (Macquarie Wealth Management, 2017)

Based on a current study conducted by the Oliver Wyman Consulting Firm in cooperation with the German Association of the Automotive Industry (VDA) Europe, Japan, Korea and North America will lose ten percentage points of their portion of value creation to developing markets until 2030. While Europe will soon be displaced by China as the leader in manufacturing it will presumably sustain its predominance in the premium segment, as ever possessing 50 % of the overall value creation. However, it is predicted that China will catch up on this segment as well with an increase from 13 % to 20 % in generated added value by 2030. (Wyman, 2018)

5 Analysis of the Major Players in the Electric-Vehicle Revolution

To narrow down companies and prospective interview partners for the adjacent qualitative research, an overview of potential key players in the electric vehicles industry is given. Those will be divided into subchapters, namely the Manufacturers (OEMs) themselves, Suppliers and Engineering Service Providers.

5.1 The OEMs

China has established itself as a market leader in both supplying and demanding electric vehicles (Hertzke et al., 2017). Due to China's dominance on the electric vehicle market the manufacturers have been subclassified into two groups, that is to say inside and outside of China. Distinctive performance figures have been collected and compiled in a spreadsheet which can be found in Table 2 below. This table allows a comparison of the major OEMs in terms of commitment to electrification and magnitude. Companies in China are highlighted in grey, outside of China in blue. It is necessary to clarify that the term "new electric vehicle" (NEV) is a classification predominantly used in China that covers both pure (BEV) and hybrid electric vehicles (PHEV). (Kimble & Wang, 2013) Revenue, Profit and the Number of Employees as of June 6, 2018 have been gathered from www.forbes.com as indicated by the number 1 in superscript in the header of the table below. The revenue for Zotye Auto could only been found for the first half of the year 2018 and italic values represent rounded numbers. The number of cars sold in 2018 were taken from publicly available sales figures.

Table 2: Distinctive Performance Figures of Leading OEMs Inside and Outside of China [own illustration]

Company	Country	Revenue[1]	Profit[1]	Founded	Employees[1]	BEV	PHEV	NEV (Sum)	Total Car Sales	% NEV
BYD	China	$16.3B	$523.0M	1995	200,949	103,263	123,889	227,152	520,687	43.63
Geely	Hong Kong	$13.8B	$1.6B	1973	41,600	-	-	68,549	1,500,838	4.57
BAIC Motor	China	$19.9B	$334.2M	1958	22,844	-	-	*158,000*	2,402,000	6.58
SAIC Motor	China	$136.6B	$5.4B	1995	180,749	-	-	*140,000*	7,050,000	1.99
Zotye Auto	China	$ 1.5B[4]	$ 45.1B[4]	2003	16,210	-	-	33,872	257,303	13.16
Chery	China	n.a.	n.a.	1997	16,721	-	-	90,537	752,759	12.03
RNM Alliance	France/Japan	241.5B	18.3B	1999	262,386	127,462	65,249	192,711	10,750,000	1.79
Tesla	U.S.	$12.5B	$-2340.7M	2003	37,543	191,627	-	191,627	191,627	100.00
BMW	Germany	$114.4B	$10.2B	1916	129,932	-	-	142,617	2,490,664	5.73
GM	U.S.	$144.4B	$-3182.0M	1908	180,000	18,019	18,306	36,325	2,954,037	1.23
VW Group	Germany	$272B	$21.4B	1937	642,293	*33333*	*66667*	*100,000*	10,830,000	0.92
Hyundai Motor	S. Korea	$85.9B	$3B	1967	122,217	43,789	9,325	53,114	677,946	7.83

The ratio of New Electric Vehicles or NEV to the Total number of car sales that is shown at the far right of the table (% NEV) has also been used for a short cluster analysis which can be taken from Figure 11 below. One can easily comprehend from the graph that there are three clusters in this group. Worth mentioning is the fact that the three biggest automotive companies by total car sales (the VW Group, SAIC Motor and the Renault Nissan Mitsubishi Alliance) only produce NEVs approximately in the same magnitude order than the other observed companies despite their size.

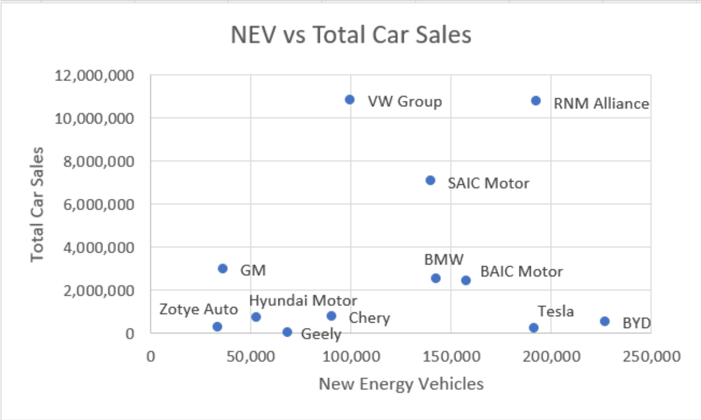

Figure 11: New Electric Vehicles vs Total Car Sales [own illustration]

According to an analysis published by the Global Fleet Network, the major players inside China consist of BYD Co Ltd., Geely, Beijing Electric Vehicle Corporation, SAIC Motor Corporation Ltd., Zotye Auto and Chery which will now be described shortly as to their relevance on the (future) electric vehicle market. (Helven, 2018)

5.1.1 BYD Auto Co., Ltd.

BYD began as a rechargeable-battery plant vying with Japanese imports for Chinese market shares and became the largest Chinese manufacturer of all kinds of rechargeable batteries (Quan et al., 2018). Nowadays the company offers a wide portfolio of products including automobiles, buses, trucks, forklifts and skyrails. BYD is by their own account the largest EV manufacturer in the world for both personal and commercial electric vehicles. The company's stated mission is to reduce the world's reliance on petroleum by creating a complete, clean-energy ecosystem. (BYD Motors Inc., 2018)

5.1.2 Geely

As of the second half of 2018 Geely has become the third-largest car manufacturer in China, outstripped only by General Motors and Volkswagen (Fusheng, 2018). The company that produced cheap cars for the masses in the 2000s went upmarket in 2010 which proved to be a right move as passenger car sales peaked in 2013 whereas the demand for upmarket SUVs kept blooming. Its parent company Zhejiang Geely Holding Group has attracted worldwide attention in the media with its acquisition of Volvo and the accumulation of a stake (9.69 %) in Daimler AG (Nicholson, 2010; Campbell, 2018). It also owns London Taxi, Lotus and many more (Helven, 2018).

5.1.3 Beijing Electric Vehicle Corporation Ltd. (BJEV)

BJEV is a subsidiary of the state-owned BAIC Group. In 2013 Daimler AG acquired a 12 % stake in BAIC and a 3.93 % stake in its subsidiary in 2018 (Daimler, 2018). BJEV is the producer of the EC180, the most affordable (less than $8,000 after subsidies) and most popular electric vehicle on the Chinese market. In addition to the EC180, BJEV makes a wide range of EVs such as SUVs, mid-sized and more luxurious sedans like the EH300. (Helven, 2018) In June 2018 Magna announced a joint venture with BEJV to develop and manufacture two premium EVs for the Chinese market. (Hanley, 2018)

5.1.4 SAIC Motor Corporation Ltd.

SAIC counts among the oldest car manufacturers in China. The enterprise is well grounded in joint ventures with Volkswagen and General Motors. In this context they produce and sell vehicles under the Volkswagen and General Motors brand names. Worth emphasising is their Maxus EV80 which is the largest fully electric van on the market achieving a maximum distance of 200km. In 2018 they have been made available in Europe. (Helven, 2018)

5.1.5 Zotye Automobile Co., Ltd.

Aside from engaging in the R&D, manufacture and sale of passenger cars Zotye also designs and manufactures engines, batteries, electronic control products transmission products and many others (Bloomberg, 2018a). Zotye is also the owner of Jiangan Auto, the company that manufactures China's most affordable car which can be purchased at a discounted price of $2,415 (De Feijter, 2016). By the end of 2017 Zotye Automobile formed a joint venture with Ford Motor around an agreement to invest a combined $756 million to build and sell small all-electric passenger vehicles in China under a new brand name (Edelstein, 2017).

5.1.6 Chery Automobile Co., Ltd.

Chery is the producer of the popular eQ, an all-electric minicar with a sticker price of below $10,000, which worked its way up to China's 4th best-selling EV in 2017. The cheap price makes it one of the most affordable electric vehicles on the market. In 2012 Chery created a joint venture with Tata Group (owner of Jaguar Land Rover) to produce Jaguar Land Rover vehicles in China. (Helven, 2018) This car manufacturer has been China's largest passenger car exporter for 15 consecutive years and it is planned to speed up the launch of new products overseas in the future. What's more, Chery is expected to realize electrification of all its models by 2020 by their own account. (Chery International, 2018)

Outside of China the major players in electric mobility have been chosen according to market share, innovativeness, growth prospects, turnover and perceived level of commitment. They turned out to be the following in no particular order: The Renault-Nissan-Mitsubishi Alliance, Tesla, BMW, General Motors, the Volkswagen Group and the Hyundai Motor Group which will be now reviewed briefly.

5.1.7 Renault-Nissan-Mitsubishi Alliance

In Europe it is this Alliance in particular that leads the EV sales by a high margin. For the first half of 2018 the Nissan LEAF for example has already been sold over 47,000 times turning it into the best-selling electric vehicle in Europe in 2018. Renault on the other hand secured 21.9 percent of all the electric vehicles sold in Europe so far with ZOE and Kangoo Z.E. (Blanco, 2018) By the end of 2017 the world's largest automotive group has sold an accumulated 540,623 all-electric vehicles since 2010 with most of them being Nissan LEAFs. The Alliance operates in almost 200 countries under the following ten brands: Renault, Nissan, Mitsubishi Motors, Dacia, Renault Samsung Motors, Alpine, Lada, Infiniti, Venucia and Datsun. (Kane, 2018b) What's more, they have concluded strategic partnerships with car producers like AvtoVAZ (Russia), Daimler (Germany), Dongfeng (China) and Ashok Leyland (India). (Groupe Renault, 2018)

5.1.8 Tesla Inc.

This American company disrupted the automotive industry in an unprecedent way, changing, for the first time ever, the image of electric vehicles to begin to look like a legitimate and profitable opportunity (Cox, 2018). Its Model S which was introduced in 2015 became the best-selling electric vehicle in 2015 and 2016 respectively. Strategic partnerships with leading competitors such as Daimler and Toyota contributed further to the expansion of the EV market. The company's success, according to Cox, stems from creating popular products, forming lucrative partnerships as well as the constant pursuit of self-disruption. (Cox, 2017) Tesla also has its own lithium-ion battery manufacture. The company has confirmed that by the end of July 2018 battery production in its Gigafactory 1 in Nevada is at approximately 20 GWh, making it the most powerful battery plant in the world. Together with Panasonic Corp., Tesla's associate, more battery cell production lines are planned to be added that should come down to an annual production rate of 35 GWh. However, this volume isn't enough yet to meet the battery needs of the company which is why Tesla has increased the planned total capacity to 105 GWh of battery cells. (Lambert, 2018f) Tesla has also sealed an agreement in July 2018 for a second car assembly plant in the Shanghai Lingang industrial zone titled Gigafactory 3. This local plant will enable Tesla to avoid import tariffs and will also make Tesla the first foreign carmaker to build a factory in China without having to do a joint-venture with a Chinese company. (Lambert, 2018b) Beyond that, Tesla's supercharging network in July 2018 encompassed 10,720 Superchargers at 1,330 stations all over the world and is growing steadily. For the majority of Model X and Model S owners the usage of these stations is for free. (Lambert, 2018c)

5.1.9 BMW AG

According to a scorecard by Bloomberg New Energy Finance (BNEF), nine of the top 10 EV car manufacturers are based in China. Germany's BMW is the only automaker outside of China to position itself on that list, ranked ninth overall with its nearly 60,000 plug-in hybrids sold in 2017. (Stock, 2018) BMW's response to the increasing demand for EVs consists in its innovative collection of electric cars grouped under "Project i". It started with the "i3", an urban all electric car which was followed by the "i8", a PHEV sports car. Both lines have proven successful and reinforced BMW to keep developing in this direction. Additionally, the aesthetics of BMW vehicles stand out from the masses which acts as a strong unique selling proposition (USP) according to Technavio, a leading market research company. (Technavio, 2018) Currently there are 7 different PHEV models available including its three top-selling sedans and the X5 SUV (BMW Group, 2018). While BMW is augmenting the capacities of some of their factories to produce all-electric cars, gas-powered vehicles and PHEVs on the same production lines they also announced to build a new factory in Hungary to manufacture EVs (Lambert, 2018e). They also invested in a new Battery Cell Competence Centre to advance the technology. It is expected to be completed in 2019 and play a key role in facilitating the company's fifth generation electric drivetrain which is planned to be released in 2021 (Lambert, 2017).

5.1.10 General Motors

US manufacturer GM entered the EV territory in late 2016 with its Chevrolet Bolt as the first fully electric vehicle with a range above 200 miles and a basic rate below $40,000, a combination that was widely held as the triggering combination for mass-market impulsion. However, besides beating Tesla's Model 3 to market, factors like the slow nationwide rollout have kept the Bolt partially epiphenomenal to the Model 3. In 2017 Chevrolet sold 23,297 Bolt EVs nationwide notwithstanding that the vehicle wasn't available in all states till August. In the first half of 2018 global Bolt sales have increased by more than 40 percent year-over-year. According to a company announcement GM will increase Bolt production by one-fifth during the fourth quarter of 2018 to meet demand and launch twenty new fully EVs by 2023. (Edelstein, 2018) To step up the Bolt production by more than 20 % a new LG battery factory is being built in Michigan to supply the GM assembly site in Orion with battery packs (Randall, 2018d). The Bolt outsold all Tesla models in October and November 2017 and came in second in U.S. sales throughout the year, leaving the Nissan Leaf far behind (Rosevear, 2018).

5.1.11 Volkswagen Group

Following its Dieselgate scandal, the German car manufacturer VW is now investing heavily in EVs. Paradoxically, this Dieselgate affair might have been exactly what put the company on the right track which before took a very conservative approach towards an electric future. (Kerler, 2018) Volkswagen Group confirmed that by 2022 they will release 27 electric models on their new "modular electric toolkit" (MEB) platform. Altogether, Volkswagen has appropriated $7 billion for making the transition to electric cars. (Evarts, 2018) This year the company also announced that it doubled its EV battery contracts to approximately $48 billion. This brings the manufacturer closer to its goal of $50 billion which will cover the planned production requirements for their EVs up to 2025. (Cheng, 2018) However, a proposed emission reduction initiative by the European Parliament with a CO_2 reduction goal of 35 % (originally 40 %) by 2030 for new vehicles to advance EV adoption led to great concerns on the part of the VW CEO Herbert Diess, claiming that this drastic reduction could cause the industry to crash. With an anticipated production of 3 million EVs per year by 2025 this raises the question how serious VW sees their EV goals in point of fact. (Lambert, 2018g)

5.1.12 Hyundai Motor Company

The Hyundai Motor Company, which includes Kia Motors, is challenging the EV market with its new all-electric SUV Kona that will be available outside of South Korea by 2019. As of now it will provide the most range of any non-Tesla electric vehicle, beating the Chevrolet Bolt EV, the former range champion, by 20 miles. (Loveday, 2018) The fully electric Kia Niro which will be released in February 2019 in Europe has a WLTP-tested combined range of 301 miles with a 64-kWh battery. Presently it is presumed to be the most efficient production EV worldwide with a range of 4.7 miles per kWh, beating the Tesla Model 3 which previously led the efficiency ranking. It also offers an unexceptional fast charging rate, filling the battery up to 80 percent in 54 minutes given a 100-kW charger. The Kia Niro EV shares the platform and some key components with the Hyundai Kona EV. (Gilboy, 2018) What's more, Hyundai is planning to launch its full portfolio of EVs in India to compete with the market leader Maruti Suzuki and to gain a higher market share of one of the world's largest automobile markets (Thakkar, 2018).

5.2 The Suppliers

Since this work focuses on batteries the analysis of influential suppliers will be limited to electric-vehicle-battery manufacturers. In consonance with C. Hembrow, Cofounder of Indian mechatronics engineering company Ayata IQ, Li-ion batteries will sustain their dominance in BEV applications mainly by reason of heavy investment trends where major players will seize a return on those expenditures for as long as economically justifiable. However, at long sight they will be substituted for more sophisticated battery technologies such as solid-state batteries that are currently in development. (Hembrow, 2016)

According to figures released by Statista, a market research company, the global top 5 lithium-ion battery makers with their respective market share shown in brackets are Panasonic Sanyo (21.1 %), CATL (14.41 %), BYD (10.99 %), LG Chem (10.59 %) and Samsung (5.57 %) for the 1st quarter of 2018 (Statista, 2018). These incumbents together with promising newcomers will now be shortly reviewed and argued as to why those companies will likely play a significant role in the future of EVs.

An analysis conducted by Shenzhen Gaogong Industry research for 2017 conveys a general understanding of the magnitude of the global players in the lithium-ion battery segment. In Figure 12 the ten leading manufacturers worldwide are represented with their respective manufacturing capacity measured in Gigawatt hours (GWh). As can be seen from the Figure there is not a single European Li-ion battery manufacturer which may result in future problems regarding resource dependencies for European car manufacturers.

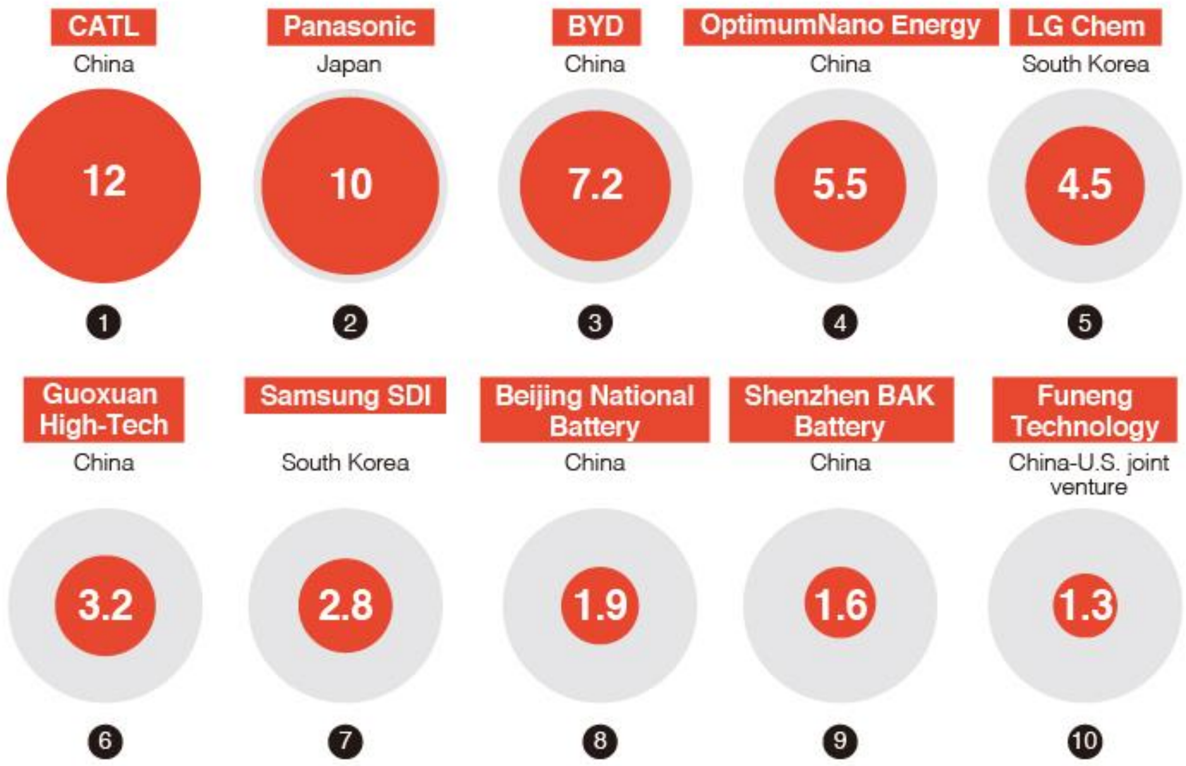

Figure 12: Lithium-ion battery capacity [in GWh] of top manufacturers in global electric-vehicle battery industry 2017 (Shenzhen Gaogang Industry Research, 2018; Tan, 2018)

5.2.1 Contemporary Amperex Technology Co. Ltd. (CATL)

CATL is a relatively young company founded in 2011 who managed to pull ahead of its competitors over the last four years. At present it operates three manufacturing plants in China, supplying leading carmakers such as Daimler AG, BMW, Geely and BAIC Motor Corp. Ltd. with battery packs. In 2017 CATL produced 11.8 GWh in battery capacity, an increase of 74 % compared to 2016. Recently the company caused a stir with the fast-track approval of their $2 billion IPO application within less than a month. Most former applicants had to wait one or two years for an approval. The company is planning to use the money gained from their IPO to build a Gigafactory that is expected to reach an annual production capacity of 150 GWh by 2020 which is second in size only to Tesla’s Gigafactory in Nevada. However, challenges and uncertainties are lying ahead of the company once the government withdraws its subsidies that boosted the electric-vehicle industry. Since BEV manufacturers have been falsifying sale numbers to gain higher subsidies Beijing reduced the rebate and will bring them to a halt altogether by 2020. (Tan, 2018) As of now CATL is maintaining supply contracts with 22 different EV manufacturers inside and outside of China and right in the middle of expanding overseas (Parkinson, 2018). To gain a competitive advantage over Korean battery makers CATL also announced that it will be the first to launch new NCM 811 battery cells for EVs in 2019. While the cathode of the current CATL NMC 532 cells comprises 20 % cobalt the new NCM 811 will halve the cobalt content per kWh while increasing energy density. CATL will also start to build a production site in Erfurt, Germany in 2019 which will run at full capacity from 2022. (Manthey, 2018a)

5.2.2 Panasonic Corp.

The Japanese electronics company that just turned 100 years old in 2018 is the exclusive battery cell supplier for Tesla's EVs. It manufactures custom-made Li-ion cells in Japan for Tesla's Model S and Model X whereas the custom cells for the Model 3 are co-developed with Tesla and produced by Panasonic at Gigafactory 1. The current annual production capacity adds up to 20 GWh. However, Panasonic is aiming to bring the total capacity of its battery cell production to 35 GWh by the end of 2018. (Lambert, 2018d) In 2018 Panasonic has also started producing battery cells at their first factory in China which is going to supply both North America and China to accommodate growing demand. It is noteworthy that Panasonic is producing Li-ion batteries with a prismatic cell design there which is the most popular amongst automotive manufacturers exempt from Tesla which stands out by having pioneered cylindrical cells in their EVs. (Lambert, 2018a) As prices of the scarce mineral cobalt, a necessary element for most Li-ion batteries, have been increasing significantly over the last few years Panasonic is also planning to halve the cobalt content of their EV batteries “over the next two to three years” according to a company executive. To tackle a potential bottleneck Panasonic already reduced the cobalt content in its nickel-cobalt-aluminium (NCA) cathode to approximately 10 %. (Fortuna, 2018)

5.2.3 BYD

According to Bernstein Research, BYD has the lowest production costs in the EV battery industry. However, their vertical integration also suggests that battery production must expand at the same rate as EV volumes which proves to be a challenge given erratic car sales. (Hamlin, 2017) In 2018 BYD launched their third Li-ion battery factory in China with a capacity of 24 GWh upon completion in 2019 which shall be expanded to reach an annual 60 GWh by 2020. Moreover, the company is expanding production beyond self-sufficiency to vend batteries to other car manufacturers. (Bloomberg, 2018b) Furthermore, BYD also announced the opening of a battery recycling plant in Shanghai in the second quarter of 2018 as a means to address battery waste and to diminish the cost of raw materials. The first load of EV battery waste will be thrown on the market this year which will reach an expected 120,000-170,000 tonnes a year by 2020 as reported by Chinese parliamentary delegates. (Daly, 2018) The company also expressed interest in building a battery factory in Europe. Up to now BYD already put bus assembly plants into operation in Hungary and France and is partnering on another bus production in the UK (Kane, 2018a).

5.2.4 LG Chem

South Korean LIB manufacturer LG Chem is planning to increase cell manufacturing capacity to 90GWh in 2020 from a precedent prognosis of 70GWh. The company gradually locks-in raw material supplies, setting up joint ventures with China's Zhejiang Huyaou Cobalt and concluding deals with Nemaska Lithium and Ganfeng Lithium. (Els, 2018) LG Chem is currently operating plants in South Korea, China and the United States. The European plant in Poland which is still under construction will operate at a production capacity of 100.000 batteries per annum. However, in prospect of an expected huge production increase in electric cars by European carmakers over the next decade LG Chem already envisages to soon triple the annual capacity to 300.000 units. (Lima, 2018) The enterprise also announced the construction of a second EV battery plant in China to meet rising demand. With breaking ground in 2018 the production is expected to begin in October 2019 (Reuters, 2018a). LG Chem has secured orders to supply Volkswagen with EV batteries beginning with the end of 2019 though it did not unfold the dimension of the deal (Reuters, 2018b). In February 2018 LG Chem also started a collaboration in advanced Li-ion battery technology affairs with Mahindra & Mahindra Ltd., an Indian multinational car manufacturing corporation. The cells will be used in the Mahindra and Ssang Yong fleet of EVs. (Mahindra, 2018)

5.2.5 Samsung SDI

South Korean company Samsung SDI revealed plans in 2018 to build a cathode production facility in Chile together with South Korean steel giant Posco with a guaranteed lithium supply by the Chilean government. The joint venture will start to produce approximately 3,200 tons of cathode materials per year starting from the second half of 2021. (Song, 2018) Samsung SDI has furthermore invested in a battery plant in Hungary that started production in 2018 with a production capacity of 50,000 batteries per year to strengthen its presence on the European continent. Synergies are expected from SDI Battery Systems, a production site of battery packs in Graz that Samsung acquired from Austrian manufacturer Magna Steyr in 2015. As of right now, Fiat, Audi and BMW are already using Li-ion batteries by Samsung SDI for some of their EVs. (Peschel, 2016) In the second quarter of 2017 Samsung Advanced Institute of Technology (SAIT) came up with a promising new technology, the so-called graphene ball, a coating material that enables a 45 % increase in capacity as well as a 500 % increase in charging speeds compared to standard Li-ion batteries. Moreover, the new battery cell possesses a higher energy density at 60°C (444 Wh/kg) than at 25°C (370 Wh/kg) and is able to keep a stable temperature of 60°C, possibly rendering Thermal Management Systems superfluous. (Lima, 2017)

5.2.6 Northvolt

One of the very few European initiatives towards EV battery production is fuelled by Northvolt, a Swedish company that is trying to set up a large-scale battery cell plant in Europe to compete with Asian rivals. In the second half of 2018 they started construction of their R&D center called Northvolt Labs which will be used for developing, testing and industrializing Li-ion battery cells prior to large-scale production. Plans are that the institution will be in operation by 2019 with a capacity of 125 MWh (around 1,250 packs of 100 kWh). To build their anticipated Gigafactory in Sweden with an annual capacity of 32Gwh by 2023 funds in the amount of $5 billion will be needed. (Kane, 2018d)

5.2.7 SK Innovation

South Korean petroleum refining company SK Innovation started construction of a battery cell facility in Komáron, Hungary in the first quarter of 2018. The production is scheduled to begin by 2020, reaching full capacity of 7.5GWh by 2022, strengthening their current battery plant in South Korea (3.9GWh annually). Hungary represents an excellent opportunity since major global carmakers operate assembly lines there as well – Audi for example started to manufacture electric cars there. SK Innovation serves major clients like Hyundai, Kia and Daimler and is an exclusive supplier of batteries for the Mercedes PHEVs. (Manthey, 2018b) Furthermore the company revealed plans to build a factory for key EV battery parts such as separators and ceramic coating for Li-ion batteries in China which will start production in the second half of 2020. Other EV battery plants are also planned in China and in the U.S., the former will be a joint venture with BAIC Motor and Beijing Electronics. (Hyonhee, 2018)

5.2.8 Daimler AG

German company Daimler AG announced plans in the second half of 2018 to expand their plants in Sindelfingen and Untertuerkheim (both in Germany) by battery manufacturing capabilities. With the retooling Daimler is sticking to its $1.75 billion transformation plan to transition from ICEs to EVs. In total Daimler will then own eight battery factories including their existing one in Kamenz (Germany) and further plants under construction in Beijing (China), Bangkok (Thailand) and Tuscaloosa (USA). (Taylor, 2018) At Daimler's wholly-owned subsidiary Deutsche Accumotive GmbH & Co KG in Kamenz a second factory will be completed in 2018. It is noteworthy that they don't actually produce but rather assemble battery cells that they currently buy from LG Chem. (Kane, 2018c)

5.3 The Automotive Engineering Service Providers

When an automotive company faces a lack of resources, is in need for specialization or wants to obtain a new technology but needs help to get started outsourcing engineering can pose a great opportunity without allowing costs to escalate uncontrollably. So-called engineering service providers (ESP) according to Blöcker (2016) are industrial companies whose turnover is for the most part achieved through the provision of development services in the form of service contracts and engineer-to-order. Production and sale of proprietary products is not the primary focus of ESP. This generally puts them at the beginning of the value chain. With its almost 60 per cent share (end-producer and supplier) the automotive industry is the main customer of ESP.

According to Grand View Research, a business consulting firm, the role of ESP has changed significantly these days. Due to pressure for cost-cutting on OEMs, increasing levels of technical complexity and shorter product life cycles the ESP business is blossoming. What's more, the role of ESP changed from being a third-party supplier to a key stakeholder in the development of products, including the provision of end-to-end solutions due to growing confidence of clients in ESPs. (Grand View Research, 2018)

The most relevant companies operating in this sector are chosen according to a market research report by Technavio, a leading global technology research company, which discusses the Automotive ESP market in the space of time from 2018 to 2022 where five key vendors crystallized (AB Newswire, 2018). Furthermore, German company Fraunhofer Society will also be included in this overview since it's Europe's largest applied research institution and has been one of the top 3 world's most innovative research institutions in 2017 according to Reuters, an international news agency (Ewalt, 2017). Lastly, Austrian startup company Kreisel Electric GmbH is also included in this enumeration due to their pioneering work in electric-mobility technologies.

5.3.1 AVL List GmbH

AVL is an Austrian company that operates in the areas of powertrain engineering, simulation, instrumentation and test systems development (AVL, 2018a). For batteries in particular AVL engages in concept development, mechanical, electrical and thermal design, thermal, mechanical and electromagnetic compatibility (EMC) simulation, virtual and prototype-based validation and verification as well as the design for production (Hennige & Parsons, 2017). AVL has a long history of engagement in sustainable electric mobility. The first hybrid vehicles engineered by AVL were manufactured in the 90s. In 2012 AVL developed the first 800V BEV, a currently widely discussed technology that lowers the charging speed considerably. To validate these types of batteries the company built battery testbeds with up to 1000V capabilities from 2010 to 2012. AVL reopened their battery testing facility in the second half of 2018 after remodelling and expanding the lab for eleven months with an investment of about 16Mio $. The area now covers 700m², containing eight testing rooms which are able to produce constant temperatures from 80 to -40°C and simulate humidity levels between 3 and 97 %. The facility also received a size-upgrade to enable testing of large batteries from electric buses and trucks. (AVL, 2018b; Randall, 2018c) AVL has been also engaging in fuel cell engineering for more than 15 years and in over 100 projects with various OEMs to explore an efficient and emission-free way to power EVs in the future (AVL, 2018c).

5.3.2 Bertrandt Group

The Bertrandt Group is a company based in Ehningen, Germany which develops individual solutions for automotive and aviation industries at 54 locations in Europe, China and the United States (Bertrandt, 2018a). The company provides services for all facets of the product development value chain, including conceptual design, tool production up to production planning and support (THM Capital, 2016). The company also started construction of its new high-voltage battery test center in Ehningen which shall be up and running by April 2019 and extend the existing one. The floor area will be around 1,200m² with a total of six test rooms, each offering two climate chambers with a temperature range of -40 °C to +120 °C. (Green Car Congress, 2018) Bertrandt is also a part of the "hyPowerRange" project which aims to develop a new battery concept that improves the performance and capacity of EV batteries while simultaneously reducing costs and cooling requirements. This shall be achieved by a modular hybrid energy storage unit. Bertrandt's task is to develop an intelligent energy management system to increase the efficiency of the battery. The battery concept will be embedded into an EV for testing and demonstrating purposes starting with 2019. (Bertrandt, 2018b)

5.3.3 EDAG Engineering GmbH

EDAG is a German-based company and one of the largest independent ESPs to the global automotive sector. The company specializes in complete vehicle development from the idea to the final prototype. With their subsidiaries the company also meets the necessary competences for electronic development as well as the planning and completion of manufacturing facilities. (EDAG Engineering GmbH, 2018a) In 2018 EDAG entered an order from the startup company VinFast to fully develop an EV specific to the Vietnamese market (Randall, 2018b). In the same year EDAG also started to cooperate with Dutch solar startup Lightyear, providing them with resources to develop a long-distance solar battery-electric vehicle, the Lightyear One, which shall be production ready by 2020 (Randall, 2018a). Furthermore, the EDAG Group successfully completed their integration development of the fuel cell propulsion system for the PHEV Mercedes GLC in 2018 with which it has been commissioned at the end of 2015 (EDAG Engineering GmbH, 2018b).

5.3.4 Fraunhofer-Gesellschaft

Fraunhofer is a Germany-based research organisation with 72 institutes and research units spread throughout the country. It is the leading company for applied R&D services in Europe and is also engaged in international activities in North- and South America, Asia and the MENA-Region. (Fraunhofer, 2018a, Fraunhofer 2018b) In 2015 researchers of the Fraunhofer have engineered an energy storage device which is substantially more cost-efficient over the complete life cycle compared to former batteries. Previously, when one of the hundreds of battery cells became defective the whole battery had to be replaced due to the battery being only as strong as its weakest cell. The prototype by Fraunhofer comprised a built-in microcontroller that keeps track of physical parameters. Therefore, an empty battery can now simply decouple from the set-up while the other cells continue to work. (Fraunhofer, 2015) Another technology has been introduced by the Fraunhofer Institute for Ceramic Technologies and Systems in Dresden together with IAV GmbH and ThyssenKrupp System Engineering that could boost the range of EVs considerably. The so-called EMBATT (chassis embedded battery) reduces internal electrical resistance and space by transferring the bipolar principle that is used for fuel cells to Li-Ion batteries, stacking the individual cells directly one above the other over a large area, eliminating the entire housing and contacting structure. (Fraunhofer, 2017)

5.3.5 IAV GmbH

This German company is a global engineering partner in the automotive industry with operations in Europe, Asia and North and South America. The company exhibits knowledge at every phase of the development process, from the first draft through simulation and component tests to the maturity phase. (IAV GmbH, 2018) As previously mentioned IAV teamed up with Fraunhofer IKTS and ThyssenKrupp System Engineering to cut the volume of a battery in half and use it as structural part in the vehicle. A Tesla battery pack for example is composed of cylindrical cells that, no matter how closely arranged, will have unused space in between neighbouring cells. In the EMBATT technology however the layers of the battery that would typically be curled up to the familiar cylindrical format are flattened out and integrated into the undercarriage of the car, hence the name “chassis embedded battery”. The energy density in today's Li-ion batteries where the cells are packaged individually amounts to only 40-60 percent compared to the density at cell level. EMBATT technology can double the ratio of storage material to battery volume. Furthermore, energy-sapping electric resistivity which occurs at the connectors of scaled-down cells can be reduced drastically. (Sigler, 2017)

5.3.6 Bosch Engineering GmbH

It is a wholly owned subsidiary of Robert Bosch GmbH headquartered in Abstatt, Germany and a globally acting development service provider for the automotive industry. The company employs 1,950 associates worldwide and develops electronics systems for automotive and non-automotive applications. The engineering services comprehend the development as well as the electrical and electronic integration of software, functions and systems in matters of powertrains, driving dynamics and safety, among many others. Apart from that one of the company's core competencies is overall vehicle development. In the powertrain segment the company develops conventional combustion engines, engines that run on alternative fuels, hybrid and electric drives. (Automotive World Ltd., 2018)

With respect to batteries, Bosch had hoped to shake up the market with a novel solid-state Li-ion battery developed by the U.S. startup Seeo that Bosch bought in 2015. However, in the first half of 2018 Bosch put the company up for sale and abandoned their in-house EV battery manufacturing. Bosch also withdrew from a joint venture called Lithium Energy and Power GmbH & Co KG (LEAP), a Li-ion battery research institution that received investments in the amount of $616 million. This certainly doesn't mean that Bosch is leaving the battery segment altogether. According to a statement by the Bosch head of mobility solutions, the company doesn't need to produce the cells themselves to be an integral part in electric mobility. (Deign, 2018)

5.3.7 Kreisel Electric GmbH & Co KG

Kreisel is a young high-tech company from Austria that is known for its innovative battery technology which was showcased a couple of times by retrofitting former ICE powered vehicles (amongst them a classic Porsche 910) with their technology. Their product properties are characterized by a high gravimetric density, compact construction, fast charging, innovative thermal management and an elevated level of safety due to liquid cooling. The firm also develops power trains and cooperates with fleet operators, manufacturers as well as transport and taxi companies. To satisfy the growing global demand Kreisel have built their first large-scale battery production factory in Rainbach, Austria. Beyond that battery packs will be also produced under licence at numerous other locations by affiliates. (Kreisel Electric GmbH & Co KG, 2016) The Rainbach location comprises a prototype workshop and a completely automated production line for the battery storage devices on well-nigh 7,000m^2 of space. It is worth mentioning that this new building runs on power generated by itself. A photovoltaic plant in combination with a battery storage device and a hot water tank measuring 17,000 litres as well as waste pumps help to come up with the required energy. According to their website Kreisel's battery pack is the lightest (less than 4.1kg/kWh) and most efficient on the market with a power density of 1.95dm^2/kWh. This allows an increase of the range of EVs by up to 65 % compared to traditional battery solutions by different producers. (Kreisel GmbH & Co KG, 2017) In September 2018 the company came up with another world innovation, an automated 2-speed transmission for EV applications, ready for production. The system has been applied in an electric sports car which accelerates from 0 to 100km/h in approximately 2.5 seconds with a maximum speed of above 300km/h. (Kreisel GmbH & Co KG, 2018)

6 Methodology – Empirical Data Collection

6.1 The Interview Guide

For the expert interview a semi-structured approach has been chosen which allows the interviewees to answer the questions in an unconstrained way, making mention of everything that comes to their mind. It therefore combines a pre-determined set of open questions with the potentiality to explore certain responses further. Those questions were separated into distinct categories as to prepare fluent interviews. Nevertheless, the order of questions was not strictly followed during the interview. It was often the case that interviewees brought up topics that were planned for a later part of the interview at the beginning, so it made sense to engross the thoughts regarding that certain topic by this point. Therefore, the interview guide was rather used as a tool to facilitate orientation during the questioning and to ensure that all aspects of the research are covered (Patton, 2002).

6.2 Conducting the Interviews

For the purpose of this thesis, four experts from different companies have been interviewed. Different channels were used to approach the target subjects. Some have been in the author's network while others have been contacted with the help of the internet, for instance using the professional networking service *LinkedIn*. One interviewee has also been recommended by another interviewee. Target subjects of the data collection are decision makers with insight into strategic and/or technological decisions (e.g. strategic management, business unit manager, C-level executives) with regard to battery technology and electric mobility respectively. It was desired to cover a broad range of different point of views, that is to say not only the OEM's perspective but also the aspect of the supplier, the ESP and the start-up company. All interviews have been conducted in German and were voice recorded. The interviewees were promised anonymity and approved the recording of the interview. Three interviews took place at the interviewees' workplace, one has been conducted over the phone. Furthermore, each interview took between 35 and 70 minutes.

6.3 Analysis

After conducting the interviews, they were transcribed and anonymized to manipulate them for subsequent analysis. The qualitative content analysis by Mayring was found to be a suitable method for this analysis. The method and how it was applied will be specified in the following.

6.3.1 Qualitative Content Analysis

The fundamental idea of the qualitative content analysis is the systematic and progressive approach to text analysis that ensures objectivity and confirmability. The category system is in the centre of the analysis and allows the systematic reduction of the data material into content analytical units. The found categories are carefully revised within the process of analysis (feedback loops). (Mayring, 2010) It seems to be a useful method because it tries to build on the strengths of the quantitative content analysis and "widen them to a concept of qualitative procedure" (Mayring 2000).

For the data analysis the open access web application *QCAmap* was used to evaluate the transcripts. The approach that was used to analyse the data can be taken from Figure 13 below and will now be explained shortly:

The first step in conducting qualitative content analysis is to define the source material, that is to say who was interviewed, how were the representatives chosen, what were the basic conditions of the interviews and how was the text generated as it was done in 6.2 (Conducting the Interviews). Additionally, the intention of the analysis as well as the underlying research question must be thoroughly explained. The research question as well as the theoretical background have been elaborated in the theoretical part of the study and were then integrated in the coding agenda. This coding agenda has the purpose to help differentiate the categories from each other and supports the categories with examples to ensure a consistent and reasonable analysis. (Mayring, 2003)

In a next step the selection criterion must be defined that sets limits to the text passages that will be categorised and beyond that provides a reference on how much in depth the interview has to go. Furthermore, the level of abstraction is determined that defines "how specific or general the categories have to be formulated" (Mayring, 2014, p.82). The coding unit has been specified to be meaningful phrases which means that neither single words nor full sentences need to be encoded. The complete interview has been defined as the context unit. The accruing system of categories refers to all analysed interviews. In step 3 the transcribed material is waded through, searching for suitable pieces of text with respect to the category definition. Based on the level of abstraction, categories are then formed. After a certain amount of material has been encoded, the established system of categories was revised to verify whether modifications of said categories need to be done (Step 4). In a subsequent step the single categories were summed up in main categories.

The category definition used for the analysis was specified to be the following: "Any indication of changes in the way value is created in the course of technological changes."

The level of abstraction was determined as: "concretely describable changes in value creation for the company in question."

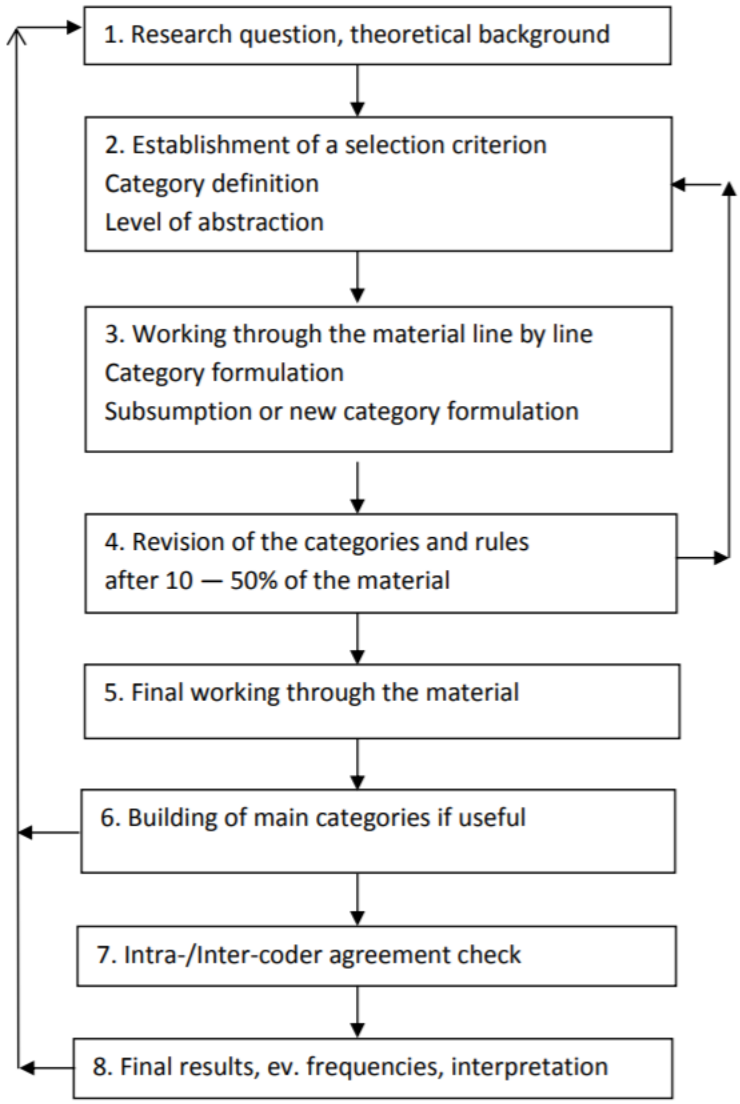

Figure 13: Process Model of Inductive Category Formation (Mayring, 2014)

6.3.1.1 Discussion of the Method

Qualitative content analysis is a useful method for this thesis as it allows the consideration of the context in which the material was created while at the same time considering the theoretical background of the research. The coding process is done by using a structured category system which allows to reconstruct the course of action of the analysis. Hence, the analysis' reliability as well as the comparability of the results becomes substantiated. (Mayring, 2012) To guarantee higher reliability, multiple researchers would be required for coding. This was the case with this thesis as the supervisors counterchecked and gave valuable inputs during the whole coding process.

An essential output of the qualitative analysis is a hierarchical data structure commonly in the shape of a horizontal tree-shaped form. To obtain this the author first paraphrased informative and useful sentences from the interviews and then grouped these into "first order" concepts according to the “Gioia method” (Gioia et al., 2012). This method allows to simplify the results in a structured and logical way without compromising the data’s validity. This was followed by the search for connections between first-order concepts via "axial coding" which then led to "second order" themes located at an advanced level of abstraction. By further comparing the data a limited number of "core categories" or "aggregated dimensions" were disclosed with the purpose of summarizing the elements of an accruing theoretical model. (Langley et al, 2011) It is noteworthy that during the data analysis some of the categories had to be changed or merged, e.g. due to their interrelation. Besides, the findings relocated the focus of the study and augmented the scope by a Business Ecosystem (BE) point of view.

For a better understanding of the procedure an excerpt of the first order deductions (to the left) and the aggregated dimensions (to the right) is visualized in Figure 14 on the following page. Due to reasons of data protection only the last two derivatives are shown in this thesis. This means that, due to the mutually determined General Data Protection Regulation between the researcher and the interviewees, the whole structure can’t be shown in this study as it might allow conclusions to be drawn regarding the respective company’s identity. However, in the data analysis individual paraphrases will be shown for the sake of gaining insights. Information on the selected interview partners can be taken from Table 3 below.

Table 3: Outline of the Interviews

Nr.	Position	Duration of the Interview	Date
1	Group Product Manager	68:13 min	15.01.2019
2	Director Product Engineering	39:18 min	19.02.2019
3	Vice President	56:11 min	31.01.2019
4	Head of Mechanical & Electrical Engineering	65:12 min	01.02.2019

technologies to increase value for a company's customers customization of technologies to increase value for customers successful BMI as a response to new technologies is a matter of clear corporate structure restructurings in the company due to shifts in technologies can be facilitated by a trial and error mindset develop next generation technologies and products in parallel to fulfilling customer requests understand the customer's degree of outsourcing and their impact on the BM	**Technology and Business Model Innovation**
Customization of technologies to increase value for customer access to technologies through collaboration in the BE access to customer's wishes by collaborations in the BE technologies to increase value for a company's customer	**Technology and Business Ecosystem activities**
balancing potential customer pains and gains offered by technology role of right time-to-market for technology in BE role of systems-level approach for technology in BE	**Challenges for technological developments in Business Ecosystem**
role of communication in a BE for delivered value between actors anticipating future customer needs is a key for business success	**Communication between Business Ecosystem actors**
business Model Innovation in the Business Ecosystem to address customer's needs	**Business Model Innovation in Business Ecosystem**
outsourcing of non-essential company-activities into the BE	**Utilisation of Business Ecosystem resources**

Figure 14: Second Order Deduction and Aggregated Dimension

7 Results

This section outlines the challenges that the regarded companies have to face concerning BMI due to the introduction of new technologies. The found inductive categories and accordingly aggregated values derived from the qualitative content analysis as well as their frequentness can be taken from the list below:

- Challenges for technological developments in the Business Ecosystem 7
- Business Model Innovation in the Business Ecosystem 2
- Communication between Business Ecosystem actors 6
- Technology and Business Ecosystem activities 11
- Technology and Business Model Innovation 13
- Utilisation of Business Ecosystem resources 3

7.1 Challenges for Technological Developments in the Business Ecosystem

A comparatively high number of statements made in the interviews, 7 in total, could be summarized within the category "Challenges for technological developments in the Business Ecosystem". The analysis emphasized for example that there are uncertainties with the implementation of new technologies, especially when there is no clear "winner" emerging over the preceding technology, in this case the ICE with its attendant conventional powertrain.

As one Interview partner fittingly put it:

> *[...] the customers don't want to settle [on a specific technology] and we are therefore forced to offer more flexible solutions. It's not the case that it was our idea, we rather see that the customers don't want to make a commitment, they don't want to invest large amounts of money in something where they don't know if it will have a long-term future and that's why we are under compulsion to offer innovative, new business models to relieve them of the investment risk. There is just a huge investment risk in the air for them, but also, we partially see this in the provision of services, that the OEMs don't know whether they should develop a BEV, more hybrids, what is the most appropriate concept that they should develop?*

Another aspect mentioned by interview partner 1 was the increasing importance of time-to-market which today outplays technological leadership and quality and therefore involves substantial implications on the BMs as well. Hence, being late with commercial launches erodes the potential market (Rowe, 2010). The corresponding paraphrase can be found in Table 4 below. Lastly, because near-term changes in legislation strongly impact the automotive industry some suppliers embark on a strategy where they try to keep the risk low by offering multipurpose products that are not confined to a specific powertrain.

Table 4 below shows the most important argumentations concerning this aggregated dimension stated by the respective interviewees distinguished by the numbers to the left.

Table 4: Challenges for technological developments in the Business Ecosystem

Interview partner	Paraphrase
1	*Time-to-market has become one of the key factors in the current marketplace and significantly changed the BM; technological leadership and quality do not suffice in order to be competitive anymore.*
2	*As the technology shift strongly depends on legislation which is often subject to short notice change, suppliers try to pursue a strategy where they keep the risk for the product mix low e.g. continue offering conventional products which can be used in multiple powertrains.*
2	*There is a trend towards diversification of the portfolio, to gain a broader positioning with respect to technological solutions. The customers don't want to commit themselves yet [to a certain technology] due to a wide spectrum of problems. Hence customers demand flexible BMs.*
4	*Efficiency is a crucial factor to quickly go from a concept to a design and realisation.*

7.2 Business Model Innovation in the Business Ecosystem

The second category sheds light on the BM ecosystem and the innovation of BMs among the actors. One respondent argued that BMI in the BE is necessary to address customer's needs. Customers in the BE demand the offering of a wide spectrum of technologies that can only be accomplished by flexible BMs. Furthermore, there is a big transition in the sales channels and the development of customer relations such as the utilisation of new cloud or pay-per-use solutions as a tool to reach customers. Table 5 depicts this statement in a paraphrase mentioned by interview partner 1.

Table 5: Business Model Innovation in the Business Ecosystem

Interview partner	Paraphrase
1	*Momentous change in the channels of distribution and establishment of customer relations; e.g. use of new cloud technologies as a tool to reach customers.*

7.3 Communication between Business Ecosystem actors

This category gives a résumé on the role of communication in the Business Ecosystem for a delivered value between the actors. A key fact that was mentioned was the big change in the customer environment where classic OEMs and suppliers are today augmented by a wide range of new entries that require a totally different approach, which have a different set of expectations and which act more agile in their decision-making process. This different set of expectations is reflected in changes in the communication and in sales and postulates a distinction in customer types which hitherto wasn't necessary. However, one can only speculate on how that different approach may look like or how the different set of expectations manifests itself as the respondent didn't go into more detail regarding these statements.

Furthermore, the same interviewee emphasized the importance of the ability to draw the right conclusions from customer discussions in order to transform those into a product or derive a sales strategy. This becomes increasingly important as the time-to-market is playing an ever more important role and, according to interviewee 3, one cannot afford to wait until the customer approaches with the specification sheet as this would be far too late.

To anticipate the customer's requirements requires a willingness to help and requires effective communication skills to deal with the customer's needs. Another important mention was to constantly assess who the present customers are, what they get delivered at the moment and what product mix do the customers want in the future and to develop this product mix in a timely manner. Table 6 below summarizes the most important statements regarding the communication in the Business Ecosystem.

Table 6: Communication between Business Ecosystem actors

Interview partner	Paraphrase
1	*Big changes in the customer environment with a vast sphere of new entries that have an outright different approach and therefore need to be served in another way, starting with sales and communication; A differentiation in client types becomes necessary as new entries are more agile and have different expectations.*
2	*Launch of a division dedicated to the analysis of future customer expectations and demands with various time horizons.*
2	*Understand the product mix that customers want to have in the future to develop the right products in a timely manner; e.g. management meetings to understand who our present customers are, what we deliver to them at the moment and what the substitute technology will be.*

3	*Important is the awareness-raising for the customers that the product is already technologically and regulatory feasible today, not somewhere in the far future.*
3	*Determine the trajectory of a certain technology on the basis of shifts in the cell supplier and customer situation to react accordingly and stay ahead of the competition.*

7.4 Technology and Business Ecosystem activities

This aggregated dimension summarizes all impacts of technology on activities in the Business Ecosystem. The general tone in the responses regarding this category is that being on one's own is not possible anymore in today's automotive industry. This also reflects the findings in Chapter 3.5 where a big shift in recent years became noticeable from the once pursued closed innovation strategy to an increased blurring of boundaries between an automotive company and its environment. The direction of the industry is heading strongly for partnerships, alliances, cooperation and open innovation to advance their technologies and gain insights on other new technologies.

This can for example be backed by the following statement from interviewee 1:

[...] we see that this is not possible with the new technologies, all of a sudden one now has to go outside and collect innovations and ... this sudden width can't be covered internally anymore.

It is noteworthy that according to one of the respondents a partner in that sense is preferred to be someone that not only offers e.g. manufacturing expertise but rather contributes proactively by giving creative inputs and drives cost-down measures himself. Table 7 at the bottom summarizes the most notable paraphrases.

Table 7: Technology and Business Ecosystem activities

Interview partner	Paraphrase
1	*The focus of companies has shifted from mere suppliers to partners; As engineers who previously developed the classical powertrain are now forced to work in a different field of operation companies are looking for someone to guide them in the transition to new technologies (e.g. Electrification Trend) and to exchange views with.*
1	*Diversification and distribution of risks through alliance-building and Joint Research projects not only with one OEM but rather with multiple companies*

	to decrease the risk and to cut back on investment spending, because OEMs are not able to handle everything on their own;
1	*As the company looks to advance their technologies they are today increasingly reliant on external ideas and innovations due to the sudden arising width in technologies.*
2	*Technologies are accessed through a variety of collaborations with universities.*
3	*Sustain co-development partnerships with business partners who are considerably smaller than our own company to help them grasp the whole electrification topic and learn to translate helpful processes of bigger companies into our own entity. Those bigger companies vice versa watch out for our mode of operation where you have to pay attention what to relinquish to not lose a partner.*
4	*Partners of choice are those who not only have manufacturing expertise but rather companies who contribute proactively to cost-down measures and give creative inputs.*
4	*Build alliances to get access to know-how that is difficult or undesired to have in-house.*

7.5 Technology and Business Model Innovation

The penultimate category deals with the impetus of technology for Business Model Innovation. One aspect that changed the way especially ESPs do business is that they begin to offer and actively promote tailored and adapted product features that are not yet available as Joint Research activities with an exclusive right of use for the customer. Another interviewee argued that successful BMI as a response to new technologies is a matter of a clear corporate structure and facilitates the implementation of new technologies into the right departments. One respondent stated that suppliers who are serving highly competitive markets with manufactures which are progressively turning into "me-too" products try to manoeuvre themselves into another segment and avoid being commoditised by adding sophisticated electronics and greater functionality to stay ahead of the technology curve. This on the other hand correlates with a shift in workforce demands from mechanical engineering to electronic, mechatronic and software engineers as stated by interviewee 2.

One often overlooked aspect of electrification is the indirect correlation to autonomous driving which completely overthrows current BMs with concepts such as Carsharing or People movers. One interviewee explained that their BMs adapt depending upon the fields that the customer requests come from but that the basic structure of it is maintained. The same person stated that they on the one hand use technology screening to understand what the competition and the customers go for. Furthermore, how normative framework conditions and legislation are changing. On the other hand, this interviewee emphasized the importance of additionally using macroeconomic analysis to grasp how the markets are connecting, how BMs are transferring to augment the drawn conclusions. The respondent stated the whole topic of blurring that goes on between individual mobility with the supply of energy and interconnected energy systems. Furthermore, there is an influence on the BM whether the customer strives for its own development capabilities or wants to fully outsource the development and one has to constantly ascertain whether that corresponds to the company's strategy.

Lastly, successful BMI as a response to new technologies can be supported by the right conditions in which creativity and free thinking can flourish freely. The aforementioned trend towards open innovation and alliance-building is also represented in the selection of statements in Table 8 below.

Table 8: Technology and Business Model Innovation

Interview partner	Paraphrase
1	*Actively promoting software features as joint research activities that are not available yet with a promised exploitation right for the customer.*
1	*In light of constantly changing market demands customers are reluctant to settle on a specific technology without knowing if it will have a long-term future; Therefore, BMs are requested that reduce the investment risk of the customers.*
2	*Electrification also correlates indirectly with autonomous driving which completely changes the BMs of our customers, e.g. car-sharing concepts.*
3	*Restructuring in the organisation is tricky when you don't know the significant value of a certain technology for the company yet; a simple structure makes it easy to implement new technologies into the departments.*
4	*On the one hand the offering of a standard [battery] module and the reaction to customer requests, on the other hand the proprietary development of the median of customer enquiries.*
4	*The company needs to facilitate innovation and free thinking through own projects and a trial-and-error culture to improve the system.*

7.6 Utilisation of Business Ecosystem resources

The final category "Utilisation of Business Ecosystem resources" sums up all mentions where the interviewed companies resort to the Business Ecosystem resources. During the course of this qualitative study only three statements fell into this category. The main message of the first statement is that non-essential company-activities shall be outsourced into the Business Ecosystem. For this purpose, the respective company must first elaborate its core competences that make it beneficial for the customers (Table 9). The second respondent argued on the basis of a battery pack that they rely on tried and tested standard components as well as manufacturing expertise from the BE. This means that the venture buys the battery cells and standard components such as plugs off-the-shelf to develop and manufacture the battery packs in their own right. Furthermore, in vehicle propulsion systems the integration topic was underlined to be the core competence in the venture which is why they do not develop power electronics or electric motors themselves and rather focus on the interplay of the components.

Table 9: Utilisation of Business Ecosystem resources

Interview partner	Paraphrase
2	*Changes in technology require an analysis on the core competences of a company that make them a valuable partner for the customers to not outsource the potential for differentiation.*
3	*This depends on the department, the measurement instrumentation for example buys power electronics etc. from external partners; in engine development for instance you need cast metal housing where it's very beneficial to have a good partner that is proficient in this area, that offers the latest production techniques; since we also manufacture prototypes in-house we need partners to assist the process, from which we can learn new production processes;*
4	*Products are obtained globally, e.g. the battery cell through collaboration with various cell suppliers, from small ones at the local level to global ones which provides a good overview on who offers what quality; Besides, the whole scope of outsourced items, ranging from standard components such as plugs and electronics to drawing parts where providers of various manufacturing technologies, depending on the customer requirements, are in demand; Lastly, the integration topic of vehicle propulsion systems where validated components are bought in addition such as power electronics and electric motors, where it is more important to know how to link them in the most optimal way.*

7.7 Initiatives Towards Technologies

The following initiatives that firms undertake towards innovations in technology have been found in the course of the qualitative study and are summarized below, subclassified into the three groups identified in Chapter 5.

7.7.1 Engineering Service Provider

One major strategy mentioned by the ESP was the concept of diversification. As there is no clear "winner" in the energy storage solution race yet, the company diversifies products, processes and BMs to gain a broader positioning and approach the current uncertainty. The diversification in BMs manifests itself for example in the offering of flexible BMs such as a token-based licensing approach on the software side as mentioned by interviewee 1.

Another new approach is the differentiation in client types that, according to the respondent, has become inevitable as new entries move into the market which have different expectations and hence need to be served differently. An important topic that was addressed in this context was the importance of positioning and showcasing the company's capabilities with respect to new technologies to get noticed.

When it comes to management interview data suggests putting someone in charge of new technology departments with a venturesome personality, someone that lets the people grow and research. In addition, the access to technologies through a variety of collaborations with universities was named which was also seen as a source of future employees.

Lastly, the importance of cooperation for example via joint research projects with multiple companies concurrently was mentioned to distribute risks and to streamline operations. Particular emphasis was placed on the collaboration with battery cell manufacturers to gain insights on newest technologies.

7.7.2 Supplier

The consulted supplier spoke about the significance of divisions that analyse future customer expectations and demands. Beyond that it is important to understand how OEMs are going to accomplish the CO_2 goals via management meetings, as the respondent pointed out. To create incentives for the customer an attempt is being made to combine CO_2 targets with an added value. This added value is often the perpetuation of the character of the respective OEM that they want to retain, e.g. driving pleasure and dynamics in the case of BMW. Moreover, it is necessary to find the company's core competences to understand what makes the company valuable for the customers.

Another initiative that was mentioned was the cooperation with partners which have the same or a higher level of knowledge on a certain topic. The interviewee stressed the importance of finding partners which do not only have manufacturing expertise but rather contribute proactively and give self-contained creative inputs.

A further relevant predication whose importance was emphasized by two interviewees was to build up system understanding and application know-how instead of simply serving the customer's specification sheet. This was further substantiated by the statement that if one doesn't know what makes an OEM tick one must wait for the product concept catalogue. The interviewee also mentioned that suppliers who struggle to be commoditised try to resist by adding sophisticated electronics and greater functionality to make their products more intelligent which puts them in another segment.

On a final note the respondent underlined the momentousness of covering related technologies as well such as autonomous driving and artificial intelligence in the case of electrification.

7.7.3 Engineering Service Provider Start-up

This interviewee emphasized the importance of technology screenings augmented by a macroeconomic point of view which helps to gain a deeper understanding of how the markets are connecting. It is beyond that of avail to regularly check whether the customer strives for its own development capabilities or plans to fully outsource the development and ascertain whether that corresponds to the own strategy. One can determine the trajectory of a certain technology by observing the change in suppliers of your own customers. The BM reportedly consists of three main pillars, the first one being the customer-specific development where the company builds upon its basic modules and arranges them for a specific application. It ranges from the concept phase through the test phase to the optimisation for series production, where smaller quantities can be produced directly in the company itself and larger quantities at the customer's facilities. In the second pillar the venture tries to generate own products which originated from previous projects. The third way the regarded company creates value is to contract out licenses for other companies to make use of the technology themselves.

Furthermore, the interviewed person brought forward the argument that awareness raising among the customers is necessary, to show that the product is already technologically and regulatory feasible today. Above all, it was noted that this individual company helps smaller business partners to develop and grow bigger, as competition is a healthy part of any industry, boosting innovation and offering the possibility to learn from one another. On the other hand, this venture also learns to translate helpful processes of bigger companies into the own business.

To facilitate innovation and free thinking in the company a "trial-and-error culture" is established and maintained that includes risk taking and continuous learning. Regarding the BM the respondent revealed that the company maintains a basic core structure but lets the BM adapt upon the fields of customer requests. Furthermore, said venture serves on the one hand regular customer requests while doing proprietary development and research on the other.

7.8 Influence on the Value Creation

This subchapter tries to assess the influence of the initiatives identified in subchapter 7.7 on the value creation aspects of investigated firms and summarizes the most important points.

Value creation opportunities in the examined companies resulted from an innovative configuration of physical products and services, the integration of resources as well as the relationships among actors of the business ecosystem. For example, the regarded ESP offers tailored and adapted software features as part of Joint Research activities to increase value for its customers. The same ESP creates new value by acting as an intermediary, establishing the link between the battery cell manufacturer who knows their cell but has no knowledge of automotive requirements and the OEM with whom it is exactly the opposite. All of this of course in exchange for valuable insights in the newest technologies.

It has also been shown by the qualitative study that one company creates value with new technologies by contracting out licenses for other companies to make use of their technology. One important aspect of value creation mentioned by another respondent was the combination of CO_2 targets with an added value.

It was mentioned at least once by every interviewee, that the anticipation of customer wishes is essential to stay ahead of the competition, especially as time has become a critical factor in today's industry. As the ESP put this exigence to always be a few years ahead of the customer: By having the solution ready when the customer asks for it one can ensure to yield the return necessary to come up for the high development costs.

According to interviewee 2, a great deal of interest is also focused on related topics to electrification, for example autonomous driving and car-sharing concepts as they have the potential to significantly disrupt the customer's BMs, to be proficient in that topic as well.

8 Discussion of Results

This chapter has the purpose to interpret the results and contrast them with the theoretical background laid out in Chapter 3.

One big issue that was often mentioned by the respondents were the uncertainties related to the implementation of new technologies. This comes as no surprise though, as technological change is always characterized by a high degree of uncertainty (Rosenberg, 2009). Of peculiar interest in this matter would be to understand the essential characteristics of aforesaid uncertainties and the approach to overcome the immanent obstacles, which proves to be a difficult undertaking. According to Kline & Rosenberg the degree of uncertainty in innovation processes strongly correlates with the rate of technological change. (Kline & Rosenberg, 1986) The rate and direction of technical change is only partially influenceable by the automotive industry itself. They can try to overcome consumer resistance to innovation by technology enhancements and by disclosing relative advantages of their technology over the prevailing one, but EV adoption also depends greatly on external factors such as tight emission regulations, rising fuel prices and financial incentives (Nie et al., 2016). For every plug-in electric car on the road there were still 250 ICE vehicles by the end of 2018, a ratio that translates into 0.4 % of all passenger vehicles on the world's roads (Coren, 2019). Therefore, actual progress on the markets may still take some time to emerge. The above-mentioned uncertainty derived from the interviews indicates a trend towards diversification on the supplier- and ESP-side which manifests itself in the development of flexible BMs and capabilities.

As stated in the theoretical part in Chapter 3.2 there are two views on how companies generally deal with imminent critical changes in the business environment where they either respond by making substantial changes to their BM or become strategically myopic and stick to practiced decisions. The qualitative interview data suggests that all regarded companies came up with a rather ambidextrous approach as a response to the impending critical changes in the industry. While not losing sight of today's business the considered companies showed initiatives to make their businesses more flexible and adaptable to cope with tomorrow's changing market requirements. However, it became evident from the vehicle sales shown in the theoretical part (Chapter 5.1) that most OEMs contrariwise try to exhaust the amenities of their traditional BMs with the selling and servicing of conventional ICEs for as long as possible while postponing the commitment to alternative propulsion methods. This is substantiated by a lack of advertisement, very limited choice of EVs and long waiting times to get these cars. Furthermore, carmakers are still not able to keep up with their own sales targets for BEV and PHEV in Europe due to the aforementioned reasons. (European Federation for Transport and Environment AISBL, 2018) In agreement with Niewenhuis & Wells (2003) the aftermarket, especially post-sales maintenance is an important revenue stream and can often be more lucrative than new car sales. As EVs require less maintenance (due to the simplicity of the electric motor) new BMs will be required in this sector for OEMs to strengthen their position in the aftermarket. As current car dealership BMs don't add up for EVs they rather act as an inhibitor on EV sales. However, with epiphenomenona such as connected vehicles and digitization there also arise new opportunities to explore like remote diagnosing, battery swapping, leasing, renting etc.

The high number of references regarding the impact of technology on both BMI and BE activities is particularly striking. This was reflected by the imperative to increase customer value and to address their specific exigencies. This coincides with the literature in so far that BMI has become even more important to a company's success than service or product innovation (Schallmo & Brecht, 2010; Snihur & Zott, 2013). One interviewee stated that BMI occurs in their organisation naturally by finding gaps in the market and consequentially developing a new company direction.

Furthermore, innovative distribution practices are introduced in an effort to make them more flexible and responsive. One example that was mentioned by one of the interviewees was that of cloud technologies as a tool to reach customers. This reflects the opinion of Oliver Wyman (2018), a management consulting company which sees the digitization of processes play a major role in the automotive industry together with changes in customer structure and new distribution channels such as pay-per-use concepts which was mentioned by interviewee 1 to an extent with the token-based licensing approach.

The interviewees also indicated the increasing importance of collaboration and alliance-building as a response to new technologies. Along with other problems that have been mentioned it boils down to the fact that companies are unable to deal with the increasing range of ever-changing technologies on their own anymore. Arguments in favour of the increasing willingness to build partnerships were the distribution of risks, the diversification and the access to technologies from actors within the Business Ecosystem. This finding largely tallies with the literature where automotive manufacturers seek for expertise by joint-venture for vertical integration as stated by Ward (2017). The increasing awareness among automotive companies that they are going to need help conquering the radical changes of the next decade also coincides with Lee (2016) who disclosed the high number of joint forces between tech-companies and automotive firms in 2016 alone. This seems reasonable given the fact that no automobile manufacturer is big enough on their own to get to grips with the market power of digital companies such as Google or Facebook as it is argued by Vieser (2017). Moreover, it could be seen from the interview data that the concept of open innovation (see also Chapter 3.5) has become an integral part in all the contemplated businesses.

However, as Lang & Lindemann (2015, p.1) point out, "a major obstacle for making the Open Innovation Information (OII) collected into products is the integration of the OII into the company [itself]". This change in the approach also implicates innovation of the BM due to its central role in converting R&D into commercial value, hence determining what companies allow to go outside the firm and what to bring inside. Interview data suggests that there is a challenge of weighing up what information to divulge and what to keep to oneself as a company has to be interesting for potential partners on the one hand but must not give away too much critical information on the other.

Conforming to Frigant (2011), automotive companies are increasingly making use of their core competencies, designing vehicles and selling mobility solutions, while outsourcing other activities. This development was also supported by interviewee 2. However, it is to assume that with the increasing level of partnership instead of a hitherto mere vendor-relationship as stated in some predications the number of outsourcing activities may increase overall.

The noticeable trend towards delegating greater responsibilities to the suppliers (Legner et al, 2009) that has been outlined in the theoretical part has also been discussed by interviewee 2 who mentioned the favouritism of proactive partner companies which do not only offer manufacturing expertise but also bring in new ideas and drive cost-down measures.

As mentioned in Chapter 7.5 the urge of some suppliers to add electronics to their products correlates with a shift in workforce demands to electronics, mechatronics and software. Together with the increasing automation in production, the expected expansion of OEMs to the provision of "mobility services" as well as the consequent workforce depletion of blue-collar workers predicted by Deloitte (2017) could provide a vague direction of the employment outlook in the automotive industry.

Especially in the electrification topic, interviewee 1 mentioned that up until now its customers didn't demand detailed vertical solutions (that the company already had available) but rather required a mere superficial view on the subject due to the wide variety of problems such as the lack of awareness, information and knowledge pertaining to new EVs and all that that entails. He concluded that this superficial view is now slowly changing to a new phase where customers show deeper interest in the matter. Until now however, there was no use in coming up with more sophisticated solutions. This hesitation can be supported by findings in the literature where the battery is seen as the single most important factor and the main obstacle for a large-scale introduction of electric powertrains as indicated in Chapter 4.3.

One important problem that crystallized from the interviews, that was also touched upon in the theoretical part, were the challenges that come with EVs and the vehicle design (Klug, 2013). Although an EV may look similar than an ICE from the outside, there are major technical differences on the inside, especially if the body platform is purpose-built for an electric automobile. EVs are fundamentally disparate, from the engine to the powertrain and software. This may be the reason why it is so hard for companies with an ICE background, ICE engineers and ICE tools to build EVs, as stated by some of the interviewees. On that score many incumbent automakers try to half-heartedly step up their game by launching what they call "electrified vehicles", which does not mean that those automotive companies are going to phase out ICEs in the near future, quite the contrary. Most electrified vehicles are de facto combustion motors with their inherent carbon emissions which is elusive for sales statistics and potential customers as they still pollute the air we breathe. A lot of the proclaimed commitment of OEMs towards “electrification” of the car fleet in fact means the incorporation of hybrid features into combustion vehicles. Although this might be a step towards the right direction it’s still far afield from a pure electric vehicle.

Lastly, one respondent argued that for them as an ESP the introduction of new technologies is not a risk, but rather a potential. Since ESPs usually do not invest in for instance a new transmission type but rather develop the technology behind it they are unaffected by the number of transmissions that will be sold because they’ll need the expertise anyway. In the case of the current tipping point regarding the alternative energy storage solutions in automotive applications the observed company tries to cover all foreseeable alternatives to the ICE. Whatever technology will take hold in the end is irrelevant as it solely moves the capacities within the organisation. This looks rather different for suppliers and carmakers as they have to speculate on a certain technology with dedicated production equipment, supplier contracts etc.

Pertaining to BMI, two interviewees indicated the importance of a trial-and-error culture to facilitate innovation in the company, a viewpoint that is also reflected in the literature where trial-and-error learning is seen as an important aspect of BMI (Sosna et al., 2010).

To answer the research question or rather how the value creation aspect of BMs in the automotive supply chain has changed due to upcoming ESS one has to keep in mind that for EVs a plurality of value is created in the battery (Ward, 2017). Up until now OEM's core competences did not lie in battery production but rather in a technical setting centred around ICEs. Consequently, carmakers are increasingly confronted with the question how much vertical integration they should carry out to ensure that a sufficient share of value is created in-house and to confine the possible influence gain of the suppliers over the OEMs. On the other hand, OEMs are progressively relying on the collaboration with suppliers in their technological innovation processes as part of the open innovation approach.

As suggested in some studies perchance automobility has reached its climax in mature industrial countries and car ownership will decline in the following years (Wells, 2015). However, with new trends such as electrification, digitization and big data on the horizon value can be obtained by disruptive BMs, using service-based approaches such as mobility on demand or grid integration solutions. New value creation possibilities may also arise out of collaborations with tech companies as well as financing or leasing services.

When it comes to the suppliers only those can expect to grow that will come up with new innovations, technological improvements and necessary cost reductions. Those that rely on highly commoditized products have to continuously work to bring the costs below those of competitors or try to move into another business segment by upgrading their products. Others are focusing the product offering or are working more closely with OEMs to tackle their needs and make themselves an invaluable supplier (Schiele, 2012). To meet this demand for innovation for their part, suppliers are in need for new knowledge and talent, shifting from mechanical engineers to software and electric engineers.

9 Conclusio

The qualitative analysis of the four interviews indicated that the indecisiveness of actors in the Automotive Ecosystem postulates Business Model Innovation as a means to address the risk aversion of said actors. Furthermore, it has been demonstrated that the introduction of new technologies evoked an increasing importance of collaboration within the Business Ecosystem for the regarded companies, not only to distribute risks but also to diversify and get access to technologies from actors within that Ecosystem. In doing so automotive companies are also able to position themselves without making strong commitments. The uncertainties that have been mentioned by the respondents can be divided into three categories, namely regulatory, economic and technological uncertainties whereupon the latter may be the most impactful. Beyond that, the Time-to-Market has become a key factor with new technologies where good timing may even be better than a superior product. Interview data suggests that it doesn't matter how innovative your product is if you can't get it on the market before the competition does. Beyond that, it is noteworthy that a simple and clear organisational structure facilitates the implementation of new technologies by making it easy for innovation and new technologies to flow throughout the venture. One interviewee stressed the importance of anticipating unexpressed (future) customer needs rather than to wait for the customer to approach you with specific requests in order to gain business success. Furthermore, it is noticeable that companies increasingly distance themselves from the notion of a rigid BM and start to see the need for flexible and adaptive BMs as a means to prepare for irresolute customers and the uncertain future outlook of the industry. Hence, one could argue that there is also a positive side to the uncertainty in the current drive technology.

Most importantly, the qualitative study indicated that the main actors are only just in the middle of a profound transformation. The upheaval in the market triggered by the electrification trend set the ball rolling with shifts in BMs and changes in customer relationships as well as altered sales and distribution channels. It is evident that the automotive market which is currently affected by uncertainties and multidirectional efforts is on a turning point with prospective massive implications for the whole automotive sector. The initiatives outlaid in this study disclose a certain reservation in facing the technological changes by alternative energy storage systems such as the battery. It will be interesting to see how the automotive industry will respond to the imminent paradigm shift in propulsion technology. A possible pitfall, namely sacrificing long-term benefits for near-term wins may occur.

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AB Newswire, 2018: *Automotive Engineering Service Providers (ESP) Market 2018 Global Industry - Key Players, Size, Trends, Growth-Analysis to 2022*, http://www.abnewswire.com/pressreleases/automotive-engineering-service-providers-esp-market-2018-global-industry-key-players-size-trends-growth-analysis-to-2022_227308.html, accessed: 16/11/2018.

Abruña, H.D., Kiya, Y., Henderson, J.C., 2008: *Batteries and Electrochemical Capacitors*, in: Physics Today, Volume 61, Issue 12, pp. 43-47.

Altmann, P.; Li, J.; 2011: *The Novelty of Open Innovation*, https://www.diva-portal.org/smash/get/diva2:471149/FULLTEXT01.pdf, accessed: 20/12/2018.

Amirante, R., Cassone, E., Distaso, E., Tamburrano, P., 2017: *Overview on Recent Developments in Energy Storage: Mechanical, Electrochemical and Hydrogen Technologies*, in: Energy Conversion and Management, Volume 132, pp. 372-387.

Amit, R., Zott, C., 2012: *Creating Value Through Business Model Innovation*, MIT Sloan Management Review, Vol. 53, No. 3, pp 41 – 49.

Automotive World Ltd., 2018: *Bosch Engineering GmbH: Development Partner for the Automotive Industry*, https://www.automotiveworld.com/news-releases/bosch-engineering-gmbh-development-partner-automotive-industry/, accessed: 05/12/2018.

AVL, 2018a: *Company*, https://www.avl.com/company, accessed: 07/11/2018.

AVL, 2018b: *Press Release: AVL opened one of Europe's Most Advanced Battery Labs in Graz*, https://www.avl.com/press-releases-2018/-/asset_publisher/oDSd2AyrCZjG/content/avl-opened-one-of-europe-s-most-advanced-battery-labs-in-graz, accessed: 08/11/2018.

AVL, 2018c: *Fuel Cell Solutions for Engineering and Testing*, https://www.avl.com/fuel-cell-engineering1/-/asset_publisher/gYjUpY19vEA8/content/fuel-cell-solutions-for-engineering-and-testi-1?inheritRedirect=false&redirect=https%3A%2F%2Fwww.avl.com%3A443%2Ffuel-cell-engineering1%3Fp_p_id%3D101_INSTANCE_gYjUpY19vEA8%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-2%26p_p_col_count%3D1, accessed: 18/11/2018.

Bashir, M., Verma, R., 2017: *Why Business Model Innovation Is the New Competitive Advantage*, in: The IUP Journal of Business Strategy, Vol. 14(1), pp. 7-17.

Benchmark Mineral Intelligence, 2018: *Panasonic Reduces Tesla's Cobalt Consumption By 60% in 6 Years*, https://www.benchmarkminerals.com/panasonic-reduces-teslas-cobalt-consumption-by-60-in-6-years/, accessed: 20/12/2018.

Bertrandt, 2018b: *Intelligent Energy Management for Electric Cars*, in: Bertrandtmagazine, No.18, p. 6.

Bertrandt, 2018a: *Company*, https://www.bertrandt.com/en/company.html, accessed: 16/11/2018.

Blanco, S., 2018: *Renault-Nissan-Mitsubishi Continue EV Sales Leadership in Europe*, https://www.forbes.com/sites/sebastianblanco/2018/07/27/renault-nissan-mitsubishi-ev-sales-leadership-europe/#40dc11fc30e3, accessed: 29/09/2018.

Blöcker, A., 2016: *Branchenanalyse Entwicklungsdienstleister*, Working Paper Forschungsförderung, No.017, Hans-Böckler-Stiftung, Düsseldorf, https://www.boeckler.de/pdf/p_fofoe_WP_017_2016.pdf, accessed: 04/11/2018.

Bloomberg, 2018a: *Company Overview of Zotye Automobile Co., Ltd*, https://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=322404493, accessed: 22/09/2018.

Bloomberg, 2018b: *In Race for the Biggest EV Battery Plant, BYD Steals a March*, https://www.bloomberg.com/news/articles/2018-06-27/byd-builds-massive-car-battery-plant-to-boost-capacity-fourfold, accessed: 21/10/2018.

BMW Group, 2018: *BMW PLUG-IN HYBRID RANGE.*, https://www.bmw.co.uk/model-types/plug-in-hybrid/range, accessed: 04/10/2018.

Bogner, A., Menz, W., 2005: *Das theoriegenerierende Experteninterview. Erkenntnisinteresse, Wissensformen, Interaktion.*, in: A. Bogner, B. Littig, & W. Menz (Ed.), Das Experteninterview: Theorie, Methode, Anwendung (2nd Ed.). Wiesbaden, Verlag für Sozialwissenschaften.

Bohnsack, R., Pinkse, J., Kolk, A., 2014: *Business Models for Sustainable Technologies: Exploring Business Model Evolution in the Case of Electric Vehicles*, in: Research Policy, Volume, 43, issue 2, pp.284-300.

Breeze, P., 2018: *Power System Energy Storage Technologies*, 1. edition, Elsevier Science Publishing Co Inc, San Diego, pp. 23-31.

Burkert, A., 2018: *One Powertrain is Not Enough*, https://www.springerprofessional.de/en/drivetrain/emissions/one-powertrain-is-not-enough/15433066, accessed: 20/08/2018.

BYD Motors Inc., 2018: *BYD Info*, http://en.byd.com/usa/about/, accessed: 16/09/2018.

Campbell, P.,/Financial Times, 2018: *China's Geely Acquires 9.69% Stake in Daimler*, https://www.ft.com/content/0531f54c-18c1-11e8-9376-4a6390addb44, accessed: 16/09/2018.

Chatzivasileiadi, A., Ampatzi, E., Knight, I., 2013: *Characteristics of Electrical Energy Storage Technologies and Their Applications in Buildings*, in: Renewable and Sustainable Energy Reviews, Volume 25, pp. 814-830.

Chau, K. T., Li, W., 2014: *Overview of Electric Machines for Electric And Hybrid Vehicles*, in: International Journal of Vehicle Design, Vol. 64, No. 1, pp. 46-71.

Cheng, M., 2018: *Volkswagen Increases EV Battery Contracts to $48 Billion*, http://www.futurecar.com/2255/Volkswagen-Increases-EV-Battery-Contracts-to-$48-Billion, accessed: 18/08/2018.

Chery International, 2018: *Chery Brings an Array of Black Technology Products to Auto China 2018, Highlighting Intelligence and Globalization*, accessed: 22/09/2018.

Chesbrough, H., Rosenbloom R. S., 2002: *The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-Off Companies*, in: Industrial and Corporate Change, Volume 11, Number 3, pp. 529 – 555.

Chesbrough, H. W., 2003: *The Era of Open Innovation*, in: MIT Sloan Management Review, Volume 44, Issue 3, pp. 35-41.

Chesbrough, H., 2006: *Open Business Models: How to Thrive in the New Innovation Landscape*, 1. edition, Harvard Business Review Press, Boston, Massachusetts.

Chiam, S.L, Lim, H., Hafiz, S.M., Pandikumar, A., Ming, H.N., 2018: *Electrochemical Performance of Supercapacitor with Stacked Copper Foils Coated with Graphene Nanoplatelets*, in: Scientific Reports, Volume 8, Issue 1, pp. 10830.

Coren, M.J., 2019: *Automakers May Have Completely Overestimated How Many People Want Electric Cars*, https://qz.com/1533976/automakers-may-overproduce-14-million-electric-cars-by-2030/, accessed: 05/03/2019.

Cox, L., 2017: *Tesla Motors: Relentless Innovation as a Strategy*, https://disruptionhub.com/tesla-motors-disruption-strategy/, accessed: 29/09/2018.

Cox, L., 2018: *Manufacturers Race to Dominate the Electric Vehicle Market*, https://disruptionhub.com/manufacturers-race-electric-vehicles/, accessed: 29/09/2018.

Curry, C., 2017: *Lithium-ion Battery Costs and Market*, https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf, accessed: 06/12/2018.

Daimler, 2018: *Commited to Electric Mobility in China: Daimler Becomes Shareholder of BJEV*, https://media.daimler.com/marsMediaSite/en/instance/ko/Committed-to-electric-mobility-in-China-Daimler-becomes-shareholder-of-BJEV.xhtml?oid=33976464, accessed: 22/09/2018.

Daly, T., 2018: *Chinese Carmaker BYD Close to Completing Battery Recycling Plant*, https://www.reuters.com/article/us-china-byd-batteries-recycling/chinese-carmaker-byd-close-to-completing-battery-recycling-plant-idUSKBN1GX1EZ, accessed: 22/10/2018.

De Feijter, T., *This Is the Cheapest Car in China*, https://www.forbes.com/sites/tychodefeijter/2016/05/19/this-is-the-cheapest-car-in-china/#62ac601a2fe0, accessed: 22/09/2018.

Deign, J., 2018: *Bosch Abandons EV Battery Making as Asian Firms Dominate*, https://www.greentechmedia.com/articles/read/bosch-abandons-ev-battery-manufacturing#gs.7CMeVV8, accessed: 05/12/2018.

Deloitte, 2017: *The Future of the Automotive Value Chain. A 2025 Industry Outlook*, https://www2.deloitte.com/content/dam/Deloitte/us/Documents/consumer-business/us-auto-the-future-of-the-automotive-value-chain.pdf, accessed 18/08/2018.

de Sisternes, F.J., Jenkins J.D., Botterud, A., 2016: *The Value of Energy Storage in Decarbonizing the Electricity Sector*, in: Applied Energy, Volume 175, p.368-379.

Dincer, I., Rosen, M.A., 2011: *Thermal Energy Storage: Systems and Applications*, 2. edition, John Wiley & Sons Ltd., USA.

Dudenhöffer, F., 2018: *Global Automotive Market Slows Down in 2018 – Diesel burdens Europe*, in: Rubber Fibres Plastics, Volume 13, Issue 1, pp.250-252.

EDAG Engineering GmbH, 2018a: *The Engineering Partner for the Automotive World*, https://www.edag.de/en/vehicle-development.html, accessed: 18/11/2018.

EDAG Engineering GmbH, 2018b: *The Hydrogen of which the Future is Made*, https://www.edag.de/en/edag/news-detail/news/detail/News/the-hydrogen-of-which-the-future-is-made.html, accessed: 18/11/2018.

Edelstein, S., 2017: *Ford Partners with Zotye to Build Electric Cars in China*, http://www.thedrive.com/sheetmetal/15920/ford-partners-with-zotye-to-build-electric-cars-in-china, accessed: 22/09/2018.

Edelstein, S., 2018: *GM to Boost Chevrolet Bolt EV Production by 20 Percent to Meet Growing Demand*, https://www.digitaltrends.com/cars/chevrolet-bolt-ev-production-increase-2018/, accessed: 06/10/2018.

Edwards, L., Mashhadi, J., 2018: *Electric Vehicles Spurring New Business Models*, https://www.out-law.com/en/articles/2018/march/electric-vehicles-spurring-new-business-models/, accessed: 16/11/2018.

Els, F., 2018: *Major Lithium-Ion Battery Manufacturer Planning Output That May Rival Entire 2015 LIB market: Analysts*, http://www.mining.com/major-lithium-ion-battery-manufacturer-planning-output-may-rival-entire-2015-lib-market-analysts/, accessed: 01/11/2018.

European Federation for Transport and Environment AISBL, 2018: *Carmakers Still Failing to Hit Their Own Goals for Sales of Electric Cars*, https://www.transportenvironment.org/sites/te/files/2018_06_EV_announcements_report.pdf, accessed: 21/12/2018.

Evarts, E.C., 2018: *VW Plans 27 Electric Cars by 2022 on New Platform*, https://www.greencarreports.com/news/1118857_vw-plans-27-electric-cars-by-2022-on-new-platform, accessed: 13/08/2018.

Ewalt, D., 2017: *The World's Most Innovative Research Institutions - 2017*, https://www.reuters.com/article/innovative-institutions-ranking/the-worlds-most-innovative-research-institutions-2017-idUSL2N1GC1NG, accessed: 16/11/2018.

Flick, U., 2009: *An Introduction to Qualitative Research*, Sage Publications, Los Angeles.

Fortuna, C., 2018: *Panasonic Pledges to Decrease Cobalt Content of Tesla EV Batteries*, https://cleantechnica.com/2018/07/17/panasonic-pledges-to-decrease-cobalt-content-of-tesla-ev-batteries/, accessed: 21/10/2018.

Fraunhofer, 2018a: *Fraunhofer Institutes and Research Establishments*, https://www.fraunhofer.de/en/institutes.html, accessed: 08/11/2018.

Fraunhofer, 2018b: *International Locations*, https://www.fraunhofer.de/en/institutes/international.html, accessed: 08/11/2018.

Fraunhofer, 2015: *Electric Cars: Batteries with Brains*, https://www.fraunhofer.de/en/press/research-news/2015/December/electric-cars-batteries-with-brains.html, accessed: 08/11/2018.

Fraunhofer, 2017: *1000km Range Thanks to a New Battery Concept*, https://www.fraunhofer.de/en/press/research-news/2017/may/1000-km-range-thanks-to-a-new-battery-concept.html, accessed: 08/11/2018.

Frigant, V., 2011: *Are Carmakers on the Wrong Track? Too Much Outsourcing in an Imperfect-Modular Industry Can Be Harmful*, in: International Journal of Manufacturing Technology and Management, Vol.22, No.4, pp. 324-343.

Fusheng, L.,/China Daily, 2018: *Geely Gaining Momentum in Auto Market*, http://europe.chinadaily.com.cn/a/201808/24/WS5b7f66d4a310add14f3878d8.html, accessed: 17/09/2018.

Gassmann, O., Frankenberger, K., Csik, M., 2013: *Geschäftsmodelle entwickeln: 55 innovative Konzepte mit dem St. Galler Business Model Navigator*, 1. edition, Carl Hanser, Munich.

Gassmann, O., Frankenberger, K., Csik, M., 2014: *The St. Gallen Business Model Navigator*, Working paper: University of St. Gallen, ITEM-HSG.

Gebauer, H., Tennstedt, F., Elsässer, S., Betke, R., 2010: *The Aftermarket in the Automotive Industry: How to Optimize Aftermarket Performance in Established and Emerging Markets*, https://www.capgemini.com/wp-content/uploads/2017/07/tl_The_Aftermarket_in_the_Automotive_Industry.pdf, accessed 13/08/2018.

Gilboy, J., 2018: *Kia Niro EV Achieves 301 Miles of Range in Testing*, http://www.thedrive.com/tech/23692/kia-niro-ev-achieves-301-miles-of-range-in-testing, accessed: 08/10/2018.

Gioia, D.G. & Hamilton, A.E., 2012: *Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. Organizational Research Methods*, pp.15-31.

Gläser, J., Laudel, G., 2010: *Experteninterviews und qualitative Inhaltsanalyse als Instrumente rekonstruierender Untersuchungen*, Wiesbaden: VS Verlag für Sozialwissenschaften.

Goldsmith, C./World Finance, 2018: *Battery Metals Appear to Be Losing Their Spark as Prices Start to Fall*, https://www.worldfinance.com/markets/battery-metals-appear-to-be-losing-their-spark-as-prices-start-to-fall, accessed: 20/12/2018.

Grand View Research, 2018: *Engineering Services Outsourcing (ESO) Market Analysis by Application (Aerospace, Automotive, Construction, Semiconductor, Pharmaceutical, Telecom), By Location, By Region, And Segment Forecasts, 2018 - 2025*, https://www.grandviewresearch.com/industry-analysis/engineering-services-outsourcing-market, accessed: 16/11/2018.

Green Car Congress, 2018: *Ground-breaking Ceremony for New Bertrandt High-Voltage Battery Test Center*, https://www.greencarcongress.com/2018/09/20180918-bertrandt.html, accessed: 17/11/2018.

Groupe Renault, 2018: *Our Strategic Partnerships*, https://group.renault.com/en/our-company/a-group-an-alliance-and-partnerships/strategic-partnerships/, accessed: 29/09/2018.

Gruosso, G., 2015: *An Approach for Vehicle Electrification*, https://tec.ieee.org/newsletter/january-february-2015/an-approach-for-vehicle-electrification, accessed: 06/12/2018.

Gurz, M., Baltacioglu, E., Hames, Y., Kaya, K., 2017: *The Meeting of Hydrogen and Automotive: A review*, in: International Journal of Hydrogen Energy, Volume 42, Issue 36, pp. 23334-23346.

Hamlin, K., 2017: *Breakingviews - Buffet-backed BYD Could Use a Battery Ram*, https://www.reuters.com/article/us-byd-results-breakingviews/breakingviews-buffett-backed-byd-could-use-a-battery-ram-idUSKBN1DL09M, accessed: 22/10/2018.

Hanley, S., 2018: *Magna to Build Electric Cars in China, https://cleantechnica.com/2018/06/19/magna-to-build-electric-cars-in-china/*, accessed: 22/09/2018.

Hannan, M.A., Hoque, M.M., Mohamed, A., Ayob, A., 2017: *Review of Energy Storage Systems for Electric Vehicle Applications: Issues and Challenges*, in: Renewable and Sustainable Energy Reviews, Volume 69, pp. 771-789.

Helven, Y., 2018: *Finally, a List of Chinese EV Manufacturers*, https://www.globalfleet.com/en/manufacturers/asia-pacific/analysis/finally-list-chinese-ev-manufacturers, accessed: 15/09/2018.

Hembrow, C., 2016: *Alternatives to Lithium-Ion Batteries for Electric Vehicles*, https://ayataiq.com/alternatives-to-lithium-ion-batteries-for-electric-vehicles/, accessed: 03/11/2018.

Hennige, V., Parsons, M., 2017: *Next Generation Batteries - Cheaper, Faster, Further*, https://internetofbusiness.com/wp-content/uploads/2017/12/Volker-Heinnige-AVL.pdf, accessed: 08/11/2018.

Hertzke, P., Müller, N., Schenk, S., 2017: *China's Electric-Vehicle Market Plugs In*, https://www.mckinsey.com/featured-insights/china/chinas-electric-vehicle-market-plugs-in, accessed 15/09/2018.

Hoffmann, P., Dorgan, B., 2012: *Tomorrow's Energy: Hydrogen, Fuel Cells and the Prospects for a Cleaner Planet*, 1. edition, MIT Press, Cambridge, MA.

Hussy, W., Schreier, M., Echterhoff, G., 2010: *Forschungsmethoden in Psychologie und Sozialwissenschaften für Bachelor*., Berlin, Heidelberg, Springer Berlin Heidelberg.

Hyonhee, S., 2018: *S.Korea's SK Innovation to Invest $354 Mln in EV Battery Parts Plant in China*, https://www.reuters.com/article/sk-innovation-china/s-koreas-sk-innovation-to-invest-354-mln-in-ev-battery-parts-plant-in-china-idUSL4N1WN01Z, accessed: 03/11/2018.

IAV GmbH, 2018: *About IAV*, https://www.iav.com/en/about-iav, accessed: 18/11/2018.

Ili, S., Albers, A., Miller, S., 2010: Open Innovation in the Automotive Industry, in: The Future of Open Innovation, Special Issue R&D Management, Vol. 40, Iss. 3., pp. 246-255.

International Electrotechnical Commission, 2011: *Electrical Energy Storage*, Geneva (white paper).

International Energy Agency, 2017: *Market Report Series: Energy Efficiency 2017*, http://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf, accessed: 13/07/2018.

International Energy Agency, 2018: *Global EV Outlook 2018*, https://webstore.iea.org/download/direct/1045?fileName=Global_EV_Outlook_2018.pdf, accessed: 28/07/2018.

Jacobson, M.Z., 2009: *Review of Solutions to Global Warming, Air Pollution, and Energy Security*, in: Energy & Environmental Science, 2, pp. 148–173.

Joseph A., Shahidehpour, M., 2006, *Battery Storage Systems in Electric Power Systems*. In: Proceedings of IEEE power engineering society general meeting, pp. 1–8.

Kane, M., 2018a: *BYD Looks to Enter European Battery Market With New Factory*, https://insideevs.com/byd-looks-to-enter-european-battery-market-with-new-factory/, accessed: 01/11/2018.

Kane, M., 2018b: *Renault-Nissan-Mitsubishi Sold 540,623 Electric Vehicles Since 2010*, accessed: 29/09/2018.

Kane, M., 2018c: *Deutsche Accumotive is Daimler's Battery Arm*, https://insideevs.com/deutsche-accumotive-battery-production-video/, accessed: 04/11/2018.

Kane, M., 2018d: *Northvolt Gigafactory Moves Closer to Completion*, https://insideevs.com/northvolt-gigafactory-moves-closer-to-completion/, accessed: 03/11/2018.

Kerler, W., 2018: *How Dieselgate Saved Germany's Car Industry*, https://www.theverge.com/2018/9/19/17878730/dieselgate-saved-germanys-car-industry-vw-volkswagen-bmw-eu, accessed: 13/10/2018.

Kimble, C., Wang, H., 2013: *China's New Energy Vehicles: Value and Innovation, Journal of Business Strategy*, Emerald, pp.13-20.

Kline, S.J., Rosenberg, N., 1986: *An Overview of Innovation*, in: R. Landau, N. Rosenberg (Eds.), The Positive Sum Strategy. Harnessing Technology for Economic Growth, National Academy Press, United States of America.

Klug, F., 2013: *How Electric Car Manufacturing Transforms Automotive Supply Chains*, paper presented to: EurOMA Conference Proceedings, Dublin.

Kreisel Electric GmbH & Co KG, 2016: *Kreisel Electric Builds Factory in Upper Austria*, http://www.kreiselelectric.com/en/blog/kreisel-electric-builds-factory-upper-austria/, accessed: 06/12/2018.

Kreisel GmbH & Co KG, 2017: *Kreisel Electric Opens New High-Tech Research and Development Center As Its Headquarters,* http://www.kreiselelectric.com/en/blog/kreisel-electric-opens-new-high-tech-research-and-development-center-as-its-headquarters/, accessed: 06/12/2018.

Kreisel GmbH & Co KG, 2018: *Kreisel Shifts Up 2 Gears,* http://www.kreiselelectric.com/en/blog/kreisel-shifts-up-2-gears/, accessed: 06/12/2018.

Kurzweil, P., 2015: *Post-Lithium-ion Battery Chemistries for Hybrid Electric Vehicles and Battery Electric Vehicles,* in: Advances in Battery Technologies for Electric Vehicles, 1. edition, Woodhead Publishing, Cambridge, UK, pp. 127-171.

Lambert, F., 2017: *BMW Invest $240 Million to Bring Electric Car Range to 430 Miles with New Battery Cell Center*, https://electrek.co/2017/11/27/bmw-invest-electric-car-range-new-battery-cell-center/, accessed: 06/10/2018.

Lambert, F., 2018a, *Panasonic Starts Producing Battery Cells for Electric Cars at New Factory in China*, https://electrek.co/2018/03/13/panasonic-battery-cells-electric-cars-factory-china/, accessed: 21/10/2018.

Lambert, F., 2018b: *Tesla is Closing in on Gigafactory 3 Deal in China with 500,000 Cars Per Year capacity, report says*, https://electrek.co/2018/07/10/tesla-gigafactory-3-china-report/, accessed: 03/10/2018.

Lambert, F., 2018c: *Tesla Supercharger Network Has Now Delivered Over 400 GWh of Energy*, https://electrek.co/2018/07/25/tesla-supercharger-network-energy-output/, accessed: 03/10/2018.

Lambert, F., 2018d, *'Production at Tesla is Gaining Momentum' Says Panasonic as it Increases Battery Cell Production at Gigafactory 1*, https://electrek.co/2018/07/31/tesla-gigafactory-panasonic-battery-cell-production-model-3/, accessed: 21/10/2018.

Lambert, F., 2018e: *BMW Announces New Factory with Electric Vehicle Production Capacity*, https://electrek.co/2018/07/31/bmw-new-factory-electric-vehicle-production/, accessed: 04/10/2018.

Lambert, F., 2018f: *Tesla confirms Gigafactory 1 battery production at '~20 GWh' - more than all other carmakers combined*, https://electrek.co/2018/08/02/tesla-gigafactory-1-battery-production-20-gwh/, accessed: 29/09/2018.

Lambert, F., 2018g: *VW CEO Uses Scare Tactic Against Stricter Emission Rules Despite Claiming to Be All-in with Electric Vehicles*, https://electrek.co/2018/10/11/vw-ceo-scare-tactic-against-stricter-emission-rules-all-in-electric-vehicles/#disqus_thread, accessed: 13/08/2018.

Lang, A., & Lindemann, U. (2015). *From Open Innovation to Open Organization, Integrating External Information Successfully*, In E. Huizingh, M. Torkkeli, S. Conn, & I. Bitran (Eds.), The 2015 ISPIM Innovation Summit. Brisbane.

Langley, A., Abdallah, C., 2011: Templates and Turns in Qualitative Studies of Strategy and Management, in: Donald D. Bergh, David J. Ketchen (ed.), Building Methodological Bridges (Research Methodology in Strategy and Management, Vol. 6), Emerald Group Publishing Limited, pp. 201-235.

Lee, T.B., 2016: *The Three Big Trends That Will Reshape the Car Industry in the 2020s*, https://www.vox.com/2016/5/27/11763610/detroit-silicon-valley-disruption, accessed: 12/12/2018.

Legner, C., Pelli, D., Löhe, J., Walden, J., Fischer, T., Stein, O., 2009: *Evolving Value Chains in the Automotive Industry - Implications for Business Processes and Information Systems*, http://www.kerp.at/uploads/media/Evolving_Value_Chains_in_the_Automotive_Industry.pdf, accessed: 06/12/2018.

Libich, J., Máca, J., Vondrák, J., Čech, O., Sedlaříková, M., 2018: *Supercapacitors: Properties and Applications*, in: Journal of Energy Storage, Volume 17, pp.224-227.

Lima, P., 2017: *Samsung SDI Develops a Graphene Battery*, https://pushevs.com/2017/11/28/samsung-sdi-develops-graphene-battery/, accessed: 02/11/2018.

Lima, P., 2018: *LG Chem to Triple EV Battery Production in Poland*, https://pushevs.com/2018/03/12/lg-chem-to-triple-ev-battery-production-in-poland/, accessed: 01/11/2018.

Loveday, S., 2018: *2019 Hyundai Kona Electric Offers Most Range of Any Non-Tesla EV*, https://insideevs.com/2019-hyundai-kona-electric-range-champ/, accessed: 08/10/2018.

Lukic, S. M., Cao, J., Bansal, R. C., Rodriguez, F., Emadi, A., 2008: *Energy Storage Systems for Automotive Applications*, IEEE Transactions on Industrial Electronics, Volume 55, Issue 6, pp. 2258-2267.

Macomb Community College, 2018: *HEV Levels*, http://autocaat.org/Technologies/Hybrid_and_Battery_Electric_Vehicles/HEV_Levels/, accessed: 06/12/2018.

Macquarie Wealth Management, 2017: *Commodities Comment*, http://www.barraresources.com.au/wp-content/uploads/2017/02/MacquarieCommodities-Cobalt-070217e.pdf, accessed: 20/12/2018.

Mahindra, 2018: *Mahindra and LG Chem collaborate for Li-ion Battery Technology*, http://www.mahindra.com/news-room/press-release/mahindra-and-lg-chem-collaborate-for-li-ion-battery-technology, accessed: 01/11/2018.

Manthey, N., 2018a: *CATL Rushing to Launch NCM 811 Battery Cell First*, https://www.electrive.com/2018/08/15/catl-rushing-to-launch-ncm-811-battery-cells-first/, accessed: 02/11/2018.

Manthey, N., 2018b: *SK Innovation Kicks Off Construction of Hungarian Plant*, https://www.electrive.com/2018/03/12/sk-innovation-kicks-off-construction-of-hungarian-plant/, accessed: 03/11/2018.

Matthews, T., 2013, *Flywheel Based Kinetic Energy Recovery Systems (KERS) Integrated in Vehicles*, in: International Journal for Engineering Science and Technology, Volume 5, p.1694-1699.

Mayring, P., 2000: *Qualitative Content Analysis*, in: Forum Qualitative Social Research, 1(2), Art. 20, http://nbn-resolving.de/urn:nbn:de:0114-fqs0002204, accessed: 15/02/2019.

Mayring, P., 2003: *Qualitative Inhaltsanalyse – Grundlagen und Techniken* [*Qualitative Content Analysis – Backgrounds and Techniques*], Beltz Verlag / Deutscher Studien Verlag, Weinheim.

Mayring, P., 2012: *Qualitative Inhaltsanalyse*, in: Flick, U., von Kardorff, E., Steinke, I. (Eds.): Qualitative Forschung, 9th edition, Reinbek bei Hamburg, Rowohlt Taschenbuch Verlag. pp. 468-475.

Mayring, P., 2014: *Qualitative Content Analysis: Theoretical Background and Procedures*, in: Bikner-Ahsbahs, A., Knipping, C., Presmeg, N.: Approaches to Qualitative Research in Mathematics Education, 1. edition, Springer-Verlag, pp. 365-380.

McKinsey, 2017: *Electrifying Insights: How Automakers Can Drive Electrified Vehicle Sales and Profitability*, https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/electrifying%20insights%20how%20automakers%20can%20drive%20electrified%20vehicle%20sales%20and%20profitability/how%20automakers%20can%20drive%20electrified%20vehicle%20sales%20and%20profitabilitymck.ashx, accessed: 13/07/2018.

McKinsey&Company, 2018: *Lithium and Cobalt - a Tale of Two Commodities*, https://www.mckinsey.com/~/media/mckinsey/industries/metals%20and%20mining/our%20insights/lithium%20and%20cobalt%20a%20tale%20of%20two%20commodities/lithium-and-cobalt-a-tale-of-two-commodities.ashx, accessed: 20/12/2018.

MIT Electric Vehicle Team, 2008: *A Guide to Understanding Battery Specifications*, http://web.mit.edu/evt/summary_battery_specifications.pdf, accessed: 03/11/2018.

Müller, C., Benad, H., Rennhak, C., 2011: *E-Mobility - Treiber, Implikationen für die beteiligten Branchen und mögliche Geschäftsmodelle*, https://www.esb-business-school.de/fileadmin/user_upload/Fakultaet_ESB/Forschung/Publikationen/Diskussionsbeitraege_zu_Marketing_Management/09_WP_2011-09.pdf, accessed: 01/12/2018.

Nicholson, C.V.,/The New York Times, 2010: *Chinese Carmaker Geely Completes Acquisition of Volvo From Ford*, https://www.nytimes.com/2010/08/03/business/global/03volvo.html, accessed: 16/09/2018.

Nie, Y.M., Ghamami, M., Zockaie, A., Xiao, F., 2016: *Optimization of Incentive Polices for Plug-in Electric Vehicles*, Transportation Research Part B: Methodological, 84, 103-123.

Nieuwenhuis, P., Wells, P., 2015: *The Global Automotive Industry*, 1. edition, Wiley, Chichester, UK.

Olabi, A.G., 2017: *Renewable Energy and Energy Storage Systems*, in: Energy, Volume 136, Pages 1-6.

Osiyevskyy, O., Dewald, J., 2017: *The Pressure Cooker: When Crisis Stimulates Explorative Business Model Change Intentions,* Long Range Planning, pp. 1-21.

Parkinson, G., 2018: *Who Are the World's Biggest Makers of EV Batteries?*, https://reneweconomy.com.au/worlds-biggest-makers-ev-batteries-46208/, accessed: 19/10/2018.

Patton, M.Q., 2002: *Qualitative Research and Evaluation Methods*, 3rd edition, Thousand Oaks, London, New Delhi: Sage Publications, Inc.

Peppard, J., Rylander, A., 2006: *From Value Chain to Value Network: Insights for Mobile Operators*, in: European Management Journal, 24 (2–3), p. 128– 141.

Perner, A., Vetter, J., 2015: *Lithium-ion Batteries for Hybrid Electric Vehicles and Battery Electric Vehicles*, in: Advances in Battery Technologies for Electric Vehicles, 1. edition, Woodhead Publishing, Cambridge, UK, pp. 173-190.

Peschel, T., 2016: *Samsung Invests € 320 Million in Hungarian Car Battery Plant*, http://www.sunwindenergy.com/review/samsung-invests-eu-320-million-hungarian-car-battery-plant, accessed: 02/11/2018.

Petters, S., 2018: *ULEMCo Designs First Zero-Emission Combustion Engine Truck*, https://www.enginetechnologyinternational.com/news/emissions-control/ulemco-zero-emission-truck.html (accessed July 2018).

Prabhakar, A.J, Ferdowsi, M., 2008: *Comparison of NiMH and Li-ion Batteries in Automotive Applications*, in: 2008 IEEE Vehicle Power and Propulsion Conference, pp. 1-6.

Pullen, K.R., Dhand, A., 2014: *Mechanical and electrical flywheel hybrid technology to store energy in vehicles*, in: Alternative Fuels and Advance Vehicle Technologies for Improved Environmental Performance, 1. edition, Woodhead Publishing, London, pp. 476-504.

Quan, X.I., Loon, M., Sanderson, J., 2018: *Innovation in the Local Context: A Case Study of BYD in China, in: International Journal of Innovation and Technology Management*, Volume 15, Issue 02, pp. 1-25.

Randall, C., 2018a: *EDAG Cooperating with Solar Startup Lightyear*, https://www.electrive.com/2018/04/24/edag-cooperating-with-solar-startup-lightyear/, accessed: 18/11/2018.

Randall, C., 2018b: *EDAG Develops First EV for Vietnam*, https://www.electrive.com/2018/05/26/edag-develops-first-ev-for-vietnam/, accessed: 18/11/2018.

Randall, C., 2018c: *AVL List Completes Battery Lab Expansion in Graz*, https://www.electrive.com/2018/09/30/avl-list-completes-battery-lab-expansion-in-graz/, accessed: 08/11/2018.

Randall, C., 2018d: *LG opens new battery factory for Chevy Bolt*, https://www.electrive.com/2018/09/06/lg-opens-new-battery-factory-for-chevy-bolt/, accessed: 06/10/2018.

Reuters, 2018a: *LG Chem to Build $1.8 Billion Electric Vehicle Battery Plant in China*, https://auto.economictimes.indiatimes.com/news/auto-components/lg-chem-to-build-1-8-billion-electric-vehicle-battery-plant-in-china/65048569, accessed: 01/11/2018.

Reuters, 2018b: *LG Chem to Supply EV Batteries to Volkswagen From Late 2019*, https://www.reuters.com/article/us-lg-chem-volkswagen-batteries/lg-chem-to-supply-ev-batteries-to-volkswagen-from-late-2019-idUSKCN1ME0VZ?feedType=RSS&, accessed: 01/11/2018.

Rosenberg, N., 2009: *Uncertainty and Technological Change*, in: Studies on Science and the Innovation Process, World Scientific Publishing Co. Pte. Ltd., pp. 153-172.

Rosevear, J., 2018: *General Motors' Chevy Bolt Just Beat Tesla's Model X*, https://www.fool.com/investing/2018/01/07/general-motors-chevy-bolt-just-beat-teslas-model-x.aspx, accessed: 07/10/2018.

Rowe, K., 2010: *Time to Market is a Critical Consideration*, https://www.embedded.com/electronics-blogs/industry-comment/4027610/Time-to-market-is-a-critical-consideration, accessed: 20/12/2018.

Ryu, M., Mallette, F., Khanna, A., Santha, N., 2018: *Accelerating Electrification: Critical Steps Toward Electric Vehicle Mass Adoption*, Vol XX, Issue 34, https://www.lek.com/insights/critical-steps-toward-electric-vehicle-adoption, accessed: 16/12/2018.

Sakkers, O., 2016: *Understanding Business Model Disruption in the Mobility Industry*, https://medium.com/maniv-mobility/understanding-business-model-disruption-in-the-mobility-industry-980fa276b70e, accessed: 23/11/2018.

Sanderson, H./Financial Times, 2018: *China Tightens Grip on Global Cobalt Supplies*, https://www.ft.com/content/86dc1306-27a4-11e8-b27e-cc62a39d57a0, accessed: 20/12/2018.

Schallmo, D., Brecht, L., 2010: *Business Model Innovation in Business-to-Business Markets: Procedure and Examples*, pp. 12-15, Proceedings of the 3rd ISPIM Innovation Symposium: Managing the Art of Innovation: Turning Concepts into Reality, Quebec City, QC, Canada.

Scharrer, O., 2018: *The Powertrain in 2030 Shaped by Diversification*, in: ATZ - Automobiltechnische Zeitschrift, Volume 120, Supplement 3, pp. 52-57.

Schiele, H. 2010: *Innovationen von und mit Lieferanten*, Enschede, The Netherlands: BME-Report.

Schiele, H., 2012: *Accessing Supplier Innovation by Being Their Preferred Customer*, Research-Technology Management, 55(1), 44–50.

Schougaard, S.B., Bélanger, D., 2014: *Electrochemical Energy Storage Systems*, in: Functional Materials: For Energy, Sustainable Development and Biomedical Sciences, 1. edition, De Gruyter, Berlin, pp. 171-188.

Semadeni, M., 2003: *Energy Storage as an Essential Part of Sustainable Energy Systems: a Review on Applied Energy Storage Technologies*, CEPE working paper No.24, ETH Zentrum, Zürich, https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/147415/eth-26428-01.pdf (accessed July 2018).

Shenzhen Gaogong Industry Research Co., Ltd (GGII), 2018: *China Li-ion Power Battery Industry Research 2017*, http://www.gg-ii.com/en/Research_Report/Li_ion_Battery/2017/0518/1944.html, accessed: 19/10/2018.

Sigler, D., 2017: *EMBATT - An Embedded Battery That Combines Structure and Energy*, http://cafe.foundation/blog/embatt-an-embedded-battery-that-combines-structure-and-energy/, accessed: 18/11/2018.

Snihur, Y., Zott, C., 2013: *Legitimacy Without Imitation: How to Achieve Robust Business Model Innovation*, in 35th DRUID Celebration Conference, June, pp. 1-35.

Song, S., 2018: *Posco, Samsung SDI Win Electric Vehicle Battery Project in Chile*, http://www.koreaherald.com/view.php?ud=20180311000152, accessed: 02/11/2018.

Sosna, M., Rodríguez-Trevinyo, R. N., S. Velamuri, S. R., 2010: *Business Model Innovation through Trial-and-Error Learning: The Naturhouse Case*, Long Range Planning, 43, p.383 – 407.

Speers, P., 2018: Hydrogen Mobility Europe (H2ME): *Vehicle and Hydrogen Refuelling Station Deployment Results*, in: World Electric Vehicle Journal, Volume 9, Issue 1, pp. 2

Statista, 2018: *Global Market Share of Lithium Ion Battery Makers in the 1st Quarter of 2018*, https://www.statista.com/statistics/235323/lithium-batteries-top-manufacturers/, accessed: 14/10/2018.

Steinle, C., & Schiele, H. (2008). *Limits to Global Sourcing? Strategic Consequences of Dependency on International Suppliers: Cluster Theory, Resource-based View and Case Studies*, Journal of Purchasing and Supply Management, 14(1), 3–14.

Sterner, M., Stadler, I., 2014: *Energiespeicher – Bedarf, Technologien, Integration*, 2. edition, Springer Vieweg, Berlin.

Stock, K., 2018: *Only BMW Comes Close to China's Electric-Vehicle Heavyweights*, https://www.bloomberg.com/news/articles/2018-09-18/only-bmw-comes-close-to-china-s-electric-vehicle-heavyweights, accessed: 03/10/2018.

Tan, J., 2018: *Newcomer Surges to Top of Electric-Vehicle Battery Market*, https://www.caixinglobal.com/2018-05-08/newcomer-surges-to-top-of-electric-vehicle-battery-market-101245701.html, accessed: 19/10/2018.

Tariq, M., Maswood, A.I., Gajanayake, C.J., Gupta, A.K., 2017: *Aircraft Batteries: Current Trend Towards More Electric Aircraft*, in: IET Electrical Systems in Transportation, Volume 7, Issue 2, pp. 93-103.

Taylor, E., 2018: *Daimler to Build Battery Factories in Sindelfingen, Untertuerkheim*, https://www.reuters.com/article/us-daimler-batteries-sindelfingen/daimler-to-build-battery-factories-in-sindelfingen-untertuerkheim-idUSKBN1KF1S1, accessed: 04/11/2018.

Technavio, 2017: *Top 5 Influential Electric Vehicle Manufacturers in 2017*, https://www.technavio.com/blog/top-electric-vehicle-manufacturers, accessed: 04/10/2018.

Thakkar, K., 2018: *Hyundai Plans to Introduce Full Range of Electric Vehicles in India*, https://economictimes.indiatimes.com/industry/auto/auto-news/hyundai-plans-to-introduce-full-range-of-electric-vehicles-in-india/articleshow/65380797.cms, accessed: 13/10/2018.

The Economist Intelligence Unit, 2005: *Business 2010: Embracing the Challenge of Change*, white paper, Economist Intelligence Unit, New York, February 2005, p.2.

THM Capital, 2016: *Bertrandt - Waiting for an Attractive Price*, https://seekingalpha.com/article/3966677-bertrandt-waiting-attractive-price, accessed: 17/11/2018.

Vieser, S./Accenture, 2017: *Opportunities for Digitization. New business models. Innovative services. More efficiency*, https://www.accenture.com/t20171009T152058Z__w__/us-en/_acnmedia/PDF-61/Accenture_Automobilwoche-Supplement_English.pdf, accessed: 17/08/2018.

Ward, J./Automotive Logistics, 2017, *EV Supply Chains: Shifting Currents*, https://automotivelogistics.media/intelligence/shifting-currents, accessed: 27/07/2018.

Wells, P., 2013: *Sustainable Business Models and the Automotive Industry: A commentary*, in: IIMB Management Review, Vol. 25, Iss. 4, pp. 229-239.

Wells, P., 2015: *New Business Models and the Automotive Industry*, The Global Automotive Industry, 1. edition, Wiley, Chichester, UK.

Wells, P., Niewenhuis, P., 2015 "*Electric Vehicle Business Models in a Wider Context: Balancing changes and continuity in the automotive industry*" in: Beeton, D., Meyer, G., Electric Vehicle Business Models, 1. edition, Springer International Publishing, Switzerland, pp. 3-16.

Williander, M., Stålstad, C., 2015: *Four Business Models for a Fast Commercialization of Plug-in Cars*, in: Beeton, D., Meyer, G. (eds.): Electric Vehicle Business Models, Lecture Notes in Mobility, 1. edition, Springer International Publishing, Switzerland, pp. 17-34.

Winter, M., & Brodd, R., 2004: *What Are Batteries, Fuel Cells, and Supercapacitors?*, Chemical Reviews, Volume 104, Issue 10, pp. 4245-4270.

Woo, JR., Choi, H., Ahn, J., 2017: *Well-to-Wheel Analysis of Greenhouse Gas Emissions for Electric Vehicles Based on Electricity Generation Mix: A Global Perspective*, in: Transportation Research Part D: Transport and Environment, Volume 51, pp. 340-350.

Wyman, O., 2018: *FAST 2030: Future Automotive Industry Structure*, in: Materialien zur Automobilindustrie, Vol.51, VDA, Berlin.

Yilmaz, M., Krein, P.T., 2013: *Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-in Electric and Hybrid Vehicles*, in: IEEE Transactions on Power Electronics, Volume 28, Issue 5, pp. 2151 – 2169.

Young, K., 2018: *Research in Nickel/Metal Hydride Batteries 2017*, in: Nickel Metal Hydride Batteries 2017, 1. edition, MDPI Books, Basel, p. 1.

Zott, C., Amit, R., Massa, L., 2011: *The Business Model: Recent Developments and Future Research*, in: Journal of Management 37, 1019 - 1042.

Zubi, G., Dufo-López, R., Carvalho, M., Pasaoglu, G., 2018: *The Lithium-ion Battery: State of the Art and Future Perspectives*, in: Renewable and Sustainable Energy Reviews, Volume 89, pp. 292-308.