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Investigation of Technology-Driven Changes in Value Creation Partnerships in the Automotive Business Ecosystem

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Thanks

Writing this thesis involved blood, sweat and tears, which is why I am especially happy about the final results and insights gained through it. Achieving this kind of success would not have been possible without the great support of my family and friends. I would like to especially thank my parents Regine and Heimo and my brother Florian, who always had an open ear for me, whenever I was stuck or needed some fresh thoughts.

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Abstract

Es wird weithin angenommen, dass hochgradige technologische Innovationen das Potential haben, die Logik ganzer Industrien nachhaltig zu verändern. Betroffene Unternehmen sehen ihre einzige Möglichkeit, angesichts der veränderten Geschäftslogik wettbewerbsfähig zu bleiben häufig darin, Allianzen mit Zulieferern, Mitbewerbern oder sogar Firmen aus anderen Industriezweigen zu forcieren. Der Zweck dieser Arbeit ist es, die Veränderungen in der Automobilindustrie durch den zunehmenden Trend zu batterieelektrischen Fahrzeugen zu identifizieren und zu analysieren.

Im Rahmen dieses Vorhabens wurde das „Business Ecosystem“-Konzept als Untersuchungsrahmen gewählt, das die Dynamik von Firmennetzwerken durch Analogien zu biologischen Ökosystemen zu erklären versucht. Mithilfe dieses Werkzeuges wurden relevante Gruppen von Akteuren im „Business Ecosystem“ batterieelektrischer Fahrzeuge und deren besondere Herausforderungen identifiziert und die Veränderungen interorganisationaler Beziehungen zwischen diesen untersucht, die sich durch den zunehmenden Trend zu batterieelektrischen Fahrzeugen ergeben.

Da es sich bei dieser Arbeit um eine explorative Studie handelt, wurde eine Herangehensweise gewählt, die sich aus einer Datenbank- und Literaturanalyse sowie holistischen Fallstudien dreier großer deutscher Fahrzeughersteller zusammensetzt. Aufgrund der Tatsache, dass im Rahmen der Untersuchungen nur Sekundärdaten herangezogen werden konnten, wurde ein spezieller Ansatz entwickelt, der es erlaubt, mithilfe von Zeitstrahlen eine Theorie abzuleiten.

Die Ergebnisse dieser Arbeit bestätigen die Vermutung, dass hochgradige technologische Innovationen die Rolle, die Firmen in ihrem „Business Ecosystem“ spielen, verändern können. Gleichzeitig führen derartige Innovationen zu einer temporären Erhöhung kooperativen Verhaltens innerhalb einer Industrie und über Industriegrenzen hinweg, mit dem Ziel, möglichst schnell Kompetenzen aufzubauen. Jedoch wurde festgestellt, dass sich die Motive und die Art der Partner verändern, wenn das „Business Ecosystem“ von einer Phase seines Lebenszyklus in die nächste übergeht. Ein Erklärungsmodell wurde entwickelt, das in der Lage ist, das Verhalten von Automobilunternehmen durch drei unterschiedliche Strategiemuster zu erklären, die als „aktive Keystone-“, „passive Keystone-“ und „Nischen-“ Strategie beschrieben werden.

Die Anwendung des „Business Ecosystem“- Konzepts erlaubt es, zu zeigen, dass der Trend zu batterieelektrischen Fahrzeugen die Struktur der Automobilindustrie verändert, obwohl diese einst als eine der stabilsten und am meisten konsolidierten Industrien angesehen wurde. Wenn man diesen Strukturwandel allerdings richtig interpretiert, dann erlaubt die bewusste Ausnutzung der Vorteile einer „Keystone-Strategie“ durch das eigene Unternehmen die Verbesserung des Gesamtzustandes der Industrie, in der es tätig ist. Ein wichtiges Instrument, um dieses Ziel zu erreichen, ist dabei die Entwicklung von Plattformen, die es Dritten erlauben, ihre Leistungen auf diesen aufzubauen.

Weitere Forschung sollte darauf abzielen, die Strategie weiterer Unternehmen zu beurteilen, die sich in einer ähnlichen Situation befinden, wie die drei untersuchten Fahrzeughersteller. Des Weiteren wird vorgeschlagen, weitere Trends in der Automobilindustrie mit ähnlichen Methoden zu untersuchen und die Ergebnisse mithilfe von Interviews mit Vertretern dieser Unternehmen zu validieren, um eine ganzheitlichere Beschreibung zu ermöglichen.

Abstract

Radically new technological innovations are believed to have the potential to change the logic of whole industries. Companies might have to engage in alliances with suppliers, competitors or even actors of other industries in order to be able to stay competitive in the face of this new logic. The purpose of this research was to identify the changes that were induced in the automotive industry by the increasing shift towards BEVs.

To do this, the study used the business ecosystem concept that draws analogies between industries and biological ecosystems and focused on an identification of relevant groups of actors in the business ecosystem for BEVs, their challenges and the changes in the interorganizational relationships between them that are induced by the increasing trend towards electric mobility.

As this work is of exploratory character, a mixed approach was chosen that includes database and literature analysis and a holistic multiple-case study of three big German automotive OEMs. Due to the fact that only secondary data was available, a special research design was developed that incorporates timeline representations for theory generation.

The outcome of the present study confirms the wide-spread view that radically new technological innovations can change the role companies play within their business ecosystem and lead to a higher degree of cooperation within an industry and across industry borders in order to share knowledge. However, the motives of cooperation and the type of cooperation partners change as a newly created business ecosystem switches from one lifecycle phase to another. An underlying mechanism is proposed that results in three strategy archetypes that are described as “active keystone player”, “passive keystone player” and “niche player” strategy.

Application of the business ecosystem framework to the automotive industry shows, that although the automotive industry once was one of the most stable and consolidated industries, the shift from internal combustion engines to battery electric drives leads to a change of industry structure. If understood the right way, managers could consciously leverage the advantages of a pure keystone player strategy and increase the health of their ecosystem by creating platforms and opening them up to third party companies.

Further research is suggested to assess the strategy of companies that share the same initial conditions as the examined three OEMs. Additionally, other trends in the automotive industry are proposed to be analysed with similar methods and complemented with interviews of representatives of the involved companies in order to gain a more holistic view.

Contents

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Abbreviations

AC .... Alternating Current

BES .... Business Ecosystem

BEV .... Battery Electric Vehicle

BLDC .... Brushless DC Motor

BSR .... Buyer-Supplier Relationship

CCS .... Combined Charging System

CEN .... European Commission for Standardization

CENELEC .... European Committee for Electrotechnical Standardization

CEO .... Chief Executive Officer

CPO .... Charge Point Operator

DC .... Direct Current

DIN .... Deutsches Institut für Normung

DKE .... Deutsche Kommission Elektrotechnik Elektronik Informationstechnik

DSM .... Demand-Side Management

EAMA .... European Automobile Manufacturers Association

EC .... European Commission

EMSP .... E-Mobility Service Provider

ETSI .... European Telecommunications Standards Institute

EU .... European Union

EV .... Electric Vehicle

EVA .... Electric Vehicle Architecture

FCEV .... Fuel-Cell Electric Vehicle

HEV .... Hybrid Electric Vehicle

IEC .... International Electrotechnical Commission

ICE .... Internal Combustion Engine

ICT .... Information and Communication Technologies

ISO .... International Organization for Standardization

IT .... Information Technology

ITU .... International Telecommunication Union

LCO .... Lithium-Cobalt-Oxide Battery Chemistry

LFP .... Lithium-Iron-Phosphate Battery Chemistry

LIB .... Lithium-Ion Battery

LMO .... Lithium-Manganese-Oxide Battery Chemistry

LNO .... Lithium-Nickel-Oxide Battery Chemistry

LTO .... Lithium-Titanate Battery Chemistry

MEB ....Modularer E-Antriebs-Baukasten

MLB ....Modularer Längsbaukasten

MQB ....Modularer Querbaukasten

MRA...Mercedes Rearwheel Architecture

NCA .... Lithium-Nickel-Manganese-Cobalt-Oxide Battery Chemistry

NEDC .... New European Driving Cycle

NiCd.. Nickel-Cadmium Battery

NiMH .... Nickel-Metal Hydride Battery

NMC .... Lithium-Nickel-Manganese-Cobalt-Oxide Battery Chemistry

OEM .... Original Equipment Manufacturer

PHEV.. Plug-In Hybrid Electric Vehicle

PPE .... Premium Platform Electric

R&D .... Research and Development

REED ....Range-Extended Electric Vehicle

SDO .... Standards Development Organization

SRM .... Switched Reluctance Machine

SUV... Sports Utility Vehicle

TCO... Total Costs of Ownership

UK..United Kingdom

US(A) .... United States (of America)

WLTP ....World Harmonized Light Vehicles Test Procedure

Part I: **RESEARCH INTENT**

1 Introduction

In the introduction of this thesis, the initial conditions and the impetus for the topic are outlined and further developed into a set of research questions. The additional sections are aimed at explaining the methodological approach which was chosen.

1.1 Aim of this Work

In the course of the last couple of years, the concept of ecosystems has emerged as a new framework for analysis used by scholars in many different areas of research (Dodourova & Bevis, 2014, p. 255; Iansiti & Levien, 2004b; Moore, 1993; Moore, 1996, pp. 273–274; Tsujimoto et al., 2018). The concept itself stems from the complex interdependencies that can be observed in biological ecosystems, and consists of application of the same principles to other samples of networked actors (Iansiti & Levien, 2004b; Moore, 1996, p. 10).

Moore was the first to apply those principles to business networks in order to find a systematic approach to strategy. Companies are not seen as a part of a single industry any more but rather as part of a business ecosystem that spans over many different industries in the traditional meaning. Companies that operate in the same ecosystem coevolve capabilities and work cooperatively and competitively at the same time. (Moore, 1993)

The ecosystem concept is mainly used for analysing the evolution of rapidly changing businesses, as it seeks to explain the underlying dynamics in order to allow understanding by practitioners (Moore, 1996, pp. 5–25). Moore especially points out that the automotive industry historically never belonged to this category as change often took decades to take place (Moore, 1993; Moore, 1996, p. 95). However, he chose the U.S. automotive industry to illustrate his concepts (Moore, 1996, p. 87). Additionally, the widely distributed structure that has evolved over the years as well as the first signs of dramatic changes due to alternative drivetrain concepts have made the automotive industry very attractive to application of the business ecosystem concept (Iansiti & Levien, 2004b, p. 6; Lu et al., 2014; Moore, 1996, p. 100). A shift in the predominant propulsion system will not just pose massive challenges to the automotive industry, but also to several other industries that coexist in this business ecosystem or are traditionally even external to it (Enrietti & Patrucco, 2011, p. 4). Different actors in the automotive business ecosystem will have to engage in various forms of interorganizational and cross-industry relationships in order to be able to handle knowledge build-up, uncertainty, risk and costs that are associated with technological discontinuities or systemic disruptive change (Barthel et al., 2015, p. 16; Dinger et al., 2010, pp. 10–11; Lambe & Spekman, 1997, p. 114; Mazur et al., 2013, p. 1060; Pinske et al., 2014, p. 45; Rice et al., 1998, p. 57; Rong et al., 2017).

In spite of these clear implications, not much work has yet been carried out in the field of the automotive business ecosystem for alternative drivetrains, like for example battery electric vehicles (BEVs). Due to massive changes in the vehicle architecture, the needed infrastructure and resources, these kinds of vehicles pose massive challenges to the automotive industry as a whole, including the necessity to reconfigure supply networks, establish new business models and redefine core competencies (Kasperk et al., 2018, p. 145; Strathmann, 2019, p. 37). As a consequence, coordination and interaction between different groups of public and private actors is needed, incumbent players might be replaced by new entrants and individual companies' influence on the automotive business ecosystem might be increased or decreased (Accenture, 2014; Barthel et al., 2015, p. 25; Kampker et al., 2018, p. 53).

Although some scholars have already made efforts to analyse the reaction of actors in the automotive industry to these challenges, not many of them have adopted the business ecosystem concept as a framework for assessment. Jacobides et al. (2016) investigated the changes in the automotive business ecosystem from 1997 to 2007, with only little emphasis on the effects caused by electric or electrified drive trains. Shang et al. (2013) examined the emergence of the electric vehicle industry in the Chinese Shandong province by means of the business ecosystem concept and identified multiple case study analysis as the means to measure business ecosystem capabilities. Sovacool et al. (2019) used case studies to show the different innovation strategies chosen by different OEMs in developing electric vehicles and incorporated some ideas of the business ecosystem concept into their argumentation. Galateanu & Avasilcai (2016) analysed the electric vehicle business ecosystem in order to identify different types of niche players and their competitive behaviour. Rong et al. (2017) conducted a qualitative cross-case study in the EV industry in order to identify differences in the strategy pursued by the business ecosystem's focal companies in Europe and China. They introduced a framework for company classification consisting of two different target markets and two different growth contexts and assessed a total of eight companies regarding their characteristics on the supply side, the demand side and the role of intermediate organizations in bringing those two together. According to their research, EV activities are primarily nurtured by government in China, whilst the market is the main driver for EV development in Europe. Lu et al. (2014) studied the evolution of the Chinese electric vehicle industry by applying the business ecosystem concept. They introduced a three-dimensional theoretical framework including an extended ecosystem lifecycle, a stakeholder classification scheme and functional roles in order to track the transformation process. They used the gained insights to develop a conceptual model of agent-based systems and suggest further research into the emergence of the electric vehicle (EV) industry in other countries.

Following this suggestion, the focus of this work lies in the application of the business ecosystem concept to the automotive business ecosystem for battery electric cars. It aims at identifying the most relevant groups of actors, the impact of the trend towards electric vehicles on these actors and the way value creation partnerships changed in the course of the shift to BEVs.

1.2 Research Questions

According to the information outlined in section 1.1, the following research questions were formulated:

R1: Which are the most relevant groups of actors in the European automotive business ecosystem for BEVs?

R2: Which impact does e-mobility have on the identified actor groups in this business ecosystem?

R3: How did OEM's value creation partnerships change in the course of the shift to BEVs?

These questions have been addressed by means of an empirical study and secondary data. The exact methodology is outlined in the next chapter.

1.3 Content of the Thesis

The content of this thesis is split up in four different segments, which consist of eleven chapters in total (see Figure 1).

Part I includes the first two chapters which consist of the introduction, research questions and methodology. Chapter 1 outlines the research intent and the research questions as well as the content of this thesis; chapter 2 gives an outlook on the methodology used to answer the research questions.

Part II covers all economic and technological theoretical concepts used for this thesis. Chapter 3 is the first theoretical chapter and is used to present the business ecosystem concept. Chapter 4 defines technological innovations and includes methods to assess innovativeness, whilst chapter 5 is aimed at introducing the main characteristics of interorganizational relationships with the final goal of developing an interorganizational relationship typology to be used in the empirical part of this thesis. Finally, chapter 6 is the last theoretical chapter and covers the most important technology-related aspects of electric mobility.

Part III consists of a description of all empirical research performed for this thesis. Chapter 7 is the first empirical chapter and aimed at answering research question R1 by means of a database analysis. Chapter 8 describes the impact of the shift to BEVs for all actor groups identified in chapter 7. This allows answering of research question R2. Chapter 9 is aimed at answering research question R3 and consists of three case studies and the corresponding timelines.

The final part IV is aimed at discussing the results, summarize them and formulate further research directions. Chapter 10 includes the discussion of the results of all three empirical chapters and tries to explain the underlying dynamics. Chapter 11 summarizes the results and their meaning. Furthermore, their generalization and the limitations of the used methods are discussed. Finally, further directions of research are proposed.

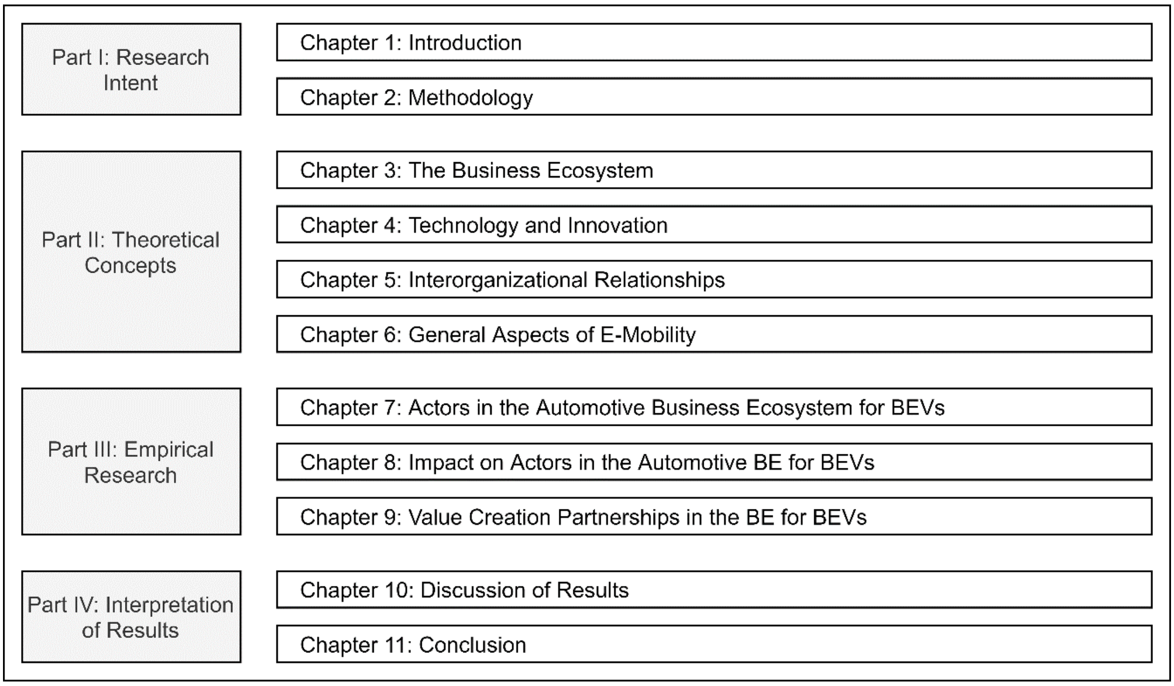


Figure 1: Content of this thesis (own creation)

2 Methodology

Three different approaches were part of the methodology for answering the research questions formulated in section 1.2.

The first research question R1 was answered by a database analysis with specified search criteria that will be outlined in chapter 7. However, as it is not possible to define exact boundaries of a business ecosystem, it has to be pointed out, that there is no way of listing all actors (Iansiti & Levien, 2004b, p. 40; Müller, 2014, p. 24). For this reason, it has to be clear that the analysis is only meant to give an impression over the general composition of actor groups in the business ecosystem for BEVs, but does not list all involved players individually.

The second research question R2 was answered by analysing relevant literature, namely publicly available scientific papers, books and reports which were complemented by business reports together with company publications. The process was continued until theoretical saturation was reached, which Eisenhardt (1989, p. 545) defines as *"the point at which incremental learning is minimal because the researchers are observing phenomena seen before"* in reference to Glaser & Strauss (1967, p. 61). Because the topic is very broad, and answers differ depending on the data source, the date of publication and other factors, the aim of theoretical saturation was combined with the pragmatic consideration of time that had already been invested into research. According to Eisenhardt (1989, p. 545), this is a common approach also in the practice of qualitative research.

The third research question R3 was answered using a mix of approaches. Although there are some theories on companies' cooperative behaviour in case of disruptive or discontinuous technological innovations in the literature (e.g. Basole et al., 2015; Ghezzi et al., 2015; Lambe & Spekman, 1997; Phillips et al., 2006; Rice et al., 1998) apart from some scientifically unbacked single statements not much information could be found on the specific case of BEVs. For this reason, exemplary companies had to be picked in order to gain insights, which meant choosing an exploratory case study research design (Gehman et al., 2017, p. 4). This approach has already been used by managerial research scholars inquiring the ramp-up of an electric vehicle industry (Galateanu & Avasilcai, 2016; Jacobides et al., 2016; Kalaitzi et al., 2019, p. 259; Mazur et al., 2013; Mazur et al., 2015; Rong et al., 2017; Shang & Shi, 2013; Sovacool et al., 2019, p. 6; Yin, 2003, p. 22).

In the course of the literature review and research process for research questions R1 and R2, original equipment manufacturers (OEMs) were identified as the most relevant players, and the German automotive industry proved to be the most active within the BEV business ecosystem (Dodourova & Bevis, 2014, p. 253; Rong et al., 2017, p. 234; Spieth & Meissner, 2018, p. 9). At the same time, according to the literature, the most important technologies incorporated in BEVs from a strategic point of view are energy storage and energy conversion technology – or in other words: battery packs, battery cells, battery reuse and recycling, charging infrastructure and electric motors (Germany Trade and Invest, 2018, p. 6; Kalaitzi et al., 2019, p. 257; Kampker et al., 2018, p. 45; Kasperk et al., 2018, p. 145). For this reason, cooperation strategies of OEMs in these areas were chosen as the focus for answering research question R3 and complemented with interorganizational relationships in research, development and manufacturing of whole BEVs, mobility services and raw materials, which were identified further relevant areas of cooperation in the results of research question R2. In contrast to many other case study research designs, only secondary data was used for the creation of cases. In order to do justice to the highly dynamic nature of the observed phenomenon, timelines were chosen as the main representation framework for the information gathered in the case studies.

2.1 Case Study Research

The development of case studies is a research strategy that focuses on single settings in order to understand certain individual, group, organizational, social, political and related phenomena. Case studies can be utilised to provide description and to test or generate theory. (Eisenhardt, 1989; Yin, 2003)

In other words:

> *A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. (Yin, 2003, p. 13)*

According to Yin (2003, p. 40), there are many different kinds of case study research, the most important ones being defined by a two-dimensional matrix that is depicted in Table 1. The first distinction has to be made depending on the number of cases considered in a case study. The second classification depends on the number of units within each case study. Altogether, there are single-case holistic designs, single-case embedded designs, multiple-case holistic designs and multiple-case embedded designs. (Yin, 2003, p. 40)

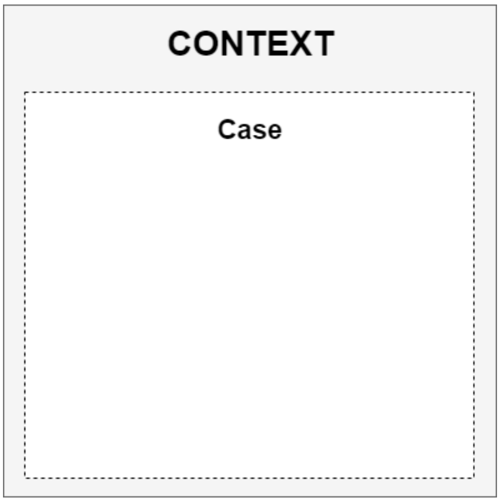
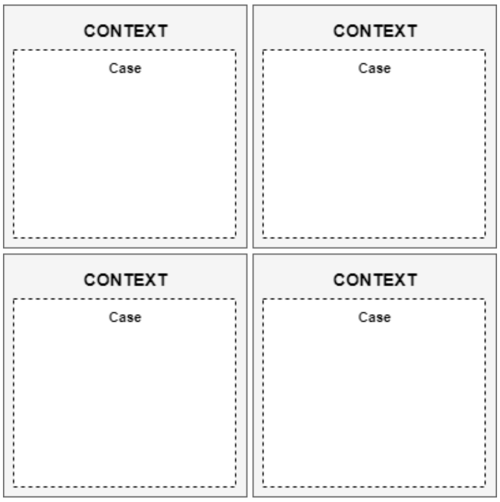
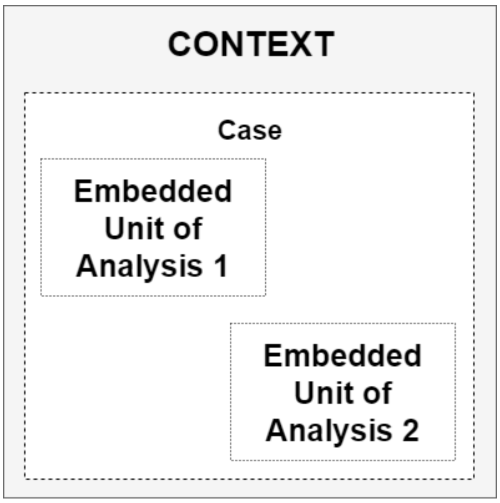
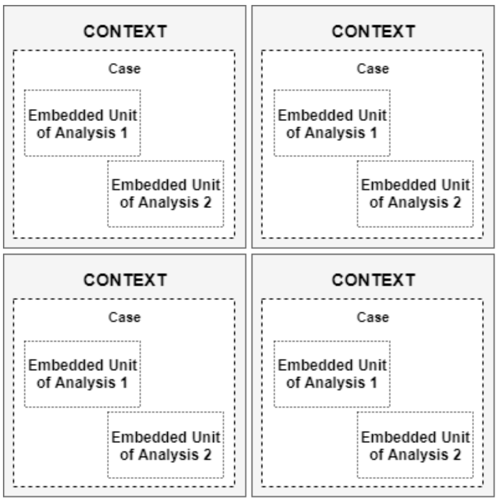
	Single-case designs	**Multiple-case designs**
Holistic (single unit of analysis)		
Embedded (multiple units of analysis)		

Table 1: Basic Types of Designs for Case Studies (according to Yin, 2003, p. 40)

Although all designs have the potential to lead to successful case studies, multiple-case designs should be preferred over single-case studies. They can prevent scepticism by other researchers and offer analytic benefits. (Yin, 2003, pp. 53–54)

The replication logic for a multiple-case study design is directly derived from experiments and not to be confused with statistical sampling of multiple respondents in a survey. The immediate research goal for the second case study is to replicate the effects observed in the first one. For this reason, there is no statistical sampling logic that allows an exact definition of the optimum number of cases. If only few cases are considered, the context conditions should be as similar as possible in order to be able to guarantee adequate support for the initial propositions. (Eisenhardt, 1989, p. 537; Yin, 2003, p. 47)

In order to guarantee for the best possible match between the evidence gained from case studies and the initial research questions, an appropriate research design is needed. This exceeds the purpose of a work plan and rather constitutes a logical than a logistical problem. (Yin, 2003, p. 21)

The five components of a case study research design listed by Yin (2003) are:

1. A study's questions (Eisenhardt, 1989, p. 536). This point has already been done by formulating the research questions in section 1.2. According to Yin (2003, pp. 21–22) case study research is most appropriate for "how" and "why" questions. This perfectly suits to research question R3.

2. Its propositions. As the research into the automotive business ecosystem for BEVs is still relatively new, an exploratory case study design was chosen (Kalaitzi et al., 2019, p. 259). Although every exploration should still have some purpose that has to be stated in the case study design, an exploratory case study does not have to have any propositions (Yin, 2003, p. 22). The purpose is already implied by the research question: to identify changes in the relationships between companies in the automotive business ecosystem caused by the trend towards BEVs.

3. Its units of analysis. As case studies are used to answer research question R3, which aims at the changes in value-creation partnerships induced by the shift to BEVs, one might think that the unit of analysis would be the interorganizational relationships between an OEM and a specific supplier of electric engines or battery technology. However, the OEMs themselves were chosen as units of analysis because these companies are the main players in the automotive business ecosystem (Dodourova & Bevis, 2014, p. 253). Following this fact, the assumption was made that all interorganizational relationships forged by OEMs with any other company are mainly derived from their own strategic considerations and their product portfolio. This allowed a concentration on the OEMs without consideration of the strategic perspective of suppliers in the case studies and meant choosing a multiple-case holistic research design.

4. The logic linking the data to the propositions. Linking was done by pattern matching, where a connection is established between information gained in the case study and a theoretical proposition (Yin, 2003, pp. 26–27). For doing this, the general tendencies illustrated by the timelines were summarized in a table that was used for theory formulation.

5. The criteria for interpreting the findings. Together with the fourth component, this has been the least well developed in case study research. For this research, the main focus was laid on the changes over time, which is why timelines - as described in chapter 2.2 - have been chosen as the means to represent the findings. In contrast to other research techniques, there is no possibility to apply statistical analysis to the results (Yin, 2003, pp. 26–27). In reference to Langley (1999), the chosen approach for research question R3 can be described as a combination of visual mapping and narrative techniques as applied in process research. Both are suitable as intermediate steps from raw data towards general theory building. By subsequently comparing a number of visual representations and creating causal maps to explain the observed differences, a more general theory can be derived. This approach is therefore especially useful for a multiple case study design. (Langley, 1999, p. 702).

In order to achieve a high quality research design, Yin (2003, pp. 33–34) named four tests for judging the quality of any empirical social research.

1. Construct validity: establishing correct operational measures for the studied concepts

This test poses a problem for case study research. Very often, subjective judgements are used to collect the data. For this thesis, three different approaches have been taken into account in order to guarantee for high construct validity.

a. The main events for the timelines, which represent a core part of all three case studies, have been chosen following press releases published by the involved companies and after searching for relevant information in databases, news portals and interviews with top management representatives. The exact procedure is outlined in section 9.2.

b. Data triangulation (see chapter 2.3) was used for case development in order to improve the accuracy of the statements. For reasons of confidentiality, no company representative could be interviewed for the case studies directly. For this reason, only secondary data could be used for case study development.

c. Timelines are chosen as the way of representing the core information gathered in the case studies. This is considered as a means to improve the objectivity of the study, as the chronological order of information ensures reporting of events in the same order as they happened. Timelines can be considered a way of visual mapping common in process research (Langley, 1999, p. 700).

2. Internal validity: establishing a causal relationship that stands in contrast to spurious relationships

   This is only needed for explanatory or causal studies, but not for descriptive or exploratory studies. However, for theory generation, causal relationships were assumed after identifying chronological sequences of events and relevant statements in business reports, press releases and publicly available transcripts of interviews with top management representatives.

3. External validity: establish a domain to which a study's findings can be generalized

   This has been especially problematic in doing case studies, especially for single-case designs. For this thesis, this problem was handled by choosing a multiple-case approach. This way, the results should be generalizable among all OEMs that are engaged in BEV development (Fixson & Park, 2008, p. 1312). The generalization is not automatically valid, but replicating the findings from the first case to the second and third case usually provides strong support for the gained insights.

4. Reliability: demonstrating that the operations of a study can be repeated with the same results.

   Three separate measures were used in order to achieve reliability:

   a) By defining and following the routine outlined in section 9.2, repeatability of the results featured in the timelines was guaranteed. If the same information sources for choosing relevant events are used, the same results should be found.

   b) In addition to that, classification scales were introduced that allowed easy categorization of interorganizational relationships and vehicle projects. Relationship types were defined to be as easily distinguishable as possible in order to allow a consistent classification regardless of the investigator. The exact definition of relationship types is given in section 5.3.

   c) A case study database was developed and complemented by case study protocols as proposed by Yin (2003, p. 101). This was used to guarantee traceability of all data sources and relevant additional information as well as for keeping an overview over the amount of information that was gathered.

Data for the development of case studies can come from many different sources of evidence, the most important ones being documentation, archival records, interviews, direct observation, participant-observation and physical artefacts (Yin, 2003, p. 83). Although the terms case study and qualitative research are often mixed up, case study research can involve a combination of quantitative and qualitative data or only one of them, and not all qualitative research includes the use of case studies (Eisenhardt, 1989, p. 538; Yin, 2003, pp. 14–15).

As there was no direct access to participants, direct observations or comprehensive archival data, and interviews were not possible due to reasons of anonymity and confidentiality, the main sources of evidence used in this study are various kinds of documentation. Those offer the advantage of stability, they are unobtrusive, exact and allow broad coverage of the topic (Yin, 2003, p. 86). However, the disadvantages of documents as a basis for case study research include low retrievability, biased selectivity in case of incomplete collections and reporting bias by the author or publisher of documents (Yin, 2003, p. 86). Low retrievability was addressed by using a case study database and creating digital copies of all used files. Biased selectivity was avoided by defining the procedure that is described in section 9.2. Of course, a reporting bias in data published by a company itself cannot be neglected. In reaction to this fact, other secondary data was used to complement the gathered information.

Methodological considerations finally resulted in the decision to pursue an exploratory holistic multiple-case approach. As the optimal number of cases is mainly dependent on the intended number of case replications, a design consisting of three different holistic cases embedded within similar environments was chosen (Yin, 2003, p. 51).

Besides the approach described by Yin (2003), many different methods for building theory out of case studies can be found in the literature, the three most-cited scholars in this area being Gioia (2012), Langley (1999) and Eisenhardt (1989). Gioia especially stresses the importance of data structure, which is mainly built up from categorizing themes emerging in interviews in first- and second order-analysis depending on the point of view taken in consideration and with the aim to build a theory that is well grounded in the collected data upon the basic skeleton of data structure (Gioia et al., 2012). In general, Gioia's method allows the description of events as experienced by those directly involved into them (Gehman et al., 2017, pp. 3–4). Eisenhardt's most important concern is exceeding the level of just describing causal sequences of events but rather shedding light on the reasons of the described events and their connections. This is mostly done by cross-case analysis and incorporating existing literature in a creative process of theory generation and hypothesis testing. The end result of this approach are theories that are based on causal laws explaining the observed phenomenon. (Gehman et al., 2017, p. 4) Langley does not propose one specific type of theory building but rather developed a framework consisting of seven generic types of building theory from process data (Langley, 1999).

In spite of their differences, those approaches all show many more similarities than differences, all having the aim to build theory that is *"parsimonious, testable, logically coherent, and empirically accurate*" from diverse data sources (Gehman et al., 2017, pp. 4–9). As theory building first and foremost is a creative process, adaptation and combination of methods should always be preferred over strict adherence to one of the presented approaches (Gehman et al., 2017, p. 10; Langley, 1999, p. 708).

For this reason, theory building strategies originating from process research and described by Langley (1999) were used for data representation and abstraction of case study data in this thesis. The step of representing the narrative data gained through case study development in the form of timelines basically is what Langley refers to as "visual mapping" (Langley, 1999, p. 702). This is a strategy that can serve as an intermediary step towards the formulation of hypothesis (Langley, 1999, p. 707).

2.2 Timelines

Case studies are the preferred way of research for examining contemporary events, whilst histories are used if a direct influence is impossible and there is no possibility to access actual behavioural events (Yin, 2003, pp. 7–8). The shift to BEVs in the automotive industry for sure is a contemporary event, although first BEVs already existed at the end of the 19th century, when the internal combustion engine (ICE) had not yet emerged as dominant technology (Gupta-Chaudhary et al., 2018, p. 8; Kampker et al., 2018, p. 4). However, as in historical research, no relevant persons could be interviewed to the exact topics of the case studies for reasons of confidentiality and anonymity. As a consequence, a different approach had to be found, that paired the advantages of case study research with the difficulty of only relying on secondary data for case development and hypothesis building. In contrast to most process studies, events investigated by this thesis are well-defined in terms of their time horizon and scope (Langley, 1999, p. 692). This is partly due to the high-level interpretation of events, which are BEV projects and interorganizational partnerships in this area (Langley, 1999, p. 693). For this special situation, the approach chosen by Mazur et al. (2015) offered a valid solution. They used a chronological graphical representation for events which they called a *"timeline"* in order to compare the efforts of German car manufacturers to reduce fleet emissions. Timelines are usually used as a didactic method for teaching in history sciences (Sauer, 2005). In process research terminology timelines are a kind of *"visual mapping"*, which is a very useful tool for providing structure in multiple-case studies (Gehman et al., 2017, p. 10). When combined with objective judgment criteria for choosing relevant data, this scheme can be regarded as an easy way to chronologically represent collected data in an objective way that can be applied in all kinds of qualitative research (Gehman et al., 2017, p. 14).

Then concept of timelines is an approach that has not yet been extensively used in combination with case studies. The advantages are: it allows for a great visual representation of the chronological order of events and the most important information can be depicted on one page (Langley, 1999, p. 700). In addition to that, an easy comparison and cross-case analysis of activities between the three considered companies is possible in spite of the huge amount of data that was collected for each case (Langley, 1999, p. 707).

However, graphical representation of data might be biased and not show all relevant dimensions. Observations like personal opinions, emotions and thoughts will most probably get lost in the step from data collection to graphical representation. For this reason, deeper generality is hard to achieve (Gehman et al., 2017, p. 8; Langley, 1999, pp. 702–703). The timelines in this thesis are developed from narratives in an intermediary step towards hypothesis building. Additionally personal opinions, emotions, thoughts and similar observations were not part of the collected data as a consequence of the reliance on secondary data only. Thus, application of timelines should be justifiable in this context, especially in combination with narratives.

Mazur et al.'s (2015) timeline concept as a type of Langley's (1999) visual mapping was further developed using different coding schemes for relationship types, the role played by each company within its business ecosystem, their relative position in the value-added chain, vehicle types and product maturity. This way, it allowed easy further analysis of data as recognition of the most important characteristics is facilitated. The exact coding and colouring schemes will be introduced in chapter 9; the basic elements of timelines are shown in Figure 2.

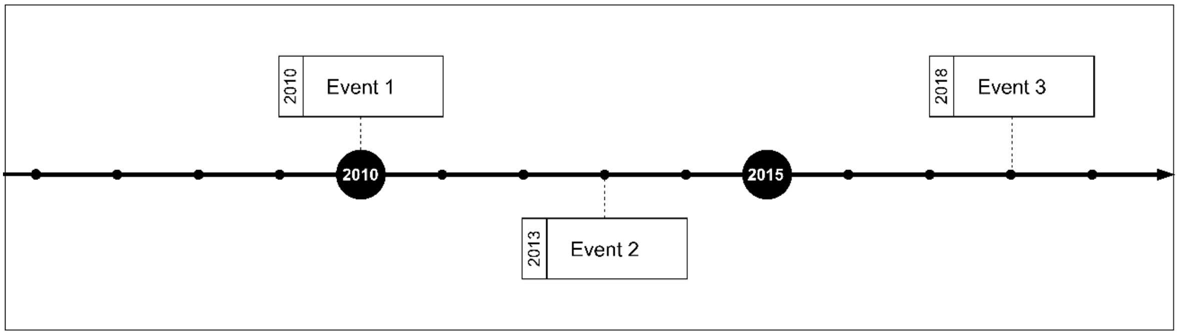


Figure 2: Basic elements of timelines (own creation according to Mazur et al., 2015)

For improving the quality of an analysis like the assignment of interorganizational relationships and vehicle projects to different categories, methods stemming from qualitative content analysis according to Mayring & Fenzl (2014, p. 550) can be used:

1. The intracoder check. After completion of the analysis task, some parts are analysed again without taking a look at the previously developed category system. This test is an indicator for the stability and reliability of the procedure.
2. The intercoder check. A second person is asked to analyse parts of the text material. Concordance of both results is an indicator for the objectivity of the procedure. In practice, total concordance is

almost impossible to achieve, which still leaves room for discussion. This is especially true if the categories were developed inductively.

Due to the low number of involved persons in this project, only the intracoder check was carried out but delivered good results. For this reason a high quality of the analysis is assumed.

2.3 Data triangulation

Triangulation means incorporating multiple sources of evidence in order to improve the accuracy of the statements made from them. The concept was first introduced to qualitative research by Denzin (1970).

According to Flick (2014, pp. 480–481), Denzin distinguishes four different kinds of triangulation:

1. Methodological triangulation. Here, different methods or different approaches within one method can be combined.
2. Data triangulation. Data that stem from different sources and have been collected at different times, at different places or from different persons are combined. This type of triangulation was used for improving the quality of this work of research. In order to reach true triangulation, information from multiple sources was collected that is aimed at the same phenomenon. By incorporating data triangulation in any research, the problem of construct validity can be addressed. (Patton, 1987; Yin, 2003, pp. 97–99)
3. Investigator triangulation. Several investigators examine the same phenomenon in order to eliminate subjective influences.
4. Theoretical triangulation. A research object is approached by using different theoretical perspectives.

In the current perception, triangulation is not just seen as a means to confirm research output by challenging it with a different approach. It rather tries to better reflect the complexity of the research object by extending the methodical and theoretical perspective. (Flick, 2014, p. 481)

Part II: **THEORETICAL CONCEPTS**

3 The Business Ecosystem

The concept of business ecosystems was first introduced by Moore in an award-winning article published in 1993 (Moore, 1996) and later extended by various additional aspects by other authors. In this chapter, first the basic concept as proposed by Moore (1993) will be introduced, followed by different definitions by other authors and Moore's lifecycle idea for business ecosystems. In addition to that, different roles and relationships within the business ecosystem are discussed. Finally, the differences of the concept in comparison with biological ecosystems are shown and an overview over other author's application to the traditional automotive industry is given.

3.1 Basic Concept

Moore (1993; 1996) attested a change in the logic of economic competition. According to his theory, traditional thinking in categories like industries, offers, markets, other companies as direct competitors and product improvement in order to better meet customers' needs is not enough anymore. In order to succeed, a company needs to break traditional industry boundaries and must also consider its context conditions – or in other words: its environment. Companies should not be seen in isolation, but as actors that are interconnected in their evolution. (Moore, 1996, p. 3)

As a consequence, he proposed a new paradigm of strategic thinking. Managers have to understand a company's surroundings and find the right approach to contribute to its development in a way that allows both the company and the company's surroundings to take advantageous strategic positions. Otherwise, even the best companies could fail if the environment around them changes. (Moore, 1996, p. 8)

In order to be able to understand the dynamics of this new business logic, system thinking is required. To facilitate this complex task, Moore proposed the use of analogies to nature. Due to many similarities, he identified biological ecosystems as an appropriate archetype to model this new economic reality. (Moore, 1996, p. 8). Consequently, he introduced the term *"business ecosystem"* for his approach. In his way of understanding, this concept stands in the tradition of what was formerly known as industries. A business ecosystem might span over several economic areas that were formerly known as industries and consists of individual actors that coevolve around innovations and work cooperatively and competitively at the same time. (Moore, 1996, p. 15) Moore (1993) also used his concept to describe the evolution of industries by the means of an ecosystem lifecycle. The exact definition of Moore's business ecosystem concept can be found in Table 2.

Coevolution is one central aspect of ecosystems. Moore (1996, p. 11) uses the definition introduced by American biologist Gregory Bateson:

"[Coevolution is] a stochastic system of evolutionary change in which two or more species interact in such a way that changes in species A set the stage for the natural selection of changes in species B. Later changes in species B , in turn, set the stage for the selecting of more similar changes in species A." (Bateson, 1979, p. 227)

This involves cooperation and competition in equal parts (Moore, 1996, p. 83). However, not just the focus of competition changed from rivalling companies to the superordinate category of rivalling ecosystems. The significance of cooperation also has changed. Whilst cooperation in the traditional industry perspective was limited to direct suppliers and customers, in the new business reality cooperation includes relationships to all players that are relevant in the innovation process (Moore, 1996, p. 56).

At the same time, Moore (1996, p. 16) also introduced another concept which he called *"opportunity environment"*. This is defined as *"a space of business possibility characterized by unmet customer needs, unharnessed technologies, potential regulatory openings, prominent investors, and many other untapped resources"* and can be understood as an equivalent to the larger environment in which a biological ecosystem is embedded (Moore, 1996, p. 16).

The aim of the business ecosystem concept is to identify and consequently nurture relationships between actors that can bring benefits to all ecosystem members (Moore, 1996, p. 28). In doing this, companies have to constantly balance efforts between strengthening the ecosystem as a whole and strengthening the own position as a leader within the ecosystem (Moore, 1996, p. 31). This is also depicted in Moore's (1996, p. 31) *"virtuous cycle of investment and return"* in Figure 3.

In this sense, the aim of strategy is to form whole business ecosystems instead of products that should be able to attract as much customer interest and as many contributing companies as possible in order to gain a competitive advantage over rival ecosystems (Moore, 1996, pp. 48–55).

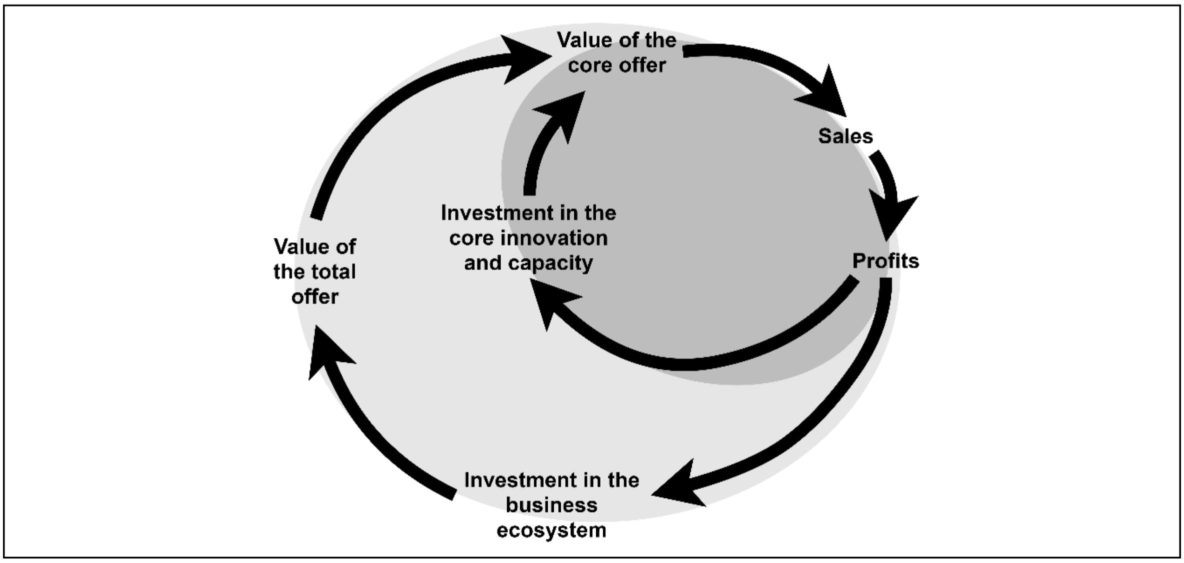


Figure 3: The virtuous cycle of investment and return (according to Moore, 1996, p. 31)

Moore (1996, p. 63) introduced a special framework within his concept that allows analysis of business ecosystems in seven dimensions. He considers these dimensions as the *"seven dimensions of competitive advantage"*, which must be addressed by campaigns in order to reach the favoured results on the two most relevant levels: the company's contribution to the ecosystem and the ecosystem itself. Those dimensions are:

1. Customers.
2. Markets.
3. Products.
4. Processes.
5. Organizations.
6. Stakeholders.
7. Government and Society.

Additionally, Moore (1996, p. 82) formulated four tests that should help practitioners to focus their thinking towards ecosystems. This way, they should be able to make sure that investment and attention are used for the creation of robust business ecosystems:

1. An established ecosystem should incorporate symbiotic relationships and create real value relative to already existing offerings by other ecosystems.
2. An established ecosystem should be able to attract critical mass for healthy expansion across available customers, markets and suppliers.
3. The company should lead innovation and coevolution within the ecosystem in order to maintain bargaining power.

4. The company must ensure that continuous performance improvements are made in order to avoid the death of the ecosystem.

3.2 Definitions of Business Ecosystems

Moore's concept led to a variety of different definitions by a range of authors. Not all were content with Moore's (1993) initial ideas and interpreted the concept differently. As already mentioned in section 3.1, Moore rather saw the concept as a successor of what was formerly known as industries and rendered obsolete by the emergence of a new economic paradigm (Moore, 1996, p. 15).

In contrast to this perception, Iansiti & Levien (2004b, p. 9) do not consider ecosystems as anything similar to industries. For them, biological ecosystems just offer great opportunities for gaining insights into different roles that can be played by companies within business networks (Iansiti & Levien, 2004b, pp. 9–35). They consider business ecosystems very similar to biological ecosystems in terms of structure, interaction, dependency and health (Iansiti & Levien, 2004b, p. 35). This analogy is regarded valid at various different levels like whole companies, business units, technologies and products, which means that the object of application is not restricted to interconnected enterprises (Iansiti & Levien, 2004b, p. 35). The main aim of Iansiti & Levien's (2004a; 2004b) work is the assessment of something they call *"ecosystem health"* and the identification of different roles that can be played within a business ecosystem in order to allow conscious utilization of each role's specific characteristics. Additionally, they stress the importance of platforms as a success factor in ecosystems, which in their view is *"a set of solutions to problems that is made available through a set of access points or interfaces"* and lays the foundation for other companies' value generation (Iansiti & Levien, 2004b, pp. 148–149). Interestingly enough, many of those topics have already been touched by Moore before, albeit superficially.

The concept of business ecosystem health as described by Iansiti & Levien (2004b, p. 46) consists of three different aspects of analysis: productivity, robustness and niche creation and can in some ways be compared to the four tests for ecosystem robustness proposed by Moore (Moore, 1996, p. 82). Productivity is understood as the rate of new technology implementation into products (Iansiti & Levien, 2004a, p. 3). In contrast to Moore's perception, robustness is just a subordinate criterion for Iansiti & Levien (2004b, p. 50) and defined as the ability of the business ecosystem to withstand environmental changes like discontinuous technological innovations without death or radical transformation so that the involved parties are able to continually benefit from the offered opportunities. Niche creation means that an ecosystem provides enough opportunities for many diverse players to be able to sustainably provide additional value to the created products and services (Iansiti & Levien, 2004b, p. 83).

Other major contributions to the theory of business ecosystems include Anggraeni et al. (2007), who developed more exact definitions for core elements of business ecosystems on the basis of social network theory, complex adaptive systems theory and the analogies offered by biological ecosystems and integrated them into a single comprehensive logic. Jacobides et al. (2018) identified business ecosystems as one of three different research directions in the field of ecosystems in strategic management. They extended the concept by a clear distinction to other sorts of interfirm interaction, a description of conditions, critical factors and mechanisms for business ecosystem evolution and alignment of actors. Peltoniemi & Vuori (2004) developed an alternative definition of business ecosystems by systematically approaching the topic from biological ecosystems and analysing possible analogies to businesses. Additionally, they connected the business ecosystem concept with complexity research in order to gain new insights. They identified four relevant complexity concepts in business ecosystems: self-organization, emergence, co-evolution and adaptation.

Different definitions of business ecosystems from the literature are shown in Table 2 in comparison with a general definition of biological ecosystems.

Authors	**Definition**	**Understanding of the concept**
Abercrombie et al (1990, p. 173)	*"Community of organisms, interacting with one another, plus the environment in which they live and with which they also interact; e.g. a lake, a forest, a grassland, tundra. Such a system includes all abiotic components such as mineral ions, organic compounds, and the climatic regime (temperature, rainfall and other physical factors). The biotic components generally include representatives from several trophic levels; primary producers (autotrophs, mainly green plants), macroconsumers (heterotrophs, mainly animals) which ingest other organisms or particulate organic matter, microconsumers (saprotrophs, again heterotrophic, mainly bacteria and fungi) which break down complex organic compounds upon death of the above organisms, releasing nutrients to the environment for use again by the primary producers."*	Biological term describing systems of organisms. The concept can be understood as real existing systems or just as an abstraction that is only useful for a discrete number of purposes.
Moore (1993)	*"In a business ecosystem, companies coevolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations."*	Systematic strategy thinking, as a successor of the industry concept. It can be focused on e.g. product categories or companies.
Moore (1996, p. 26)	*"An economic community supported by a foundation of interacting organizations and individuals - the organisms of the business world. This economic community produces goods and services of value to customers, who are themselves members of the ecosystems. The member organisms also include suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies. Those companies holding leadership roles may change over time, but the function of ecosystem leader is valued by the community because it enables members to move towards shared visions to align their investments, and to find mutually supportive roles."*	A concept to identify, understand and consequently nurture the evolution and the complex dynamics of relationships that allow success in economic communities.
Moore (2006, p. 33)	*"[…] intentional communities of economic actors whose individual business activities share in some large measure the fate of the whole community."*	A discrete organizational form.

Iansiti & Levien (2004b, pp. 8–9)	*"[…] business […] ecosystems are characterized by a large number of loosely interconnected participants who depend on each other for their mutual effectiveness and survival. […] business network participants […] share their fate with each other. If the ecosystem is healthy, individual species thrive. If the ecosystem is unhealthy, individual species suffer deeply. […] reversals in overall ecosystem health can happen very quickly."*	A concept to provide insights into the different roles that can be played by companies in their business network. It is not claimed that ecosystems are equivalent to industries or organized like them.
Anggraeni et al. (2007, p. 11)	*"The difference between a network and a business ecosystem is […] not in the object of study, but […] in the way we look at the relationships or interactions among the members and their environment, at the roles and interests of the members of the system, and at the mechanisms guiding these interactions toward the achievement of shared goal."*	A metaphor to break the traditional atomistic inside-centred view of single companies in business studies.
Jacobides et al. (2018)	*"An ecosystem is a set of actors with varying degrees of multi-lateral, non-generic complementarities that are not fully hierarchically controlled. [In business ecosystems] the ecosystem is […] an economic community of interacting actors that all affect each other through their activities, considering all relevant actors beyond the boundaries of a single industry."*	A discrete organizational form of economic activities that are complementary to each other.
Peltoniemi & Vuori (2004, p. 13)	*"[…] a dynamic structure which consists of an interconnected population of organizations. These organizations can be small firms, large corporations, universities, research centers, public sector organizations, and other parties which influence the system. Business ecosystem develops through self-organization, emergence and coevolution, which help it to acquire adaptability. In a business ecosystem there is both competition and cooperation present simultaneously."*	A complex, self-sustaining evolving system.

Table 2: Different definitions of business ecosystems

As can be seen from Table 2, there are two different approaches: Some see business ecosystems as a distinct organizational form, whereas others refer to the term as a metaphor that facilitates understanding of the complex system dynamics of modern economic communities and enables insights into the underlying mechanisms. Interestingly enough, this not only holds true for business ecosystems. Depending on the approach, also biological ecosystems can either be seen as real existing systems that are described by the concept or just as an analogy that is only applicable for a discrete set of purposes (Jax, 2006). The first is referred to as ontological approach, the second is known as epistemological approach (Scheiner et al., 1993; Sorokine et al., 2004). For this thesis, the latter interpretation should be used.

3.3 Lifecycle of a Business Ecosystem

Together with his initial idea of using biological ecosystems as an analogy to explain modern business dynamics, Moore (1993; 1996) introduced a lifecycle of business ecosystems, consisting of four sequential stages:

1. Pioneering

   At the first stage, a new business ecosystem is formed around a particular innovation that outperforms existing products or services. Although at this stage the ecosystem is just being formed, it still has to be complete enough in order to be able to deliver the whole value to early adopters. The aim of this phase is to reach approval for the viability of the concept and business model. In contrast to traditional value chains, this task is dynamic in character as it means actively creating new value chains by reorganizing internal and external capabilities. (Moore, 1996)

   In stage 1, the most critical of the seven tests for a robust business ecosystem is value, as the value of the new offering has to be high enough to create enthusiasm, commitment of resources and surmount the disadvantage of switching costs for both suppliers and customers (Moore, 1996, p. 72). For the leading company wanting to initiate a new ecosystem, this means it has to provide a new structure for synergistic relationships (Moore, 1996, p. 153). Additionally, it has to survey the overall performance and prevent replication or substitution of the core delivery at the same time (Moore, 1996, p. 127). Although ignored by many leading companies, relationships to government also have the potential to bring the decision for or against success of an emerging ecosystem (Moore, 1996, p. 130). Concurrently, anticipation of future events and developing capabilities for responding is a vital task for all members of the business ecosystem (Moore, 1996, p. 133).

   According to Moore (1996, p. 162), the pioneering stage of ecosystems can be facilitated by creating so-called *"micro-opportunities"* in the face of missing protection by national or other boundaries. Those are small niches that are considered irrelevant by big players and therefore allow safe growth until a number of them can be strung together in order to reach economies of scale or scope. In stage 1, protection offers advantages, although it might ultimately lead to vulnerability and competitive disadvantages of the whole ecosystem (Moore, 1996, p. 143).

2. Expansion

   At the second stage, the ecosystem should expand and fill up all available space (Moore, 1996, p. 72). This includes absorbing as high shares as possible of existing demand, key components and complementary products and services in order to avoid any other ecosystem from establishing in the same market segment or geographic region (Moore, 1996, p. 72). Competition in the new business reality does not concentrate on individual companies any more but mainly takes place between whole ecosystems (Moore, 1996, p. 163). This stage is marked by fierce competition and defensive action between rivalling business ecosystems that battle over territory, standards and market shares (Moore, 1996).

   In stage 2, the most important of the four tests for a robust business ecosystem is critical mass (Moore, 1996, p. 74). The ecosystem has to concentrate its forces on improved reliability and replication of the offering in order to recruit additional actors (Moore, 1996, p. 73). This includes incentives on all of Moore's (1996, p. 63) seven levels of competitive advantage (Moore, 1996, p. 141). However, it is not just pure numbers that count. The main challenge is to identify and evangelize the strongest suppliers and the best customers in order to render the whole business ecosystem as attractive as possible while at the same time still leading the direction of its development (Moore, 1996, p. 73). Success in taking over the leading role in ecosystem growth is not dependent on single entities like companies or people but rather on the capability of creating frameworks for cooperation and coevolution in the relationships between entities (Moore, 1996, p. 159). Sometimes, additional incentives are necessary at this stage in order to reach a sustaining level of growth (Moore, 1996, p. 140). Increasing scale and volume have to be complemented by increasing diversity of members which guarantees for a higher robustness and resilience of the ecosystem (Moore, 1996, pp. 138–139).

   Stage 2 is marked by a couple of internal as well as external challenges. Processes, organizations and stakeholders have to be able to handle risks and provide resources for scaling up (Moore, 1996, p. 142). External challenges include differentiation from other ecosystems and the difficult task of gaining the support of new partners which not only has the potential to strengthen the position of the own ecosystem but also to weaken other expanding ecosystems (Moore, 1996, p. 141).

3. Authority

At the third stage, a stable state is reached which puts an end to the highly dynamic processes that are significant for the second stage (Moore, 1993). However, this static state rather affects structure than size (Moore, 1996, p. 191). Players that were by chance able to secure an advantageous position within the ecosystem in the course of its growth now find themselves in some of the best roles as relationships and structures become fixed (Moore, 1996, pp. 75–76). This structure might also involve indirect links between players (Moore, 1996, pp. 75–76). Altogether, the mutual dependency of single players to the efforts of the whole ecosystem leads to an aversion against change that is shared by most of its members (Moore, 1993). The stability is held on to until adaption is necessary due to changes in environmental conditions like regulatory shifts, alterations in customer interest or fierce competition by another ecosystem (Moore, 1996, pp. 75–76).

The stability that comes along with maturity of the ecosystem leaves it vulnerable to attack by outsiders who imitate offerings that are essential to the business ecosystem. Therefore, while still fighting over the leadership of the ecosystem, companies have to make sure that their ecosystem exceeds the level of attraction offered by rival ecosystems. In order to continue its successful track, the leading company has to maintain a common vision of the future among ecosystem members and direct investments made by them. (Moore, 1996, pp. 76–77) As a consequence, keeping up authority is the main challenge in stage 3, especially as resistance to change can become a major issue (Moore, 1996).

The fierce internal and external competition leads to a squeeze in margins which makes cooperation and rationalization important matters (Moore, 1996, p. 192). However, a company should not put all eggs in one basket. Cutting costs through outsourcing, disintegration and other measures of rationalization should not be the only reaction to decreasing margins (Moore, 1996, pp. 192–193). In order to keep a status of authority within the ecosystem and a competitive advantage over other ecosystems, an *"innovation trajectory"* should be followed (Moore, 1996, p. 200). This is the only way to reverse the vicious cycle of decreasing margins and rationalization (Moore, 1996, p. 195). An innovation trajectory is defined by Moore (1996, p. 51) as *"a line of contribution that is invested in over time with singular commitment to attain deep and unique practical capabilities".*

Additionally, a company should make sure, that their innovation trajectory is a significant driver of improvement within the whole ecosystem and that investment made by others reinforces the company's position as the main technological pacemaker of the ecosystem. Those two terms are referred to by Moore (1996, pp. 203–205) as *"criticality"* and *"embeddedness".* Together with the innovation trajectory, they lead to bargaining power that is the key factor to success in this stage of a business ecosystem (Moore, 1996, p. 206). This mechanism is depicted in Figure 4. Following a successful innovation trajectory results in an ecosystem of disintegrated players instead of traditional vertically integrated companies (Moore, 1996, p. 202).

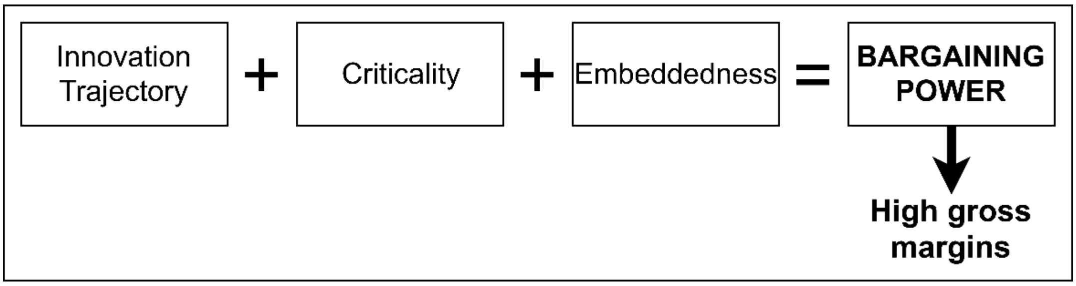


Figure 4: Components of bargaining power in business ecosystems (Moore, 1996, pp. 203–205)

4. Renewal or Death

Even a dominant ecosystem always bares the risk of becoming obsolete and being replaced by a radically new ecosystem that offers greater value to customers (Moore, 1996, pp. 80–81). Catalysts for developments like this might be changes in environmental conditions, or the emergence of superior ecosystems (Moore, 1996).

In order to avoid serious damage and prolong life, continuous performance improvement is the most important of the four fundamental tests. This process is referred to as *"technology insertion"* of innovations into existing ecosystems or *"asset reuse"* if existing assets are recombined. In some cases, companies try to direct customer demand to incremental innovations instead of radical performance improvements. This strategy can prove very dangerous because it leaves the door widely open for intruders or potential substitution. (Moore, 1996, p. 81)

Even if an ecosystem is heavily threatened, death is not the only possible outcome. There always is the chance of successful renewal, if the ability to recognize threats, rethink business models and remodel assets abounds in the affected ecosystem members (Moore, 1996, p. 231). Even the death of an ecosystem provides fertile ground for its successors (Moore, 1996, p. 231).

In order to maximize the probability of successful positioning for the future, companies should try to meet a good balance between investments in old and emerging ecosystems. Sometimes even synergies between those two efforts are possible. (Moore, 1996, p. 261)

The question of the right balance between involvement in new and old business ecosystems is often answered by using the well-known S-curve invented by Foster (1986). As in technological innovations, performance improvements are only marginal in the last stage of an ecosystems' lifecycle, regardless of the volume of investment. The application of the S-curve concept to business ecosystems is depicted in Figure 5. (Moore, 1996, p. 258)

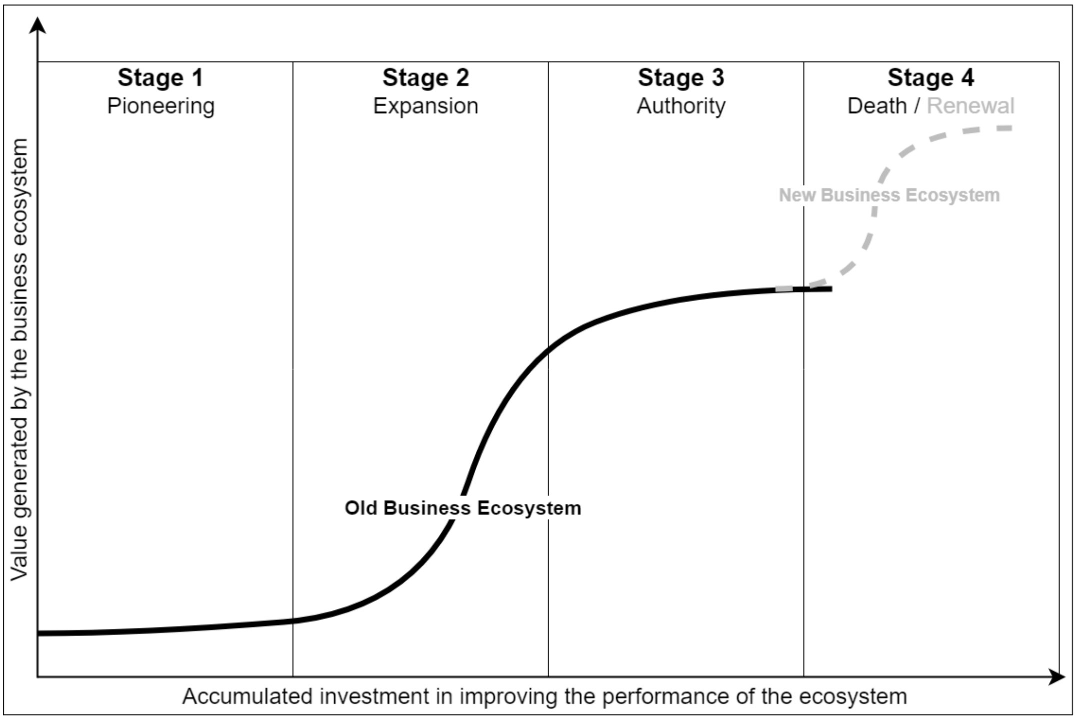


Figure 5: The S-curve of business ecosystems (according to Moore, 1996, p. 258)

3.4 Participants and their Roles in the Business Ecosystem

Moore's (1993; 1996) initial concept of business ecosystems did not include exact definitions of ecosystem entities. According to his ideas, ecosystems can establish around single products or services, groups of products or services, business models, central companies or even capabilities (Moore, 1993; Moore, 1996).

Although Iansiti & Levien (2004a, p. 3; 2004b, p. 39) consider it almost impossible to define exact boundaries of a given business ecosystem, they list a few typical components of ecosystems. Besides the core company they list suppliers, distributors, outsourcing companies, providers and makers of related products, services and technology as the key actors (Iansiti & Levien, 2004a, p. 1). Moore's (1996, p. 27) definition of ecosystem boundaries is quite similar, although he stresses that the question of which actors belong to one specific business ecosystem is easy to answer. According to him, a business ecosystem consists of *"customers, market intermediaries (including agents and channels, and those who sell complementary products and services), suppliers, and, of course, oneself"*. However, he remarks that those are just the main actors. Other relevant actors include the remaining stakeholders of the involved companies, government agencies, standards bodies, and even potential competitors. A typical business ecosystem following this description is depicted in Figure 6.

The inner sphere consists of direct suppliers, the core contributing company and its distribution channels. Together with suppliers of suppliers, direct customers, indirect customers, standards bodies and complementary companies, they make up the extended enterprise. Finally, the business ecosystem additionally includes government agencies, other stakeholders and competing organizations. (Moore, 1996, p. 27)

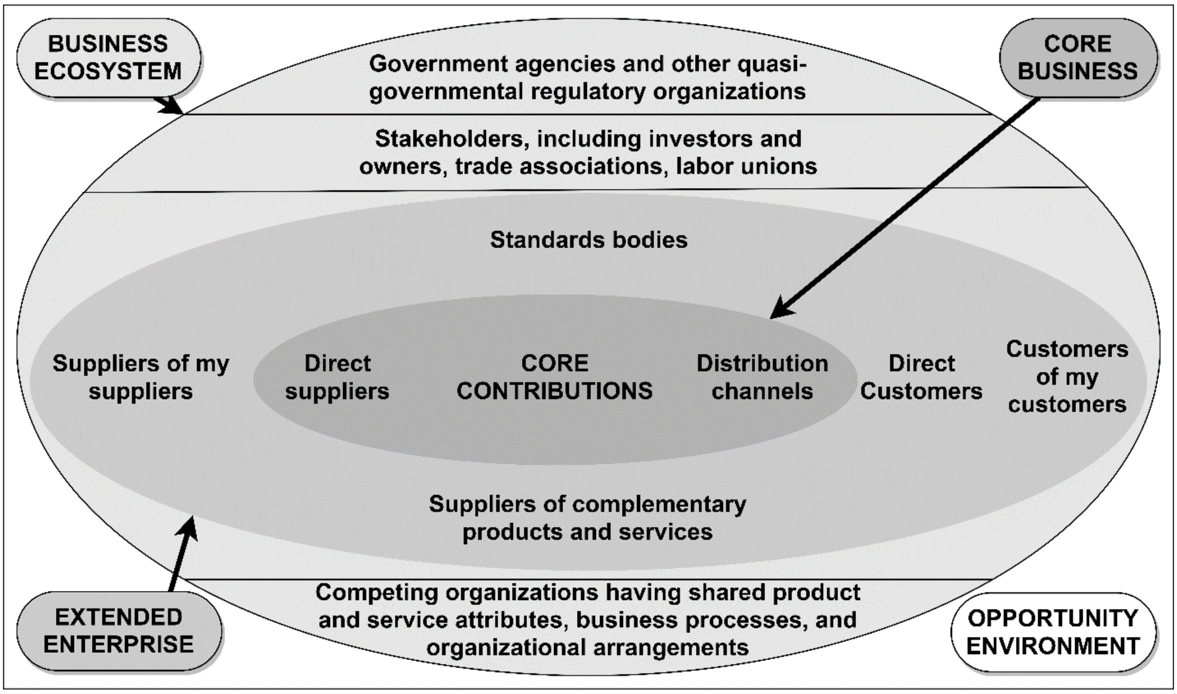


Figure 6: A typical business ecosystem (according to Moore, 1996, p. 27)

In traditional strategy thinking, the focus of attention most often did not even exceed the core business. The idea of business ecosystems is to extend this view and consider the whole business ecosystem which comprises of more companies than those the core contributing company has direct links to. (Moore, 1996, p. 26)

Iansiti & Levien (2004a; 2004b) extended Moore's business ecosystem concept by introducing different roles that can be played by actors in order to improve ecosystem health. Those exceed the level of Moore's contributions in this area by far, who only identified the two distinct roles of ecosystem leaders and ecosystem followers (Moore, 1993; Moore, 1996, p. 193). According to Iansiti & Levien (2004a, p. 7), the role a company should choose to play within its ecosystem depends mainly on its type and plans for the future. However, they also point out that this choice can also be influenced by two factors belonging to its environment: the rate of change and innovations – called *"turbulence"* - and the complexity of its relationships to other actors in the ecosystem.

Following this framework, four distinctive strategies can be chosen by companies, as also depicted in Figure 7: commodity, keystone, niche and physical dominator. These types serve as archetypes, which means that actual companies might follow one type of strategy in one domain, while still acting consistent with another strategy in other domains (Iansiti & Levien, 2004b, pp. 103–104). As companies might be involved in more than just a single business ecosystem, this means they can also play different roles in each of the ecosystems they are part of. Additionally, companies might change their chosen strategy in the course of the ecosystem lifecycle or their own evolution (Iansiti & Levien, 2004a, p. 10; Iansiti & Levien, 2004b, p. 140).

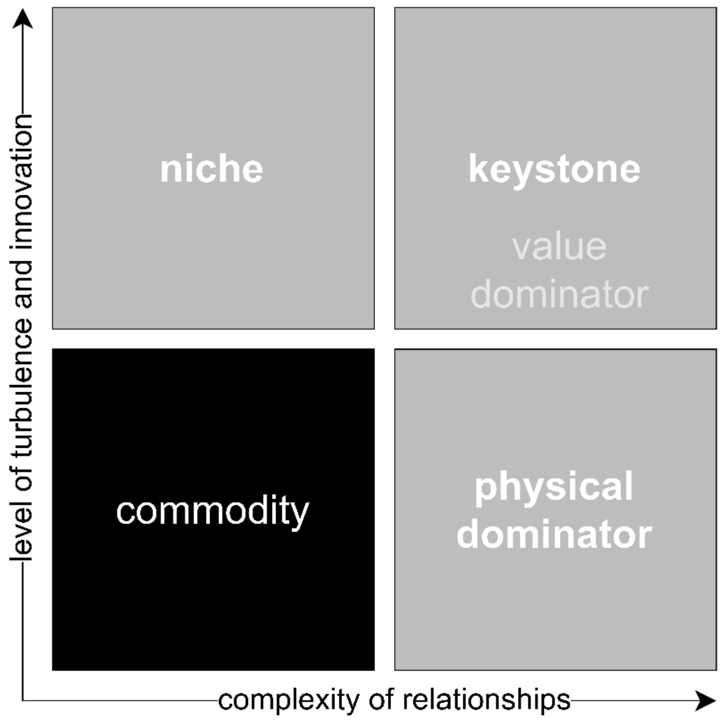


Figure 7: The choice of ecosystem strategy (Iansiti & Levien, 2004a, p. 7)

1. Commodity

   There are some certain cases, where ecosystem thinking is not necessary and the old business logic is still in place. This applies to companies that act in stable and mature business contexts and which are relatively independent from other organizations. However, even in these environments, ecosystem thinking is likely to become necessary in the future. (Iansiti & Levien, 2004a, p. 7)

2. Keystone Players

   In biological ecosystems, species that strengthen their own position within the ecosystem by providing benefits to the ecosystem as a whole are called keystone players. As the term suggests, removal of these species can have dramatic consequences, lead to the collapse of the whole ecosystem or extinction of many more species. (Iansiti & Levien, 2004b, pp. 68–69) This term can be transferred easily to business ecosystems. According to Iansiti and Levien (2004b, p. 9), hubs of business networks most often play the role of such keystones. They provide platforms, manage external resources, serve as regulators and by doing so promote diversity and consequently increase ecosystem health.

Keystones do not follow this strategy without egoistic motives. By encouraging change and increasing ecosystem health, they first and foremost increase the probability of their own survival in the face of disruptive changes (Iansiti & Levien, 2004b, p. 71). Despite their dramatic influence on the whole ecosystem, keystone players only constitute a small physical share of their respective ecosystem and do not have any ambitions to occupy every existing niche in their ecosystem (Iansiti & Levien, 2004b, p. 79). In fact, they act quite the contrary by creating niches that allow other players to thrive. They invest in the integration of technological innovations, make them available to others and this way represent the corner stones for the efforts of niche players. (Iansiti & Levien, 2004b, p. 83) In ecology, this type of mutually beneficial cooperation is known as *"symbiosis"* (Iansiti & Levien, 2004b, p. 217).

Iansiti & Levien (2004b, p. 91) identified two general components of this type of strategy. The first is to create value, the second to share the created value with other members of the ecosystem in a way that is easily scalable without an explosion of costs (Iansiti & Levien, 2004b, p. 96). Balancing these two components is the main challenge in following a keystone strategy. While sharing value in order to increase ecosystem health, the company still has to extract the right amount of value for its own sake (Iansiti & Levien, 2004b, p. 75).

Value sharing is often accomplished by providing platforms. According to Iansiti & Levien (2004b, pp. 148–149), platforms *"serve as an embodiment of the functionality that forms the foundation of the ecosystem, packaged and presented to members of the ecosystem through a common set of interfaces"*. This way, they lay the foundation for other companies' value generation.

Due to its robustness, a keystone strategy is especially recommendable in situations of changes in technology or market behaviour (Iansiti & Levien, 2004b, p. 117). The concept of keystone players resembles the idea of Moore's (1996, p. 31) *"ecosystem leader"*, although he actually mentions keystones as the most critical species in an ecosystem. Similar concepts have been identified by Dhanaraj & Parkhe (2006) in *"network orchestrators"*, *"hub firms"*, *"key actors"*, *"triggering entities"*, *"strategic centers"* and *"flagship firms"*.

3. Dominators

Besides keystone players, companies in hub positions of a business network can also choose a dominator strategy. According to Iansiti and Levien (2004b, p. 74), there are two different types of dominators: classical or *"physical dominators"* and *"value dominators"* or *"hub landlords*".

   a. Classical dominators / Physical dominators

   A classical dominator aims to secure a huge share of control and the majority of both value creation and value capture within its ecosystem for its own (Iansiti & Levien, 2004b, p. 74). This is accomplished mainly by seeking vertical or horizontal integration as in traditional industry-cantered business paradigms and finally ends in the conversion of the company into its own ecosystem (Iansiti & Levien, 2004a, p. 7; Iansiti & Levien, 2004b, 115-116). In contrast to keystone players and value dominators, classical dominators make up for a high physical portion of the ecosystem by taking over the roles and functions of other players, effectively eliminating them from the ecosystem (Iansiti & Levien, 2004b). Of course, the consequence is a decrease in diversity. Although this can prove beneficial if too much diversity threatens stability or compatibility, it might ultimately affect ecosystem health (Iansiti & Levien, 2004b, pp. 116–120).

   In order to secure the future of its business, classical dominators have to invest heavily in internal research and development, this way compensating the inexistent contributions by other ecosystem members. In stable conditions, this strategy can play out very well and lead to extraordinarily high returns in the short run. However, in the long turn, the company finds itself exposed to a myriad of threads, which might eventually lead to a collapse of the whole ecosystem or substitution by alternative, more open business ecosystems. Even if collapse fails to materialize, this strategy at least keeps the ecosystem from unleashing its full potential and impairs an ecosystem's robustness, especially in changing environmental conditions. (Iansiti & Levien, 2004b, pp. 116–118).

Despite the risks that are inherent in following a classical dominator strategy under uncertain technological and economic conditions, the approach can prove quite appropriate under different circumstances. This includes situations in which the pace of innovation is low, whenever large and highly focused commitment is needed for innovation and especially in cases where risk is too high for decentralized business networks to bear. (Iansiti & Levien, 2004b, p. 119)

b. Value dominators / Hub landlords

In contrast to classical dominators, value dominators try to extract as much value from the ecosystem as possible, but without contributing to value creation in an equal scale. They decline to integrate vertically or horizontally in order to have actual control over the assets their own contribution depends on, but at the same time want to improve their own value capture to a level that renders the business models of their niche players unsustainable (Iansiti & Levien, 2004b, p. 113).

The impact on ecosystem productivity is disastrous, as not just niche players are eliminated from the ecosystem but also their actual niches and the functions they performed (Iansiti & Levien, 2004b, p. 120). At the same time, value dominators do not take any actions to ensure the persistence of their ecosystem. Their only innovative efforts are concentrated on new ways to increase value extraction even further (Iansiti & Levien, 2004b, p. 119). For this reason, value dominator strategies prove highly pernicious not just for the business ecosystem but ultimately also for the company itself by undermining the ecosystem's fundamental stability (Iansiti & Levien, 2004a, p. 7; Iansiti & Levien, 2004b, p. 113).

Like keystone players and quite contrary to classical dominators, value dominators only occupy a small number of actual hubs in their ecosystem (Iansiti & Levien, 2004b, p. 75). Regardless of the technological or economic circumstances and the relationships to other members in the ecosystem, value dominator strategies are always fundamentally deficient (Iansiti & Levien, 2004a, p. 7).

4. Niche players

Whilst keystone and dominator strategies are suitable for companies that occupy hubs in their respective business ecosystems, these only contribute for a small amount of all ecosystem actors (Iansiti & Levien, 2004b, p. 10). The bulk of the ecosystem is made up of a high number of small firms occupying niches that are created by keystone players and which only have an average number of relationships to other companies (Iansiti & Levien, 2004b). Those so-called *"niche players*" are focused on developing their own highly specialized capabilities and leveraging key assets and technologies provided by others through symbiotic relationships, mainly in the shape of platforms (Iansiti & Levien, 2004b, p. 10).

Niche players are the main contributors to value creation and innovation within an ecosystem as innovation is their only raison d'être (Iansiti & Levien, 2004b, p. 10). If a niche player is not able follow the route of innovation, chances are high it will get in conflict with other ecosystem members, eventually becoming a commodity and being incorporated into the platform offered by the keystone player (Iansiti & Levien, 2004a, p. 9). For this reason, specialization and differentiation are the main factors of success for niche players (Iansiti & Levien, 2004b, p. 126).

Companies following a niche strategy should always keep an eye on their dependency on keystone players' contributions and opt for interfaces that allow interchangeability of their partners (Iansiti & Levien, 2004b, pp. 135–136). This way they are able to improve their collective bargaining position and switch to another ecosystem if a keystone player tries to exert dominance over the niche players of its ecosystem or becomes obsolete in the face of other emerging ecosystems or technologies (Iansiti & Levien, 2004a, p. 10; Iansiti & Levien, 2004b, pp. 137–139). According to Iansiti & Levien (2004b, pp. 138–139), it is exactly this competition of business ecosystems for *"mobile niche players"* that keeps keystone players honest and business ecosystems healthy. However, tight coupling between partners usually is more efficient (Iansiti & Levien, 2004b, pp. 136–137).

Table 3 gives a short overview over the main characteristics of the roles as defined by Iansiti & Levien (2004b).

Strategy	Definition	Presence	Value Creation	Value Capture	Focus and Challenges
Keystone	Actively improves the overall health of the ecosystem and, in doing so, benefits the sustained performance of the firm.	Generally low physical presence for its impact; occupies relatively few nodes.	Leaves vast majority of value creation to network; what value it creates internally it shares widely.	Shares value widely throughout network; balances this with capture in selective areas.	Focused on creating platforms and sharing solutions to problems throughout the network. A significant challenge is to sustain value creation while balancing value extraction and sharing. Deciding which areas to selectively dominate is another challenge.
Classical dominator	Integrates vertically or horizontally to manage and control a large part of its network.	High physical presence; occupies most nodes.	Responsible for most value creation itself.	Captures most value for itself.	Primary focus is on control and ownership – defining, owning, and directing most of what the network does.
Value dominator	Extracts as much value as possible from its network without directly controlling it.	Low physical presence; occupies few nodes.	Creates little if any value; relies on the rest of the network for value creation.	Captures most value for itself.	A fundamentally inconsistent strategy. Though landlords refuse to control their networks while relying on them as their only source of value, they simultaneously extract so much value from those networks that they put their existence at risk.
Niche player	Develops specialized capabilities that differentiate it from other firms in the network.	Very low physical presence individually but constitute the bulk of ecosystems where they are allowed to thrive.	Collectively create much of the value in a healthy ecosystem.	Capture much of the value they create.	Focused on specializing in areas where they have or can develop capabilities, while leveraging the services provided by the keystones in their ecosystem.

Table 3: Characteristics of different ecosystem strategies (Iansiti & Levien, 2004b, p. 75)

3.5 Differences between Biological and Business Ecosystems

Despite the useful analogies that biological ecosystems offer for gaining insights into the dynamics of networked business entities, their explanatory power is limited. Similarities in characteristics between business ecosystems and biological ecosystems include their structure, mutual dependency, the shared fate of individual members with the whole network, the pace of changes, the complexity of interactions, robustness against external shocks, specialization of members and innovation capability. (Anggraeni et al., 2007, p. 20; Iansiti & Levien, 2004b, pp. 36–37)

The analogy works equally well for different levels of consideration; be it whole companies, business units, technologies, processes or products (Iansiti & Levien, 2004b, p. 35; Moore, 1996, p. 26). Interactions at one level often shape interactions at another level (Iansiti & Levien, 2004b, p. 35).

However, some modifications have to be made in order to allow better suitability of the concept to corporate strategy. It is important to at least keep them consciously in mind in order to make use of the concept's full potential.

The major difference between species in a biological ecosystems and companies is the consciousness of decisions. Unlike biological ecosystems, business ecosystems consist of real people who make decisions and therefore are social systems. Although animals sometimes choose their partner, their habitat or their behaviour deliberately, they lack the understanding of the entire system and the vision of the future that is pursued by strategists, managers and investors alike (Moore, 1996, p. 18).

Additionally, business ecosystems often compete with each other over market shares, customers, partners and resources (Iansiti & Levien, 2004b, p. 38). This ecosystem-to-ecosystem competition does not have an equivalent in biological ecosystems, the closest analogue being a gardener battling with weeds (Moore, 1996, p. 163). The same holds true for the attention of outside observers like customers and the mobility of ecosystem members to switch between different ecosystems (Iansiti & Levien, 2004b, p. 38).

In contrast to business ecosystems, ecological ecosystems are not dependent upon innovation but just concentrated on their own survival. They simply do not have to satisfy any demand or to deliver new functions in order to survive. Although it improves their chances to spread, it still is not a focus of the observations about them. (Iansiti & Levien, 2004b, p. 38)

Business ecosystems and biological ecosystems both are subject to evolution and changes that become necessary in the face of external threads. In biological ecosystems, those changes can stretch over a variety of different time scales. Some might take place within the lifespan of individual organisms, while others take generations to be completed. Because businesses can direct their evolution consciously on their own, those different time scales are compressed into one roughly similar time scale for all business domains. Of course, this is just an approximation, as for example the evolution of the U.S. automotive industry took decades, whereas the personal computer business ecosystem evolved in the course of only a couple of years. (Iansiti & Levien, 2004b, p. 54; Moore, 1993; Moore, 1996, pp. 10–11)

As can be seen from these differences, the application of biological terminology to business networks is not perfectly suitable. However, if the analogy would be adapted radically in order to achieve fully matching characteristics, it would be too simplistic to deliver real insights. For this reason, it should be clear, that the analogy to ecology is chosen in order to allow the use of familiar terminology and vivid pictures for describing phenomena of modern business realities that are often ignored by existing theories. (Iansiti & Levien, 2004a, p. 6)

3.6 Similarities to other concepts

The business ecosystem concept is only one of the many existing approaches to describing networks of business actors. Another framework that is worth mentioning is Christensen & Rosenbloom's (1995) *"value* *network"*, which they define as *"the context within which the firm identifies and responds to customers' needs, procures inputs and reacts to competitors"* (Christensen & Rosenbloom, 1995, p. 234). The concept is derived from the idea of a connection between the structure of a product's or system's components and the structure of the network of their producers or markets. Products can be seen as systems of components whose nested network-like structure is defined by product architecture. Furthermore, those products again constitute the components of a system of higher order that is defined by the user. An example for this connection is a computer, which consists of motherboard, CPU, cooling unit etc. when considered as the system in question. At a higher level, the system might consist of the computer itself and its peripheral devices like printer, monitor, keyboard and mouse. As components and sub-components of all levels are tradeable goods and services that are provided by different producers, abstraction at a higher level leads to the understanding that a nested network of organizations exists, in which the producers sell the architected components of systems to integrators of a higher level. This nested network which evolves as a consequence of the consideration of all actors on different levels of the system in question is called the value network. (Christensen & Rosenbloom, 1995, pp. 238–240)

The aim of the value network concept is to explain the differences in the perceived attractiveness and the degree of difficulty associated with the development of technological innovations. It is argued that companies are likely to adapt their structure, culture and capabilities to their position within their respective value network. As all value networks differ dramatically from each other, companies will be far worse suited for competition in other value networks than that they have traditionally been involved in. For this reason, their ability to create new market applications for technology already mastered in other contexts might be limited. (Christensen & Rosenbloom, 1995, pp. 241–242) Consequently, Christensen & Rosenbloom (1995, p. 242) propose required capabilities in conjunction with new technology, the appropriate organization for innovation and the position within the value network as the decisive factors in pursuing disruptive innovations. For them, this is the explanation for the poor success of incumbent companies in delivering architectural innovations and entrant companies' lead in real innovative force (Christensen & Rosenbloom, 1995, pp. 235–242).

In contrast to the business ecosystem concept, the framework of value networks mainly allows a static observation of the system of actors and is not able to fully describe the dynamics that shape or change the structure of links between the involved organizations. This is in spite of the fact that the authors are aware of value networks' highly dynamic nature (Christensen & Rosenbloom, 1995, p. 240). Furthermore, the approach only covers companies which are directly contributing to the value-added chain and therefore the development, manufacturing or marketing of products. As a consequence, organizations only indirectly linked to the focal company are ignored although they might as well have an impact on innovation activities and economic success of companies. This downside is resolved by Brandenburger and Nalebuff's (1997; according Ritter et al., 2004, p. 176) similar concept of a firm's *"value net"*, which consists of suppliers, customers, competitors and complementors and also additionally considers governmental, R&D and educational institutions.

Another concept that can be compared to business ecosystems are clusters. This phrase was coined by Michael Porter in his book "The Competitive Advantages of Nations" in 1990. The concept emphasizes the significance of a company's environment and of locally bundled competencies and resources for gaining an advantage in global economic competition (Porter, 1990a, p. 13; Porter, 1998, pp. 78–90). He defines clusters as *"geographic concentrations of interconnected companies and institutions in a particular field"* (Porter, 1998, p. 78). The scope of a cluster includes the most important actors and linkages for competition. Although its boundaries might be congruent with national borders, clusters might as well overarch political boundaries. (Porter, 1998, p. 79) Interestingly enough, Porter remarks that clusters are not equally successful in all nations and industrial sectors as national values, culture, economic structures and history differ and are all relevant for economic success (Porter, 1990a, p. 140).

Clusters consist of entities that are relevant for business, which might be whole industries, manufacturers, customers, providers of infrastructure, suppliers of specialized inputs, distribution channels, complementary companies and government institutions like universities, standardization bodies, think tanks and trade organizations (Porter, 1998, p. 78). However, clusters are more than the sum of their parts (Porter, 1990a, pp. 139–140). Within clusters, mutual support between industries exists both through the existence of cooperation and competition (Porter, 1998, pp. 79–80). Cooperation includes coordination, trust, information flows and diffusion of innovations between all involved actors - horizontally, vertically and even laterally (Porter, 1990a, p. 140). Competition at the same time forces companies to upgrade diversity in R&D activities, specialize in niches, investigate new ways of strategic thinking, develop new skills and accelerate the process of factor creation (Porter, 1990a, pp. 139–140; Porter, 1990b; Porter, 1998, pp. 79–80).

Generally speaking, clusters affect competition in three ways by increasing companies' productivity, driving and directing innovation and stimulating new business formation (Porter, 1998, p. 80). This way, clusters allow companies to benefit from the advantages of virtually big enterprises or formal cooperation while still enjoying full flexibility (Porter, 1998, p. 80). These advantages include increased efficiency and effectiveness, better access to suppliers, public goods, employees and specialized information and an improvement in the comparability of performance (Porter, 1990a, p. 127; Porter, 1998, pp. 79–83). As productivity is an important factor for the prosperity of whole nations, cluster formation marks an important step in the transformation of countries to advanced economies (Porter, 1990a, p. 83; Porter, 1998, pp. 86–89). Although clusters continually evolve and potentially flourish for decades, a loss of competitive advantages always lies within the scope of what is possible. The most significant external threads to clusters are technological discontinuities and a shift in buyer behaviour, both rendering obsolete much of a cluster's expertise, knowledge, capabilities and business relationships. (Porter, 1998, p. 85)

In Porter's understanding, clusters are a concept explaining the global competitive advantage some regions have in the production of specific goods like Italian shoes and clothing, Silicon Valley's IT industry or Hollywood's entertainment business (Porter, 1998, p. 78). A firm's local business environment consisting of its geographic location and the proximity to other organizations, training facilities for employees, local customers and markets dramatically influences its economic success (Porter, 1990a, p. 50). As a consequence, Porter proposes a change in mind regarding the responsibility of specific parties for certain tasks in creating the preconditions for economic success, like for example the engagement of companies in public education (Porter, 1998, p. 90). Additionally, the concept can be understood as a catalyser for change, as it encourages the promotion of cluster initiatives by governments (Porter, 1990a, p. 16; Porter, 1998, p. 89). Porter sees clusters as an intermediate category in between arm's length relationships and hierarchy along the continuum of interorganizational relationships (see section 5), which combines the advantages of both polar types (Porter, 1998, pp. 79–80). Like business ecosystems, clusters show a co-existence of both competition and cooperation, mutual dependence and collective responsibility (Porter, 1998, pp. 79–80; Porter, 1998, p. 90). However, the geographic focus and the national economic perspective driving the concept are major differences that do not allow full representation of business ecosystems by means of the cluster framework.

Both approaches, the focus on the product system perspective and the geographical perspective, are combined in the study of organizational fields, which contains organizations, which *"in the aggregate, constitute a recognized area of institutional life"* (DiMaggio & Powell, 1983, p. 148). In a modern interpretation, this means the inclusion of key suppliers, consumers, regulatory agencies, competitors, and additional stakeholders like industry associations, labour unions and non-governmental organizations. The main advantage of the concept is its neutrality regarding the focus. An organizational field can be equalled to an economic branch, a geographic region or organizations concerned with a common topic. (Duschek & Sydow, 2011, p. 60)

Table 4 shows a comparison between clusters, value networks and business ecosystems.

	Cluster	Value Network	Business Ecosystem
Background	National economics	Product structure	Business strategy
Focus	Competitive advantage of local regions in global competition	Capability to develop discontinuous innovations	Competitive advantage through understanding the business dynamics between all relevant actors
Dynamics between actors	Partly explained	Illustrated but not explained	Explained
Geography	Geographic concentration	Anything from local to global	Rejects the role of geography
Competition and cooperation	Both simultaneously	Cooperation	Both simultaneously
Industry	Rarely conform to industrial classification systems	Different industries complement each other	Finds the term "industry" obsolete
Knowledge	Rivalry limits the willingness to share	Limited to operative information	Interconnectedness as the enabler and shared fate as the motivator of cooperation
Control	Fairly independent members	One powerful actor	Decentralized decision making

Table 4: Comparison between clusters, value networks and business ecosystems (based on Peltoniemi, 2005, p. 62)

3.7 Application to the Automotive Industry

Although the business ecosystem concept is most suitable for application to companies in fast changing environments, Moore (1996) used the long history of the traditional U.S. automotive industry as an example for illustrating his concept of business ecosystem lifecycle. Like for many of the traditional large industries, its evolution through all of the four stages took many decades (Moore, 1996, p. 85). Due to the fact that the automotive industry has had a huge impact on society and is one of the most networked and widely distributed business domains, this still is a reasonable choice (Duschek & Sydow, 2011, p. 57; Iansiti & Levien, 2004b, p. 6).

Stage 1 of the automobile-centred ecosystem started at the end of the 19th century and was marked by the struggles to materialize the full potential of individual mobility. Pioneers created the first real automobile business ecosystems. (Moore, 1996, p. 88)

Stage 2 of the automobile-centred ecosystem lasted until the late 1920s and showed legendary battles between the two major ecosystems that had established in the U.S. automotive industry: General Motors and Ford. These battles were fought not just over simple market share but also over the future direction the business should take. (Moore, 1996, p. 89)

Stage 3 of the automobile-centred ecosystem was signified by struggles over the distribution of profits. Opponents in these struggles were mainly other big corporations that served as suppliers for the automotive companies: steel companies, government and the rising labour unions. The resulting lack of focus on innovation finally led to the end of this stage as Japanese car manufacturers entered the U.S. market in the

1970s and posed immense challenges to the incumbent companies that had only marginally improved their products and processes since the 1920s. (Moore, 1996, pp. 90–92)

Stage 4 of the automobile-centred ecosystem finally saw a near collapse of Chrysler and Ford and some of their suppliers in the face of the new competition by Japanese companies. Eventually, the big players of the old automotive world adopted the practices of the newly evolving companies which led to the creation of the automotive world as we know it today. (Moore, 1996, pp. 93–94)

According to this perception, the business ecosystem for traditional internal combustion-powered vehicles nowadays stands at the crossroads between death and renewal. Environmental concerns, dependency on limited oil reserves and geopolitical conflicts could have a lethal effect and increase the speed of change dramatically.

Nowadays' trend towards environmentally friendly individual mobility was already predicted by Moore (1996). He saw two possible solutions for the future of traffic in the face of oil scarcity and environmental issues. The first he called *"intelligent transportation systems"*, which are computer coordinated systems of vehicles and roads. According to Moore (1996, p. 101) it is unclear, if the value this technology offers is convincing enough to be able to lead to development of a new business ecosystem. The other possibility is called *"hypercars"* and far more promising. It combines a hybrid drive consisting of an electric engine and a small gasoline engine with a lightweight bodywork made from fibre-reinforced plastics. (Moore, 1996, p. 101)

In fact what Moore calls *"hypercars"* is a similar approach like that actually chosen by many companies like BMW and e.Go almost twenty years after the book's publication. The absence of steel bodyworks allows omitting capital-intensive dies and stamps and lowers entry barriers for new players. The consequence of this development could be an ecosystem consisting of many small assembly and directly distributing companies like in the computer opportunity space. (Moore, 1996, p. 101)

4 Technology and Innovation

Already Schumpeter (1942, p. 82) identified innovations as the driving force behind industry evolution, even exceeding the influence of environmental changes and natural economic growth. According to Moore (1996, pp. 54–55), technological innovation is the reason for the existence of business ecosystems. The effort of creating and nurturing a business ecosystem is only economically justifiable to bring innovations to customers that deliver an entirely new set of benefits (Moore, 1996, pp. 54–55). For this reason, a short overview over the definition of technological innovation, technology, technique and different types of technological innovations is given in this chapter.

4.1 Definition of Technology

A single true definition of the term technology does not exist, although many authors from different fields like organizational management, sociology, political science, economics and anthropology have tried to evaluate the exact meaning (La Carroll, 2017, pp. 6–9; Wahab et al., 2012, p. 61). The word stems from the Greek words *"logos"* which means discourse or words and *"techne"* which describes an art or a skill. Combining these two, the initial definition of the word was either the arts of language, the discourse about the arts or the terminology of a particular art. (La Carroll, 2017, p. 1; Schatzberg, 2006)

This definition nearly stayed the same for the English term *"technology"* until the end of the 19th century. *"Technology"* meant the description and teaching of a practical art, and therefore was a field of study instead of the specific object of a study. This is most prominently shown in the name of the Massachusetts Institute of Technology which was founded in 1861. (Schatzberg, 2006)

The term finally received its modern meaning from the German word *"Technik"*, which referred to the practical arts as a whole - especially concentrating on engineering and modern industry in the late 19th century - and not to the field of study. American social scientists imported the concept of this German word to English in the 1930s and used the English term of technology as a translation, as the closer terms technic and technique rather were used for describing skill in executing fine arts like music or painting. According to American social historian Eric Schatzberg (2006), what now is understood as technology was described as *"useful arts"*, *"manufacturing"*, *"industry"*, *"invention"*, *"applied science"* and *"the machine"* in the pre-1930 era. (Schatzberg, 2006)

Whilst in other languages like German and French, there has always been a clear distinction between the terms technology and technique, those two words had the same meaning in English as they were both translated by use of *"technology"*. (Schatzberg, 2006) In German, the term *"Technik"* describes *"methods and procedures of material culture, especially in engineering and industry"* and *"Technologie"* refers to the study of these activities (Schatzberg, 2006; Schuh & Klappert, 2011, pp. 33–35). According to the Merriam-Webster dictionary, in English, *"technology"* is *"the practical application of knowledge"* or *"a capability given by the practical application of knowledge"* whereas *"technique"* refers to *"the manner in which technical details are treated (as by a writer) or basic physical movements are used (as by a dancer)"* (Merriam-Webster, 2019).

Despite its unclear definition, technology has a dramatic influence on the competitiveness of companies. Technologies can embody strategic resources and can pose enormous risks at the same time. For this reason, companies are forced to develop technologies as fast as possible while at the same time considering customer orientation and potential disruptive changes. (Schuh & Klappert, 2011, p. 6)

For this thesis, "technology" shall be used according to the definition given by the Merriam-Webster dictionary. Technology therefore is seen as scientific knowledge that is brought to practical application in the development of products and services, processes or other activities.

4.2 Lifecycle Models

The strategic value of specific technologies changes depending on a variety of different factors. As acquisition of new technologies often involves high risks and financial efforts, strategies for evaluating the potential impact of technologies on markets and a company's performance have been established. The capability of using these instruments for analysis in order to deduce appropriate strategic decisions is an essential factor in business competition. (Schuh et al., 2011, pp. 37–38)

One category of approaches especially considers time aspects, as most of the changes are correlated with a time dimension. Those approaches are most often called *"life-cycle models"*, and besides technology can also be aimed at products or industries (Taylor & Taylor, 2012, pp. 542–543). They allow explanation, description and prognosis of underlying technological developments and the respective options for all dimensions of strategy. Those lifecycle models illustrate typical examples of evolution over time and show the connection between time or any other time-related factor as the independent variable and parameters of industry or technology development as the dependant variable. (Schuh et al., 2011, pp. 37–38)

Because of the similarities between technology and industry lifecycle concepts and Moore's conception of an ecosystem lifecycle, the basic features of the most important approaches are outlined in this section.

The most important technology lifecycle concepts are the S-curve model introduced by Richard N. Foster (1986) of McKinsey and the approach by Arthur D. Little. According to them, the evolution of technology can be divided into five stages overall. After the *"embryonic stage"*, where technologies are initially created, technologies in the second stage are called *"pacemaker technologies"* and still are under development. They are based on scientific findings and show a high potential for influencing a company's future success. If the market potential of those pacemaker technologies is already realized in the growth phase, those are called *"key technologies"*. Technologies in this category represent an important constituent of an industry's technology base but are still only available to a limited number of companies, making them a competitive advantage. If a technology reaches the state of being widely spread and available to all, it is called *"basic technology"*. It becomes a commodity and therefore does not offer competitive advantages any more. *"Substituted technologies"* are at the last stage of technology evolution and signify the end of a technology's life when being substituted by alternative technologies. (Schuh et al., 2011, pp. 45–47)

In contrast to the basic concept of a technology lifecycle by Arthur D. Little (as depicted in Schuh et al., 2011, pp. 45–47), where the axes are time and the degree of exhaustion of competitive potential of the considered technology, Foster chose cumulated R&D expenditures and the technology's performance as the respective axes of his model (Taylor & Taylor, 2012, pp. 544–545). This way, his concept allows an explicit depiction of the declining performance improvements of a technology once maturity is reached. A comparative depiction of the two concepts can be seen in Figure 8.

A closely related concept is the industry lifecycle, which shows an industry's evolution over time. Due to the fact that an industry's evolution depends on the evolution of product classes which in turn are underpinned by technology, the industry lifecycle concept can be seen as a partial substitute for the technology lifecycle concept. (Taylor & Taylor, 2012) Furthermore, as Moore (1996) considers industries as the predecessors of business ecosystems, this concept can be regarded as the predecessor of his ecosystem lifecycle framework. Similar to the technology lifecycle concept, the industry lifecycle concept consists of an embryonic, growth and mature phase. In the embryonic phase, product design is simple and many firms enter the industry. The following growth phase is marked by stabilising product design and a reduction in the number of producers. During the mature phase, the number of producers decreases even further. (Taylor & Taylor, 2012, p. 543)

The most problematic aspect of using lifecycle models as a means for analysis and prognosis is the definition of criteria for parameter selection and determination of the exact data points the curve consists of. Additionally, an exact identification of the current status, the distinction between different phases and the deduction of concrete actions often proves difficult. However, the concept is quite useful as an auxiliary tool for facilitating the assessment of technologies, products or industries alongside a set of other measures. (Schuh & Klappert, 2011, pp. 37–38)

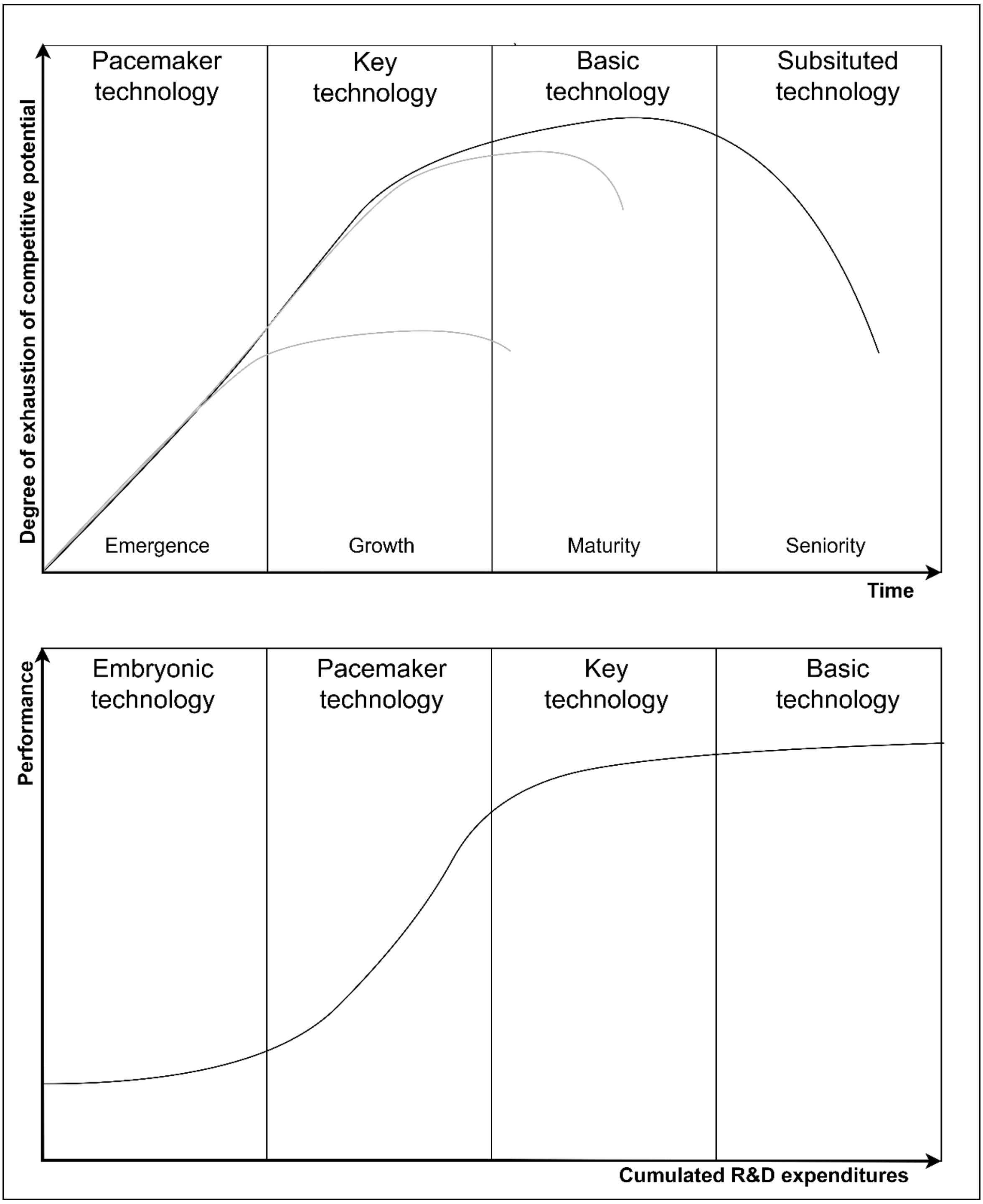


Figure 8: Technology lifecycle concepts by Little and by Foster (according to Schuh & Klappert, 2011)

4.3 Definition of Innovation

Innovations, especially in the field of technology, contribute a central accelerating force for the creation, the success and failure of enterprises. The term innovation is derived from the Latin word *"innovatio"*, which means change or renewal. Innovations are the reason for dynamics in economic development and can be the cause for competitive advantage, instability, risk and even death of whole companies or business ecosystems. Innovation often requires a network of organizations that have to coordinate their efforts in order to create one set of complementary components or products. (Moore, 1996, XV; Schuh, 2012, pp. 1–2)

The term's meaning in a business context was coined by Schumpeter (1939), who considered innovations as alterations in the production function. Nowadays, many different perceptions exist, making it impossible to identify one most prominent definition. In general, an innovation is the transformation of an invention into market success. An invention is an idea that leads to qualitative improvement of a product or a process to levels that cannot be matched by existing technology. In order to turn an invention into an innovation, the whole process consisting of successful product development, manufacturing and marketing has to be completed. (Schuh, 2012, pp. 1–2)

Garcia & Calantone (2019, p. 2) describe technological innovation using a definition originating from an OECD study. *"Innovation is an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention"*. This definition again stresses the inclusion of both technological development of an invention and successful marketing and shows another important feature of the innovation process: its iterative nature. This latter definition will be used for the purpose of this thesis. Besides the innovation process itself, also the output of this process will be referred to by using the term "innovation".

4.4 Different Types of Technological Innovations

Many different types of innovations can be distinguished, depending on the dimension under consideration. Already Schumpeter (according to Sledzik, 2013, p. 90) defined five different categories of innovations, depending on the object of innovation:

1. Launch of a new product
2. Application of new methods of production or sales of a product
3. Opening of a new market
4. Acquiring of new sources of supply
5. New industry structures

According to other sources, the innovation object can be classified according to its system structure, functional aspects or other characteristics. Zahn & Weidler (as cited in Hauschildt, 2005, p. 26) classify the objects of innovation according to functional departments, while still keeping a technological view and come up with four different categories: technological, organizational, business and social innovations. Their category of technological innovations consists of products, processes and technological knowledge. As only types of technological innovations should be considered in this section, this category will be taken as the starting point.

Apart from technological knowledge, process and product innovations can be distinguished. Process innovations are focused on new combinations of factors in the production process, which allows the cheaper, qualitatively superior, safer or faster creation of products. The aim of this kind of innovation always is an increase in efficiency. Product innovations go even further, as not just the production process, but also the marketing side is subject to significant changes. They allow customers or users to fulfil new tasks or use the product to serve new purposes. The aim of this kind of innovation is an increase in effectivity, but can also include increased efficiency. (Hauschildt, 2005, p. 26)

Another important classification scheme that is often discussed by theorists is the degree of novelty of an innovation, or "innovativeness". However, the matter is not assessed in consistent style, as some researchers define innovativeness as new to the company, others regard the relevant point of view to be new to industries, customers or markets. An explicit definition of the focus is therefore important to be able to make valid statements. Garcia & Calantone (2002, p. 113) resolve those inconsistencies by defining a macro perspective, which is focused on an innovation's capability to trigger a paradigm shift in an industry or market, and a micro perspective which considers the influence of an innovation on a company's resources, skills, capabilities, customers or strategy. Despite those variations in perspective, all concentrate on technological or marketing factors. (Garcia & Calantone, 2002, pp. 112–113)

The easiest way of systematically approaching the topic is by use of a continuum reaching from innovations with low impact – which are most often called *“incremental innovations”, “routine innovations”, “reinnovations”, “adoptions”, “reformulations”, “routine innovations”* or *“sustaining innovations”* - to innovations with high impact that might even radically transform companies or industries. Those are mostly referred to as *“radical innovations”, “evolutionary innovations”, “breakthrough innovations”, “true innovations”, “original innovations”, “revolutionary innovations”, “discontinuous innovations”* or *“disruptive innovations”.* An overview of different innovation typologies can be taken from Table 5. Although an exact definition of categories’ boundaries along this continuum is difficult, the characteristics of the two opposite archetypes are clear. (Hauschildt, 2005, p. 29; Schuh & Bender, 2012, p. 2)

According to Bower & Christensen (1995, p. 45), innovations with low impact – called *“sustaining innovations”* - maintain a rate of improvement, but only in those attributes already valued by customers. Coccia (2006) uses a definition by Freeman et al. (1982), which describes *“incremental innovations*” as innovations that occur – albeit at a varying rate – continuously. They most often do not arise as the product of formal research and development but rather as the result of suggestions made by users or people that are directly involved in the production process. They are especially important to improve the quality of products and services as well as productivity in the periods between events associated with innovations that radically transform companies, industries or business ecosystems. Although their combined effect is of high relevance, single incremental innovations may sometimes even remain unnoticed. Similar aspects are stressed by Rothwell & Gardiner (1988; as cited in Garcia & Calantone, 2002), who see incremental innovations as the addition of radically new features to an existing innovation. Garcia & Calantone (2002) define incremental innovations as products that incorporate improvements to existing technologies that are aimed at existing markets and result from the iterative nature of the innovation process. They do not have any effects on the macro perspective, but nevertheless have the potential to strengthen a company’s competitive position. However, this definition has to be treated with care, as no clear distinction between product and innovation is made.

Utterback (1994; as cited in Garcia & Calantone, 2002) defines *“continuous”* or incremental innovations as a means to standardisation and status quo, either on macro or micro level. Robertson (1967) uses the same term to describe innovations that rather are alterations of an existing product than the creation of a new product. The same characteristics are referred to by Rothwell & Gardiner (1988; as cited in Garcia & Calantone, 2002) as *“reinnovations”*, because they only improve on existing innovations and do not signify real breakthroughs in their respective industrial world. Kleinschmidt and Cooper’s (1991; as cited in Garcia & Calantone, 2002) definition of *“low innovativeness”* describes products that result from modifications, cost reductions and repositioning of existing developments. Normann (1971) refers to *“variations”* to describe new products that are similar to earlier products in many dimensions and therefore do not trigger any changes in the organisational system of companies. The same ideas underlie the term *“adopted innovation”* introduced by Maidique & Zirger (1984), which describes innovations that are based on already existing products.

Author(s)	Number of categories	Different degrees of innovativeness [Low impact – High impact]
Bower & Christensen, 1995	2	Sustaining and disruptive
Anderson & Tushman, 1990; Robertson, 1967	2	Continuous and discontinuous
Atuahene-Gima, 1995; Balachandra & Friar, 1997; Freeman et al., 1982; Freeman, 1994; Kessler & Chakrabarti, 1999; Lee & Na, 1994; Schumpeter, 1934; Stobaugh, 1988	2	Incremental and radical
Grossman, 1970	2	Ultimate and instrumental
Normann, 1971	2	Variations and reorientations
Maidique & Zirger, 1984	2	Adoptions and true
Yoon & Lilien, 1985	2	Reformulated and original
Rothwell & Gardiner, 1988	2	Reinnovations and innovations
Meyers & Tucker, 1989	2	Routine and radical
Utterback, 1994	2	Evolutionary and revolutionary
Schmidt & Calantone, 1998	2	Incremental and really new
Rice et al., 1998	2	Incremental and breakthrough
Kleinschmidt & Cooper, 1991	3	Low innovativeness, moderate innovativeness and high innovativeness
Wheelwright & Clark, 1992	3	Incremental, new generation and radically new
Coccia, 2006	3	Low impact, medium impact and high impact
Freeman, 1994	5	Unrecorded, incremental, minor, major and systematic
Garcia & Calantone, 2002	5	Imitative, incremental, discontinuous, really new and radical

Table 5: Different typologies of innovation (according to Garcia & Calantone, 2002)

Bower & Christensen's (1995) *"disruptive technologies*" - or *"disruptive innovations"*, as both terms are used by the authors - are located at the other end of the continuum. Those are innovations with high impact on companies, industries or business ecosystems. However, the concept stands out from other concepts like radical or discontinuous innovations due to its different characteristics. Disruptive technologies are not radically new in terms of technology although they incorporate two important differences to already existing products: they emphasize performance attributes that are not valued by existing customers in mainstream markets and are inferior in attributes traditionally appreciated by customers. At first, they only hold value for new markets or the use in new applications. For this reason, mainstream customers initially do not prefer disruptive innovations over traditional technologies and incumbent companies do not recognize the danger that they are exposed to. This danger arises out of the fact that disruptive innovations have the potential to improve in traditionally valued performance attributes much faster than established technologies. This way, the new technology finally can conquer the markets of mainstream customers and renders the old technology and its business ecosystem obsolete. The performance curve of a disruptive innovation can be seen in Figure 9.

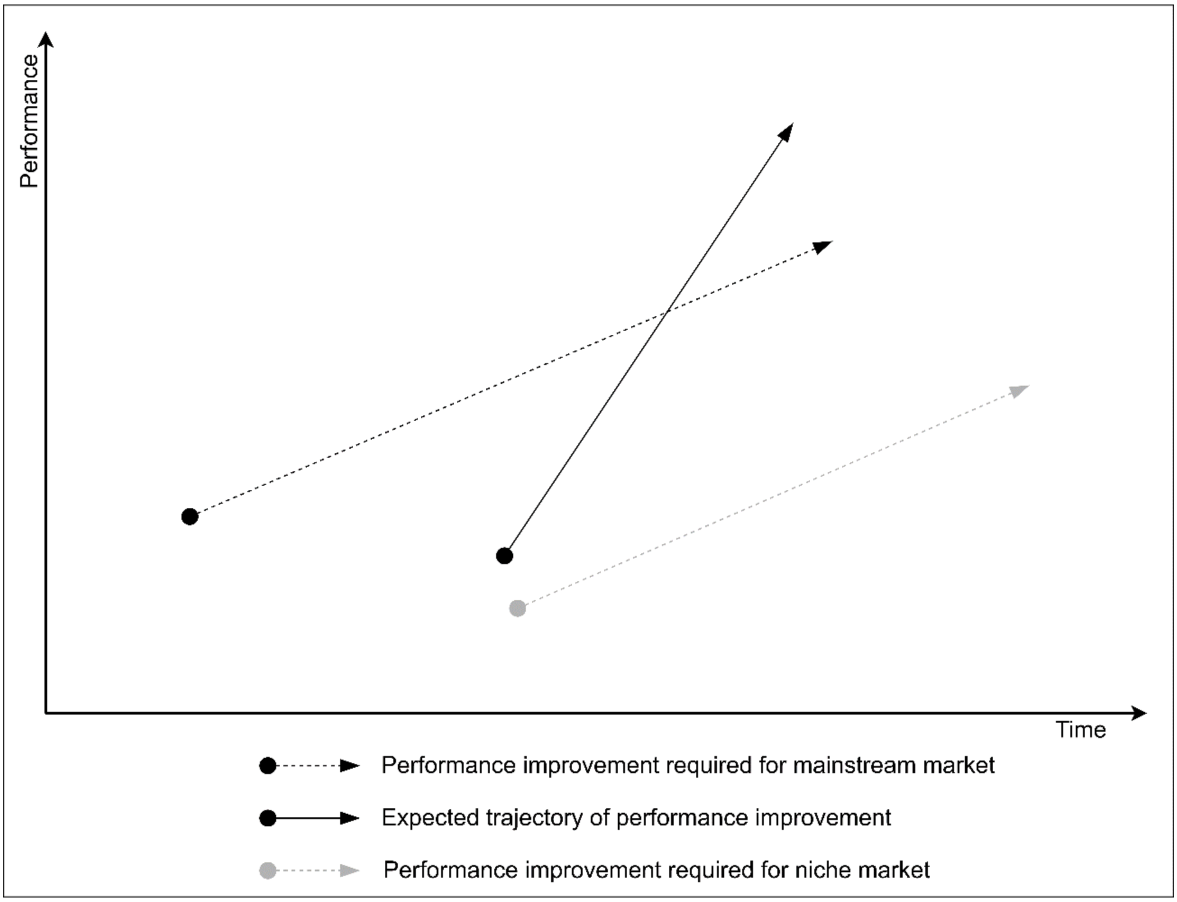


Figure 9: Performance of a disruptive innovation (according to Bower & Christensen, 1995, p. 49)

A simpler concept are *"radical innovations"*, which are often used by many authors either as a single concept or as a general description for all innovation types that trigger changes in their respective environment. Utterback (1994; as cited in Garcia & Calantone, 2002) sees this type as *"change that sweeps away much of a firm's existing investment in technical skills and knowledge, designs, production technique, plant and equipment"*. From his point of view, discontinuity at the micro or macro level originates from the introduction of radical innovations. According to Garcia & Calantone (2002), radical innovations result from a new technology that incorporates a change in market infrastructure and lead to discontinuities in both the micro and macro level. Not unlike disruptive technologies, radical innovations often create demand that has previously not been noticed by customers. Therefore the introduction of such products not only leads to creation of new markets but also to the establishment of new industries with new actors fulfilling new functions. Of course, this could also be understood as the creation of new business ecosystems.

Foster's S-curve concept can be used as a helpful tool in the assessment of potentially radical innovations. The concept can also be applied to markets in order to show something like a lifecycle of markets. If new Scurves are initiated by an innovation in both the market and technology perspectives, an innovation can be justifiably identified as a radical innovation. (Garcia & Calantone, 2002)

Another concept that has been described by several authors is the concept of discontinuous innovations which is also used to describe technologies that have a high impact on companies, industries or even business ecosystems. The concept is based on what Schumpeter (1942, p. 83) described as *"creative destruction"*, which are revolutions of the economic structure that are driven from within its core – by innovations – and lead to destruction of old and creation of new structures. They only appear at rare occasions and differ substantially from continuous or incremental innovations (Anderson & Tushman, 1990, p. 607). Anderson & Tushman (1990, p. 608) further distinguish process discontinuities and product discontinuities. Both are marked mainly by their radical novelty and an improvement in the price vs. performance ratio in comparison to existing technologies. Robertson (1967, p. 16) describes discontinuous innovations as innovations that combine the establishment of a new product with the creation of *"new behaviour patterns"*. Rice et al. (1998) even go as far as defining exact values that signify discontinuous innovations. For them, discontinuous innovations are *"game changers"*, which have the potential to either lead to a 5-10 times performance improvement, a 30-50 percent cost reduction or totally new performance attributes. Furthermore, according to them, the life cycle of a discontinuous innovation is marked by long-term character, high uncertainty, non-linear and stochastic processes, high context-dependency and sporadic progress.

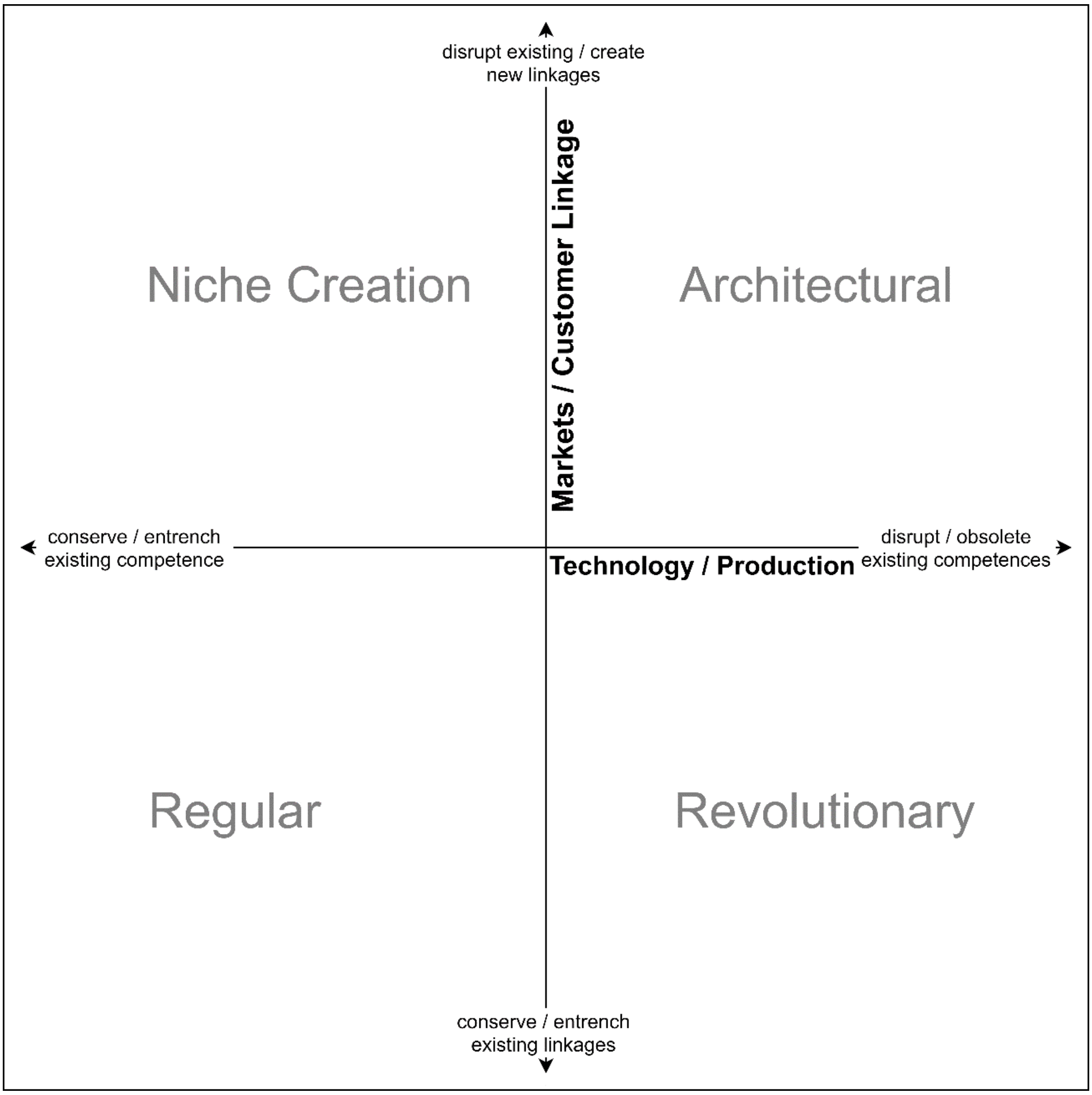


Figure 10: Transilience map of innovations (Abernathy & Clark, 1985)

According to Garcia & Calantone (2002) and Anderson & Tushman (1990), discontinuous innovations do not necessarily lead to the immediate substitution of existing technologies in the marketplace. Abernathy & Clark (1985) tried to eliminate this inconsistency by extending the simple continuum model of technological innovativeness by explicitly considering the competitive advantage that arises through the introduction of an innovation. The resulting widely-spread framework is a matrix consisting of four different categories that the authors call a *"transilience map"*, with the term "transilience" describing an innovation's *"capacity to influence the firm's existing resources, skills and knowledge"* (Abernathy & Clark, 1985, p. 5). The transilience map is composed of four different categories of innovation, which are *"architectural innovations"*, *"market niche innovations"*, *"regular innovations*" and *"revolutionary innovations"* (see Figure 10). Architectural innovations create new industries by departing from existing technologies and at the same time establishing new linkages to markets and users. Innovations in niche markets incorporate existing technologies but open up new market opportunities. Revolutionary innovations are based on new technological advancements but do not lead to the creation of new markets or linkages to new customers. Consequently, regular innovations do not include novelty in either of the categories.

Many scholars in the existing literature use examples from the automotive industry to elucidate their concepts. Abernathy & Clark (1985) present Ford's Model T as an example for an architectural innovation, whilst its successor Model A is considered a market niche innovation due to its different target group among customers and the technological proximity to its predecessor. Proceeding with advancements made in this era, they claim electric starters as regular innovations because they were based on existing technology and did not impact the product's appeal to additional customers. When automatic transmissions were introduced to series production by GM in 1940, they embodied all characteristics of a revolutionary innovation by redefining the technological base of automobiles while at the same time conserving existing market linkages.

The question, which category BEVs belong to is very difficult to answer. Unfortunately, the concept of disruptive innovations introduced by Bower & Christensen (1995) is not suitable to answer this question in a satisfying fashion, as it has been claimed to be primarily useful for ex-post identification of relevant innovations (Christensen et al., 2018, p. 1051). Nevertheless, the technology for sure holds the potential to induce disruptive changes in the automotive industry (Strathmann, 2019, pp. 29–30). Garcia & Calantone (2002, p. 119) point out, that a product's innovativeness depends on a firm's existing capabilities, meaning that an electric vehicle developed and manufactured by a company originating from outside the automotive industry would mean a discontinuous innovation whereas the same product would not be considered this way if introduced by an established manufacturer of motorized vehicles.

The degree of novelty of an innovation is also closely connected to the technology lifecycle. The model that is most often referred to in this context is Foster's S-curve model, starting with the introduction of a new product class or a discontinuity in the evolution of existing technologies, followed by the fight for critical mass and an increase in the pace of product performance that is ended when product standards or other limits begin to slow down performance improvements (Lambe & Spekman, 1997, p. 105). Innovations with a high impact usually trigger the start of a new S-curve, whilst innovations of low impact are rather located at the end of a technology's lifecycle.

All of the presented concepts have to be used carefully, always keeping in mind the often very subjective character of the categorisation. In many cases, application of different classification schemes leads to very different outcomes. Many authors have tried to close the gap of a consistent methodology that incorporates all different types of innovation described in the literature. Examples include Garcia & Calantone (2002) and Coccia (2006).

4.5 Technology Strategy/ Innovation Strategy

A technology strategy describes, how a technology is best brought to market success by a company. This includes the choice of technology that should be deployed for a certain purpose, the determination of the required performance level, the timing of all related efforts and selection of the right technology source and exploitation of a technology's potential. The choice in all of the mentioned dimensions has to be made individually for every single technology that is part of a company's knowledge base. By doing this, the future development of both resources and capabilities is set. (Schulte-Gehrmann et al., 2011, p. 56)

Research in technology strategy can be split up in two distinct approaches. The first one is the inside-out perspective which is focused on a company's internal resources and capabilities as a source of competitive advantage. The second approach is the outside-in perspective that concentrates on a company's surroundings. By considering the market situation and competitor's activities, an appropriate strategy is developed in order to take a position that holds advantages. For companies that mainly operate in technology-intense industries, Schulte-Gehrmann et al. (2011, p. 57) recommend the adoption of an inside-out approach, as the pace of technological progress often is far higher than that of changes in the market place. (Schulte-Gehrmann et al., 2011, pp. 57–58)

Examples of this approach are the resource-based view first introduced by Edith Penrose (1959) and the theory of the *"core competences of the company"* by Prahalad and Hamel (1990). Penrose (1959, p. 21) considers a company as a bundle of resources that are disposed over by administration. An extension of this theory is the resource-dependence theory. It assumes that due to the insufficiency of the existing resources within most companies, they have to exchange resources with other firms in order to achieve a competitively beneficial status (Paulraj & Chen, 2007, p. 30). Prahalad and Hamel (1990) stress the importance of specific competences within a company for gaining a competitive advantage and set up a framework for identifying and enhancing them.

The timing aspect of technology covers both the timing of technology development and market activities over the whole lifecycle of a technology. For the timing of market entry two options are possible: Pioneering the market by being the first to introduce a technology to customers or early or late follower by imitating or building upon efforts already made by the pioneering company. (Schulte-Gehrmann et al., 2011, p. 68)

Very similar to technology strategy, the four main dimensions of innovation strategies are the sourcing of technological knowledge, the right deployment of an innovation, the origin of the impetus for innovation and the determination of the right timing for market entry. In many dimensions a clear distinction between technology and innovation management is difficult, as both cover similar aspects and are often mixed up in the literature. (Schuh, 2012, pp. 9–10)

As can be seen, the sourcing of technology and technological knowledge are part of both the innovation and technology strategy. This dimension of strategy is the most relevant one for the scope of this thesis and therefore will be paid some further attention to.

The technology sourcing strategy covers all aspects of technology acquisition, and is a superordinate category that has to be coordinated with all other strategies for production, supply, marketing and R&D. In many cases, decisions regarding the technology sourcing strategy are firmly embedded in the organisation innovation process in the form of interdisciplinary committees. In general, options are internal development of new technology or external sourcing, which are often referred to by the term "make-or-buy decision". This decision spans over both innovation and technology strategy and even influences the procurement strategy. (Bullinger & Renz, 2005, pp. 90–91; Schulte-Gehrmann et al., 2011, p. 83)

In the case of internal technology sourcing by development in a company's own R&D-department, the company is free to act independently from possible partners and to dispose over its achievements exclusively. This increases the probability of advantages in the public perception of the company's innovativeness. However, this strategy entails the risk of high insecurity in conjunction with high efforts in terms of resources. Moreover, technology that is internally developed takes a long period of time until it reaches a level of reliability that finally allows marketing in a product. For these reasons, internal technology sourcing is to be favoured in areas that touch a company's core competences and key technology base, leading to sustaining competitive advantages. (Bullinger & Renz, 2005, pp. 90–91; Schulte-Gehrmann et al., 2011, pp. 72–73)

External sourcing of technology is especially advisable for basic technologies that do not hold the potential to differentiate a company's offering from its competitors'. The advantages of this approach include shortened development cycles, a reduction in costs and risks of technology development, exploitation of suppliers' capabilities and improved flexibility in the face of discontinuities or technological uncertainty. However, it holds the risk of dependency on external partners and unintended transfer of core competencies over firm boundaries. In general, internal efforts should be increased the higher a technology's competitive relevance and the internal knowledge base regarding this technology are. (Bullinger & Renz, 2005, pp. 90–91; Schuh, 2012, p. 24; Schulte-Gehrmann et al., 2011, pp. 72–73)

In reality, a myriad of different concepts exist between the two generic types of internal development and simple purchase of technology from a supplier. Some external sourcing strategies include cooperation with partners or even shareholding in other companies or common enterprises that are set up together with suppliers or competitors. Section 5 tries to give an overview over the many approaches to categorization of these different types. Examples are cooperation, external development by engineering service providers, licencing, purchase of foreign technologies and different kinds of equity investment (Bullinger & Renz, 2005, pp. 90–91; Schuh & Klappert, 2011, pp. 72–73; Schulte-Gehrmann et al., 2011, pp. 72–73)

Historically, internal technology sourcing was the method of choice in many industrial enterprises until the end of the last century. Especially in the automotive industry, this strategy was replaced by the trend towards outsourcing of value added as the diversity of offered products and product variants is only manageable by concentrating internal efforts on core competences. (Kampker et al., 2018, pp. 44–45) As the business ecosystem concept aims to explain the dynamics of interconnected business entities, its application is most appropriate if the considered companies to some extent follow external sourcing strategies (Iansiti & Levien, 2004b, pp. 6–9).

5 Interorganizational Relationships

This chapter aims to explain the definition, characteristics and significance of interorganizational relationships (IORs) in order to be able to subsequently elaborate a typology of interorganizational relationships to be used for the case studies in chapter 9.

5.1 Definition and Significance of IORs

According to Oliver (1990, p. 241), interorganizational relationships are *"relatively enduring transactions, flows and linkages that occur among or between an organization and one or more organizations in its environment."* A similar definition is given for business relationships by Anderson & Narus (1991; as cited in Ritter et al., 2004, p. 176), who describe them as processes, where *"two firms or other types of organizations form strong and extensive social, economic, service and technical ties over time, with the intent of lowering total costs and/or increasing value, thereby achieving mutual benefit."* Other words describing the same concept are *"interfirm relations"* or *"alliances"* (Ritter & Gemünden, 2003, p. 692). Interorganizational relationships do not necessarily have to involve businesses but can also consist of universities or other organizations different from purely economically oriented enterprises (Duschek & Sydow, 2011, p. 31). Organizations in this context are social systems that show the two central features of formal rules in many activities that are performed by members of them and reflexivity in monitoring their own activities. In general, central features of interorganizational relationships are long-term orientation, process character, dynamic changes over time, the necessity of all involved parties to invest time, money and resources, and the existence of power and dependence which means they involve aspects of trust, commitment and adaptation (Ritter & Gemünden, 2003, p. 692; Ritter et al., 2004, p. 175). The aims of interorganizational relationships are always of economic nature although they fulfil many different functions either directly or indirectly (Ritter & Gemünden, 2003, p. 694; Ritter et al., 2004, p. 175). Relationships are the constituent parts of networks and in turn are composed of a set of ongoing interactions (Ritter et al., 2004, pp. 177–178). Thus, the management of relationships and networks rather is a management of interaction with others and is a two-way process (Ritter et al., 2004, p. 178).

Cooperative strategies are increasingly vital in technology and innovation management (Enrietti & Patrucco, 2011, p. 8; Gerybadze, 2005, p. 157). They allow a bundling of scattered resources from different companies and managing economic risks in the face of environmental uncertainty (Barthel et al., 2015, p. 16; Lambe & Spekman, 1997, p. 107). This holds true especially for the automotive industry as the technological and economic challenges associated with electric vehicles necessitate networks of suppliers that share large parts of value added (Kampker et al., 2018). In order to have all the needed technological and organisational competences to their disposal, one possible option for automotive companies is to engage in cooperation (Enrietti & Patrucco, 2011, p. 5). This way, knowledge on disruptive technologies is often acquired from third parties (Mazur et al., 2013, p. 1060). Cooperative challenges are also an important aspect in Moore's (1996, p. 83) business ecosystem theory as business ecosystems describe a network of interconnected business players and therefore sets of interorganizational relationships. For Moore, the expansion of cooperation scope from containing only direct suppliers and customers to all relevant players relevant for innovation is a central feature of business ecosystems (Moore, 1996, p. 56). In general, efficient management of complex interorganizational relationships and coordination of cooperative efforts can be a major competitive advantage (Kampker et al., 2018, p. 42). Some authors even consider the ability to successfully manage interorganizational relationships a core competence of companies (Ritter et al., 2004, p. 176).

5.2 Characteristics of Interorganizational Relationships

Every interorganizational relationship has its own characteristics along different dimensions, which all have the ability to influence the success and the outcome of the cooperation. Figure 11 gives an overview over different aspects that have to be considered in this context.

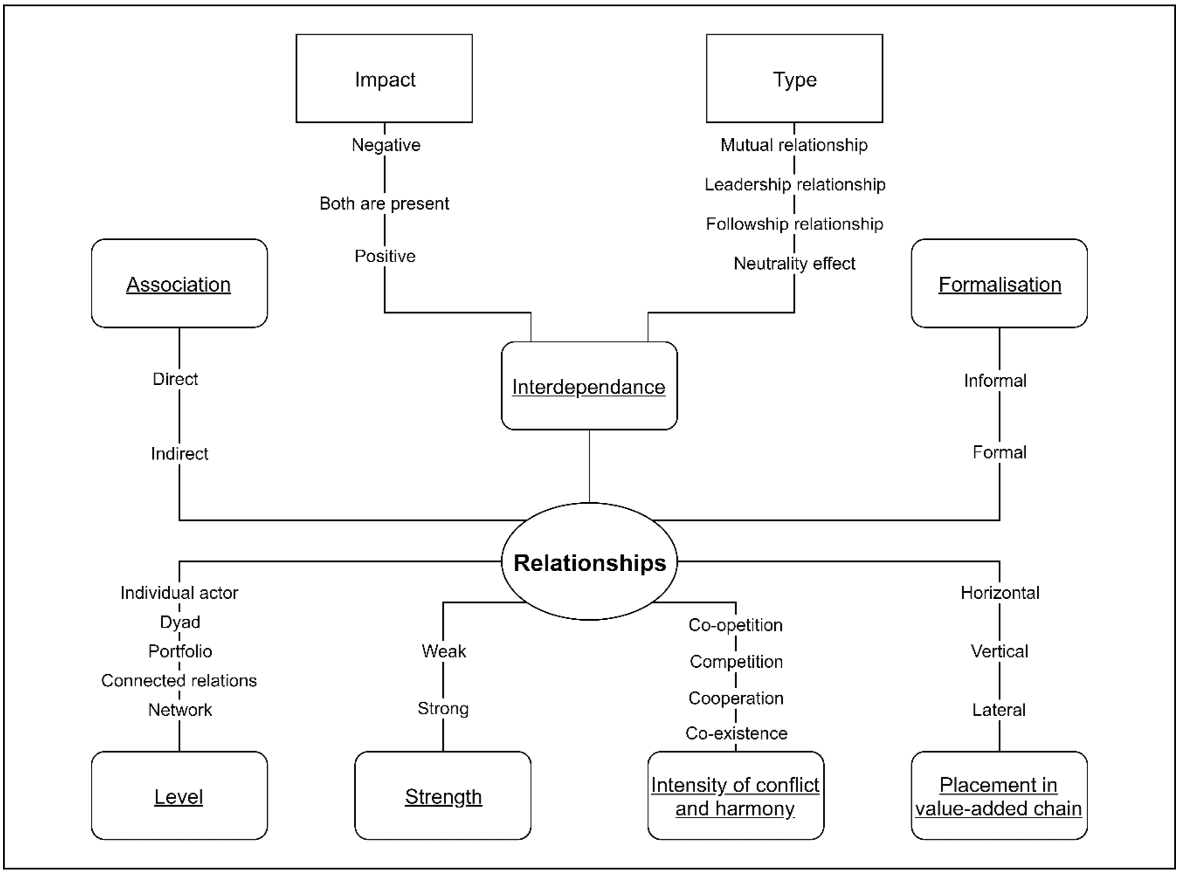


Figure 11: Characteristics of relationships (based on Müller, 2014, p. 48)

5.2.1 Relationship Level

Ritter et al. (2004) distinguish four different levels of relationships that are also depicted in Figure 12. The first level are isolated individual actors, which are also the focus of resource-based models of technology and innovation strategy. Although individual firms can be considered as intraorganizational networks of people and departments on their own, models only concentrating on individual actors do not fully resemble real firms as those most often are connected to other organizations through managed relationships. Single interactions between actors can be considered part of this category as well (Ritter & Gemünden, 2003, p. 693). Relationships belonging to the second level are dyadic relationships involving two different companies, which are influenced by some kind of history (Ritter & Gemünden, 2003, p. 693). Much research has been carried out in this area, mostly concentrating on buyer-supplier or buyer-seller relationships (BSRs). In this context, it is important to consider the influence both organizations have on the relationship and reciprocally on each other through the relationship (Lettice et al., 2010, p. 310). All dyadic relationships an organization is involved in can be aggregated to its relationship portfolio, which is similar to the idea of a core business used by Moore (1996, p. 26). Relationships of the third level are called connected relations and additionally include indirect links like between a company and the customers of its customers or the suppliers of its suppliers. They are still focused on one focal firm which stands at the centre of all interactions (Ritter & Gemünden, 2003, p. 693). Consequently, this can be considered as a description of the relationships involved in Moore's (1996, p. 26) extended enterprise. An important aspect of these connected relations are the indirect influences that the relationships have on each other. The fourth relationship level are networks which are characterized by interactions within as well as between organizations, the inclusion of business and non-business entities like government agencies and the importance of architecture, integration and the management of transactions (Iansiti & Levien, 2004b, p. 145; Ritter et al., 2004, p. 179). Networks can be described by the three elements of actors, resources and activities. They are self-organizing systems and at the same time are managed and perform management activities (Ritter & Gemünden, 2003, p. 693). A network is the relationship level that best describes relations involved in business ecosystems, as the concept in Iansiti & Levien's (2004b, pp. 8–9) understanding was introduced to provide analogies for understanding business networks. Networks are increasingly gaining importance in business economics due to an evolution in social, economic, business and technological systems (Iansiti & Levien, 2004b, p. 5). Moreover, networks around OEMs are considered the appropriate organizational form for the automotive industry in order to reach technology and knowledge sharing and a reduction of costs and risks (Dodourova & Bevis, 2014, p. 260). This holds especially true for the development of electric cars and the necessary infrastructure (Enrietti & Patrucco, 2011, p. 5).

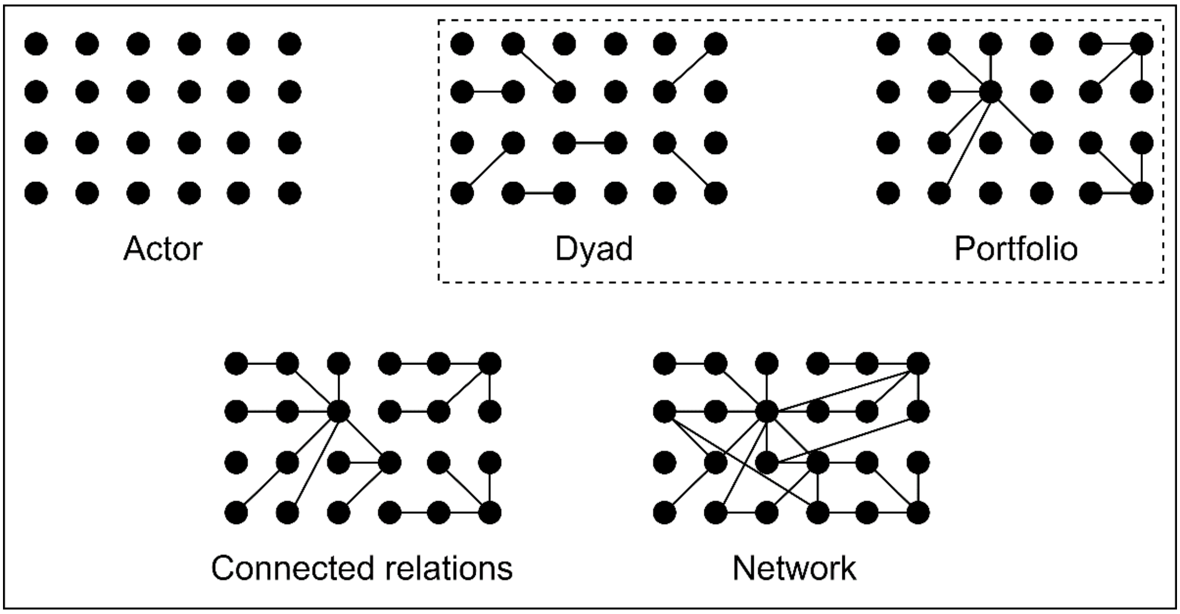


Figure 12: Different relationship levels (Ritter et al., 2004, p. 179)

5.2.2 Interdependence

The interdependence in relationships can be assessed according to its type and impact.

1. Type

Depending on the power each company has over its partner in a relationship, four different types of interdependence can be discriminated. If one company is dependent upon the other one in a dyadic relationship, the latter can exert power over the first one. Depending on the degree of dependence, this power can be dramatically high or rather low. From the dependent firm's point of view, such relationships are called *"followship relationships"*, whilst the counterpart can consider it a *"leadership relationship"* from its position if its success is rather independent from the relationship with this specific partner. The leader in this kind of relationship can therefore freely choose among potential partners. However, if the leader really has no dependence at all on the output of the relationship due to already existing competences in the strategically important subject of the relationship, integration should be preferred over any form of cooperation (Gerybadze, 2005). In the case of companies entering in a long-time relationship or agreements that include the merger of intra-organizational systems, a situation of mutual dependency emerges. If no company is clearly more powerful than the other one, such relationships are called *"mutual relationships"*, which can involve some kind of formal or informal collaborative agreement. Of course, real relationships do not always exactly fit in one of the mentioned categories but rather are mixtures. Table 6 further illustrates the different ideal types. (Ritter et al., 2004, p. 178)

		B’s perceived power over A **(= A’s perceived dependence on B)**	
		Low	High
A’s perceived power over B **(= B’s perceived dependence on A)**	Low	No relationship	Followship relationship
	High	Leadership relationship	Mutual relationship

Table 6: Types of interdependence (Ritter et al., 2004, p. 178)

2. Impact

Dependence in interorganizational relationships can influence the performance of either organization in a positive or negative manner. If another firm’s efforts facilitate the achievement of objectives, this is called a positive dependence. Most often, this holds true for relationships to customers, suppliers or complementors, where cooperative aspects prevail over competition. Negative dependence hinders a company’s success and is typical in relationships with competitors. Real relationships most often include elements of cooperation, competition and conflict, which leads to negative and positive dependencies at the same time. (Ritter et al., 2004, p. 178)

5.2.3 Placement of Activities Regarding Value-Added Steps

A distinction has to be made between vertical relationships between companies that perform activities in sequential steps of value added and horizontal relationships between companies that perform activities on the same step of value creation (Duschek & Sydow, 2011, pp. 33–36; Gerybadze, 2005, p. 158; Phillips et al., 2006, pp. 451–452). Whilst vertical relationships are often formed on a voluntary basis and maintenance of interaction is intended by the involved actors, horizontal relationships sometimes establish due to external forces although competitors try to avoid interaction due to conflicting interests (Bengtsson & Kock, 2000, p. 414). The third category are lateral relationships which connect companies that are not involved in the same value-added chain or the same step within their respective value-added chains (Duschek & Sydow, 2011, pp. 36–37). Ritter et al. (2004, pp. 176–177) further distinguish regarding relationship partners. According to them, vertical relationships include relationships with customers or suppliers, which both hold the potential for competitive advantages. Horizontal and lateral relationships can involve competitors and complementors. Figure 13 shows the different types of relationships according to their placement in the value-added chain.

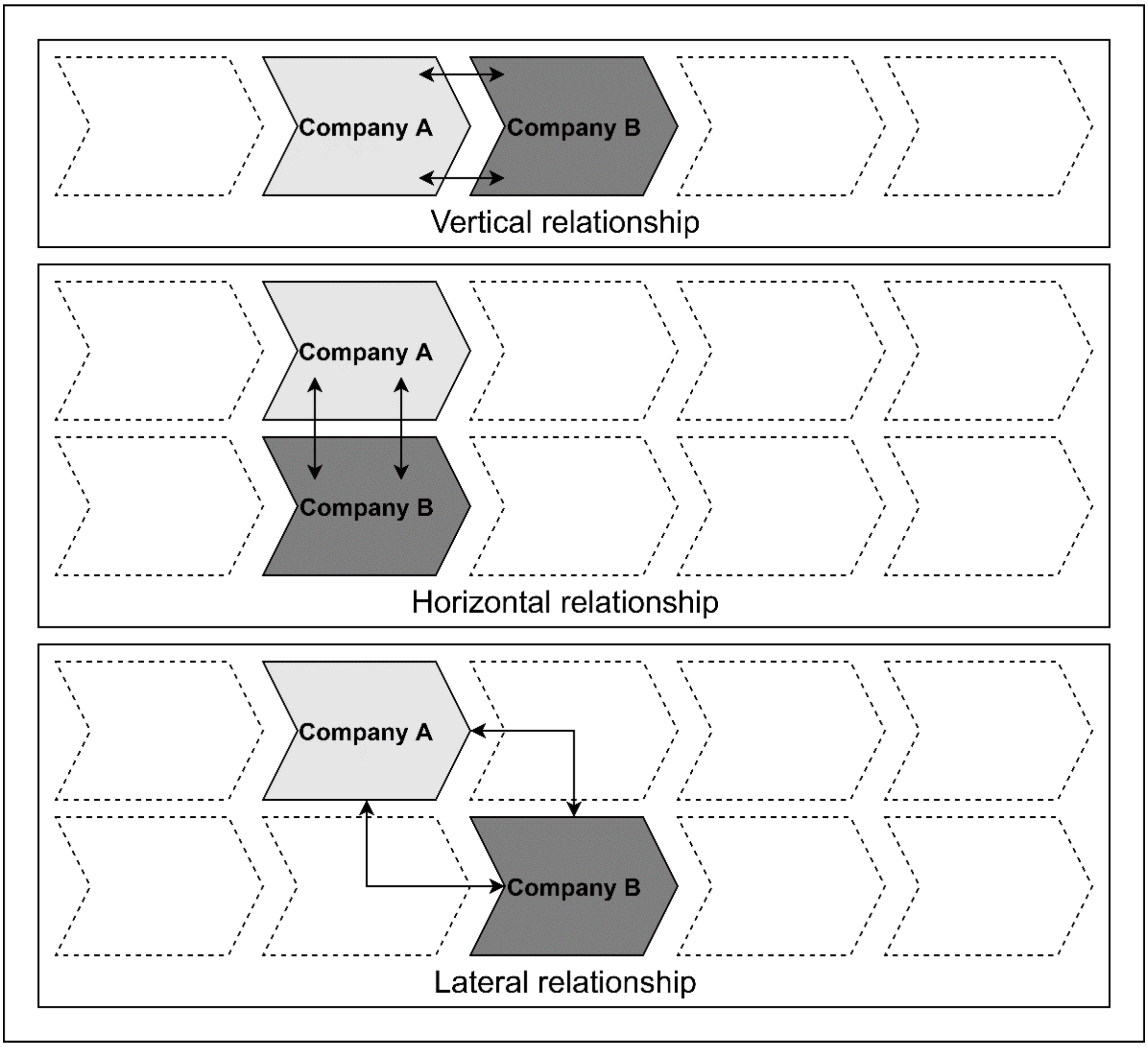


Figure 13: Placement of partners in the value-added chain (own creation)

5.2.4 Intensity of Conflict and Harmony

The relations by which companies are interconnected can be competitive, cooperative, coopetitive or just in the form of co-existence (Vuori, 2005). In cooperation, individual actors collectively perform actions in order to reach common goals. In such a relationship, all actors appreciate the social structure of mutual benefits and its continuity more than the maximization of their individual interests (Bengtsson & Kock, 2000, p. 416). Cooperation is especially appropriate if the involved parties have shared goals and complement each other in strategically important capabilities and resources (Gerybadze, 2005, p. 159). Competition is the direct rivalry between companies that is created through industry structures. It is an interactive process that is a vital driving force behind the innovating activities of corporations (Bengtsson & Kock, 2000, p. 413). A player in the market can be considered a competitor if *"customers value your product less when they have the other player's product than when they have your product alone"* (Bengtsson & Kock, 2000, p. 415). The idea behind competition is that all individual actors try to maximize their own advantage which leads to conflicting aims and hinders collective action. However, cooperative relationships between competitors do exist. Those involve both competition and cooperation at the same time and are referred to by the term *"coopetition"* or *"co-opetition"* (Bengtsson & Kock, 2000, p. 411; Vuori, 2005). Although also vertical relationships are marked by the existence of both competitive and cooperative actions, this concept is of particularly high relevance for horizontal cooperative relationships (Bengtsson & Kock, 2000, p. 414; Gnyawali et al., 2016, p. 15). This kind of relationship is even regarded as the most advantageous one as it enhances competition by driving innovation activities and enables reduction of risks and costs at the same time, ultimately resulting in superior long-time performance (Basole et al., 2015, p. 539; Bengtsson & Kock, 2000, p. 412). Coopetitive relationships are very complex due to the fundamentally controversial logics of competition and cooperation (Gnyawali et al., 2016, p. 7). Therefore, in order to allow a segmentation of cooperative and competitive efforts, examination of the phenomenon has to concentrate on activities, which cannot be cooperative and competitive at the same time (Bengtsson & Kock, 2000, p. 415). In real examples, cooperative and competitive activities are most often split up between different steps in the value-added chain or different business units (Bengtsson & Kock, 2000). Competitors most often form strategic alliances in areas far upstream in the value-added chain and compete with each other for the attention of customers in the marketing step (Bengtsson & Kock, 2000, p. 421). Coopetition is also an important characteristic of business ecosystems, with its central feature of coevolution consisting of both cooperation and competition (Moore, 1996, p. 83).

5.2.5 Association

Like in any other connection, direct or indirect links between actors are possible (Müller, 2014, p. 48). In direct relationships, interaction takes place directly between participants. Indirect relationships may include some kind of mediator between the involved parties, like for example customers or suppliers (Dodourova & Bevis, 2014, p. 258). In some cases, clear distinction between direct and indirect relationships is a matter of definition, and not possible in an objective manner (Vuori, 2005). Although parties are only connected indirectly, there can be high mutual influences through indirect relationships (Iansiti & Levien, 2004b, p. 40; Ritter et al., 2004, p. 179).

5.2.6 Strength

All relationships have some kind of atmosphere that is marked by the state of conflict and overall closeness or distance between parties that can also be considered as strength of a relationship (Ritter & Gemünden, 2003, p. 692). Close relationships include open sharing of information and knowledge and trust in the relationship and the other parties. The closer a relationship is, the less prominent are competitive aspects within the relationship. (Vuori, 2005) According to Donaldson & O'Toole (2000, p. 495), relationship strength highly depends on both belief and action components, meaning a distinction between passive and active elements. The belief component involves behaviour and the underlying mechanisms like trust, openness and the belief one party has over the other's motives. Action components include all economic content like investment patterns or economic dependence between partners. Other possible measures for the strength of a relationship are the amount of time and resources dedicated to its development, the emotional relevance of the connection and the amount of knowledge exchanged (Basole et al., 2015, p. 543; Müller, 2014, p. 47). Weak ties are especially important for serving as bridges between different areas of strong ties (Ritter et al., 2004, p. 179). Especially in the development of technological innovations, close ties bring significant advantages (Phillips et al., 2006, pp. 451–452).

5.2.7 Formalisation

Interorganizational relationships can be either formal by existence of some kind of relationship contract or informal, consisting only of informal interactions without any formal agreement defining the scale and scope of the relationship (Schuh, 2012, pp. 44–48). Although the aim of formalization is a clear definition of a relationship's characteristics, all relationships include informal components due to the fact that organizations are social systems that are subject to continuous changes (Ritter et al., 2004, p. 180). Most of the times, horizontal relationships have a more informal character than vertical relationships, as information and personal exchange is more usual than economic exchange (Bengtsson & Kock, 2000, p. 414).

5.3 Typology of Relationships

A myriad of different typologies for distinguishing generic categories of interorganizational relationships exist. Especially when described by the companies involved in them, the number of different concepts is overwhelmingly big, making the definition of ideal types necessary (Donaldson & O'Toole, 2000, p. 500). However, even ideal types described by different authors are ambiguous and differ significantly in their characteristics (Webster, 1992, p. 5). An overview of different approaches existing in the literature can be taken from Table 7.

With respect to the focus of the case studies carried out in the empirical part, the attention for this thesis should be concentrated on dyadic direct relationships. Those are constituent parts of all networks, embody the second level of relationship management and consist of a set of continuous interactions (Ritter et al., 2004, p. 179). Although business ecosystems exceed the scope of classical buyer-supplier relationships, theory on these relationships is taken as a starting point and complemented by further technology acquisition approaches (Jacobides et al., 2018). Additionally, the centre of attention for most research in dyadic relationships are vertical relationships between buyers and suppliers or sellers (Ritter et al., 2004, p. 179).

In general, the exchange relationships between buyers and suppliers can be categorised along a few certain dimensions. The dimensions most often occurring in the literature can be separated in two groups. Approaches belonging to the first group include attributes that are associated to transaction-specific investment and the distribution of power and dependence in the relationship. Consequently, those approaches are referred to as concentrating on *"power-dependence attributes"*. The other category are typologies focusing on *"relational attributes"* like cooperative efforts, relational norms, trust, integration and commitment, which can be compared to the strength aspect described in section 5.2. (Tangpong et al., 2015, p. 154) Furthermore, typologies can be created from theoretical constructs alone or be based on or validated by a collection of empirical data (Vesalainen & Kohtamäki, 2015, p. 106).

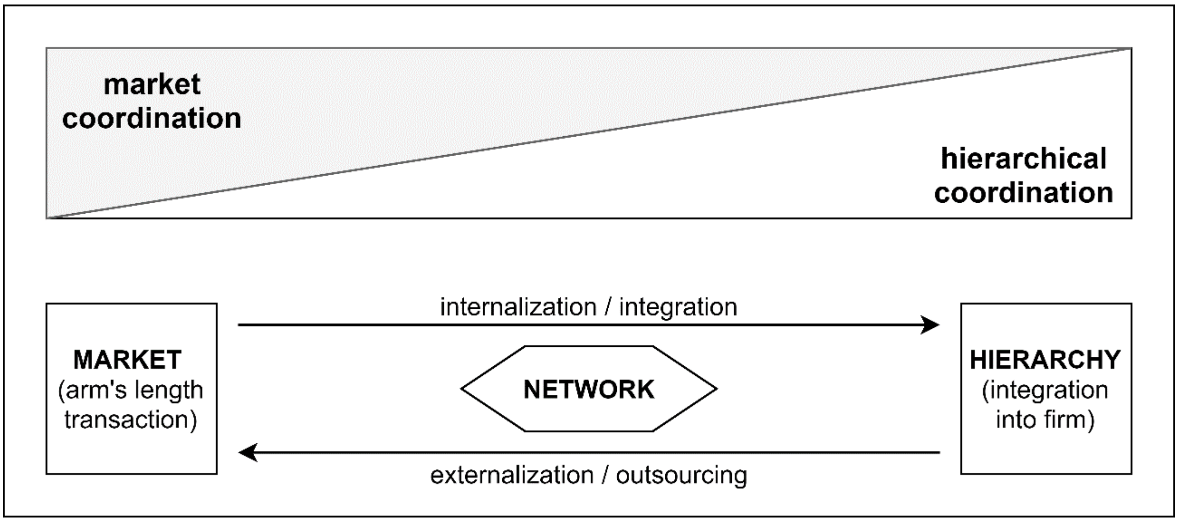


Figure 14: The continuum of interorganizational relationships (according to Duschek & Sydow, 2011, p. 66)

Focusing on relational attributes, interorganizational relationships can be classified along a continuum reaching from arm's length relationships to vertical integration or merger of the two companies (Lambert et al., 1996, p. 2; Oliver, 1990; Webster, 1992). The dimension covered by this continuum can also be described as the governance mechanism, with the polar types of market and organization or hierarchy (see Figure 14). Here, also the formalization aspect described in section 5.2 comes into play. Governance in this context means a set of formal and informal rules for coordination of activities. (Duschek & Sydow, 2011, p. 42) Arm's length relationships governed by market rules are economic exchange processes between equal actors that can either be of singular nature or consist of a series of interactions spanning over a longer period of time. Hierarchical governance exists if suppliers or functions initially performed by suppliers are integrated into the focal company itself. However, interorganizational relationships consist of technological, social and economic layers, which makes a clear determination of the position within the continuum very difficult. (Duschek & Sydow, 2011, p. 43) Additionally, in practice many organizations choose plural forms of governance in their relationships at the same time (Duschek & Sydow, 2011, pp. 45–46). It has to be mentioned that a continuum is never capable of depicting the variety of interactions in business practice. However, it proves a useful starting point due to its simplicity. (Vesalainen & Kohtamäki, 2015, pp. 105–106) The appropriateness of different governance forms in one specific situation can be assessed by using transaction cost or resource dependence theory. Transaction cost theory is focused on efficiency in transactions. According to this framework, market mechanisms are especially inefficient in case of transaction-specific investments and uncertainty. For all interorganizational relationships, potential costs might arise for safeguarding, adaptation and evaluation. Resource dependence theory especially stresses aspects of effectiveness and the ability to comply with the requirements of external parties. (Heide, 1994, p. 73)

Authors	**Category**	**Considered aspects**	**Relationship types**
Dwyer et al., 1987	Power-dependence attributes	Motivation to invest in relationships	Discrete exchanges, buyer's market, seller's market, bilateral relationships
Oliver, 1990	Relational and power-dependence attributes	Reasons for the development of relationships	Trade associations, joint ventures, corporate-financial interlocks
Webster, 1992	Relational attributes	Bureaucratic and market control	Transactions, repeated transactions, long-term relationships, buyer-seller partnerships, strategic alliances, network organizations, vertical integration
Kamath & Liker, 1994	Relational attributes	Supplier involvement in product development	Contractual, child, mature, partner
Heide, 1994	Power-dependence attributes	Relationship initiation, relationship maintenance, relationship termination	Market, unilateral and bilateral governance
Lambert et al., 1996	Relational attributes	Drivers, facilitators and components of the relationship	Arm's length, partnerships (3 types), joint ventures, vertical integration
Lambe & Spekman, 1997	Relational attributes	Costs and control in acquisition of technology	Merger or acquisition, alliance, internal development
Bensaou, 1999	Power-dependence attributes	Buyer's and supplier's specific investments	Market exchange, captive buyer, captive supplier, strategic partnership
Donaldson & O'Toole, 2000	Relational and power-dependence attributes	Belief components / behavioural processes, action components / economic content	Discrete relationships, dominant partnerships, recurrent relationships, bilateral relationships
Cox, 2001	Power-dependence attributes	Value sharing, way of working	Adversarial arm's length, non-adversarial arm's length, adversarial collaborative, non-adversarial collaborative
Laing & Lian, 2005	Relational attributes	Trust, closeness, organisational policy	Elementary relationship, interactive relationship, embedded relationship, partnering relationship, integration

Tangpong et al., 2008	Relational and power-dependence attributes	Supplier dependence, relationalism	Market relationships, power relationships, autonomous-link relationships, constrained-link relationships
Duffy, 2008	Relational and power-dependence attributes	Relationship economy, relationship polity, relationship climate, relationship performance	Transactions, limited coordination, highly coordinated, partnerships, vertical integration
Duschek & Sydow, 2011	Relational attributes	Governance form	Purchase contract, barter transaction, long-term supply agreement / strategic alliance, licencing / franchising, joint venture, profit centre, vertical integration
Kapoor & Lee, 2013	Relational attributes	Autonomy, adaptability	Markets, alliances, hierarchy
Vesalainen & Kohtamäki, 2015	Relational and power-dependence attributes	Relationship structures, relationship-specific investments, relational capital	Eight types formed by all possible combinations of high and low values in the considered dimensions
Tangpong et al., 2015	Relational and power-dependence attributes	Relationalism, buyer dependence, supplier dependence	Market / discrete relationship, captive-supplier / buyer-dominant relationship, captive-buyer / supplier-dominant relationship, competitive / win-lose partnership, free-will / voluntary collaboration, buyer-led collaboration, supplier-led collaboration, strategic / bilateral partnership

Table 7: Different typologies of interorganizational relationships (based on Tangpong et al., 2015)

It has to be noted, however, that BSR typologies only focus on vertical relationships (Duffy, 2008, p. 229). A typology for external technology acquisition has to include horizontal relationships as well. For this reason, a new typology will be introduced in Table 8 that is based on the above mentioned continuum, but complemented by additional relationships types. As a starting point, the most important forms of interorganizational relationships for technology sourcing are:

1) Market exchange / arm's length relationship / purchase contract

   Market relationships are governed by market rules and consist of economic transaction processes between formally equal and independent partners. The often small scope of exchange is predefined according to rules dictated by competition and the ratio between offer and demand. (Duschek & Sydow, 2011, p. 42) Market relationships are characterized by short-term orientation, little communication, low dependence on each other, low relational aspects and no relevant cooperative efforts, synergies or joint activities. However, if one or both companies act in a highly uncertain environment and have made relationship-specific investments, switching costs can be high. This leads to dependences and opportunism might be possible as a consequence. Exploitation of this kind can hardly be avoided by contractual agreements. (Tangpong et al., 2008, p. 578) Other authors state that market exchanges do not include any kind of specialized assets and therefore a shift of exchange partner is possible at low costs (Bensaou, 1999). Donaldson & O'Toole (2000) stress the low level of actions to foster relationships of this kind and the low level of belief in its quality. Dwyer et al. (1987)

and Webster (1992, p. 6) note that the ideal type of discrete market transactions does not include any additional contact before and after the transaction. In this case, all transactions are independent from each other. However, this is far away from real market transactions that often are embedded in the context of ongoing relationships between the involved parties (Webster, 1992, pp. 5–6). Those are more closely resembled by Webster's (1992) concept of *"repeated transactions"*, which are more than a single transaction but still do not embody a meaningful long-term relationship. A long-term focus is featured in Webster's (1992) concept of *"long-term relationships"*, already showing some kind of mutual dependence instead of pure market mechanism in the negotiation of prices . If relational aspects are part of the relationship and it transpires over a longer time, it is considered a *"relational exchange"* (Dwyer et al., 1987). According to Lambert et al. (1996), most relationships a company is involved in are simple arm's length interactions. Purchase of technology is a common strategy in technology sourcing (Schuh & Klappert, 2011, p. 73). Pure market relationships are most often chosen for procurement of highly standardized products that do not allow differentiation. The exchange process in these cases does not include product design but only goes as far as manufacturing to the buyer's specifications. (Bensaou, 1999)

2) Licencing / Franchising

Licencing gives third parties the opportunity to use technologies or innovations that are or are not protected by intellectual property rights through conclusion of a private contract. In contrast to market transactions, licensing always has a long-term character and shows closer ties between the involved parties. Licensing grants fast access to new technologies at lower costs than when developed internally. However, most often the gained competitive advantage is not sustainable. The longer a licensing agreement endures, the more likely the licensee will be able to gain a sense of the licensed technology, finally leading to obsolescence of the relationship. Advantages for the licensor are access to new markets, and additional revenues. (Duschek & Sydow, 2011, pp. 93–97; Schuh, 2012, pp. 44–48). Franchising is a special type of licencing that additionally includes further aspects of hierarchical coordination. It is a form of cooperation where the franchisor allows a legally autonomous franchisee to use protected names, trademarks or other intellectual property for its own business interactions with customers in exchange for the payment of charges that are defined in a contract. Most often, this agreement also includes exact rules for organization systems, marketing and procurement procedures and corporate identity. (Duschek & Sydow, 2011, pp. 93–97)

3) Partnership

The terms partnership and alliance are often used synonymously, as besides strategic alilances also the term strategic partnerships exists (Bensaou, 1999; Schuh, 2012, pp. 44–48; Webster, 1992). According to Duffy (2008, p. 228), partnerships are *"ongoing relationships involving a commitment over an extended time period and a mutual sharing of information and the risks and rewards of the relationship"*. Other authors also stress the close linkage of partners' economic fates (Bensaou, 1999). Additionally important for partnerships are the absence of dependence asymmetries and mutual commitment in the relationship (Bensaou, 1999). This commitment also includes intensified bilateral communication and adjustment of internal assets and operations to the needs of the partner (Tangpong et al., 2015). In some cases, small investment in the partners' companies might be possible to show the long-term commitment to the relationship, increasing its stability (Webster, 1992, p. 8). Lambert et al. (1996), consider all types of cooperation along the continuum between market transactions and integration as partnerships, as long as they do not contain any kind of shared ownership. Consequently, they distinguish three different types of partnerships depending on the drivers, facilitators and active components of the relationship. Type 1 partnerships are restricted to a limited scope of coordination and planning, although the involved parties regard each other as partners. These partnerships are limited to a short time and only one functional area per involved organization. In type 2 partnerships, multiple divisions within both organizations are involved and – while still limited – the time horizon of the relationship is extended to longer terms.

Some activities and functions are not just coordinated but already integrated. Type 3 partnerships are marked by significant operational integration and an open-end character. Lambert et al. (1996) use a very vivid picture for describing the involved parties' attitude towards this kind of partnerships: *"Each party views the other as an extension of the own firm"*. Tangpong et al. (2015) distinguish between partnerships of mutual dependence and voluntarily established collaboration. Additionally, they point out that partnerships can involve competition although being a cooperative relationship. As companies only have limited resources, they should not engage in too many close partnerships at the same time (Lambe & Spekman, 1997, p. 113). For this reason, each company only has few partnerships of type 3 – mostly with critical customers and suppliers –, while more often being involved in type 1 partnerships (Lambert et al., 1996, p. 3). Partnerships can also be established between other types of organizations like universities or governments (Rice et al., 1998, p. 57). Partnerships are most suitable for sourcing components that require highly sophisticated technological capabilities and allow product differentiation (Bensaou, 1999). Most often, these partnerships include both development and manufacturing of products, much in contrast to arm's length relationships which only cover manufacturing to buyer's specifications (Bensaou, 1999; Webster, 1992, p. 7).

4) Strategic alliance

There is no single unambiguous definition covering the full meaning of the term. In many cases, the term strategic alliance or *"coalition"* is used as a superordinate category for a plethora of different types of interorganizational relationships (Duschek & Sydow, 2011, pp. 104–105; Porter, 1990a, p. 77). Consequently, the concepts aggregated to this category are licencing, franchising, joint ventures, various R&D consortia, partnerships and many others (Duschek & Sydow, 2011, pp. 104–105; Porter, 1990a, p. 77; Ritter & Gemünden, 2003, p. 691). Understood this way, strategic alliances are vertical, horizontal or even lateral cooperative relationships between legally autonomous organizations with the aim of using the other party's strength to compensate for the own weaknesses in reaching a predefined common goal (Lambe & Spekman, 1997, p. 103). It is exactly this common goal and its strategic relevance that distinguishes strategic alliances from partnerships, although the terms are most often used interchangeably (Webster, 1992, p. 8). Devlin and Bleackley (1988, p. 18; according to Webster, 1992) therefore define strategic alliances as taking place *"in the context of a company's strategic plan and seek to improve or dramatically change a company's competitive position"*. This involves sharing of resources, knowledge and capabilities for improving the competitive position of all involved parties as well as joint measurement of success (Aaldering et al., 2018, p. 18). Generally speaking, a broad range of different operational functions can be included in the scope of a strategic alliance. Although strategic alliances most often exist for a longer period of time and are based on formalised agreements, they do not necessarily have to involve equity investment. Depending on the degree of capital investment, equity, minority-equity and non-equity alliances can be distinguished (Duschek & Sydow, 2011, pp. 104–105). Other authors state, that normal strategic alliances only include cooperation without capital investment (Schuh & Klappert, 2011, p. 73). Schuh (2012, pp. 44–48) sees economic, legal and organizational sovereignty of all areas that are untouched by the relationship as the central feature of strategic alliances. Legal autonomy of all involved parties persists over the whole duration of the relationship. Strategic alliances can consist of two partners in the form of dyadic relationships or of multilateral partnerships which can lead to a whole alliance network (Moore, 1993) The skill to absorb the acquired technology has been identified as the most important capability of companies that choose to engage in a strategic alliance for external technology sourcing (Lambe & Spekman, 1997, p. 112). This is a major difference to traditional outsourcing in the form of pure market-based relationships, which do not lead to absorption of technological knowledge (Lambe & Spekman, 1997, p. 115). Thorough planning, preparation, implementation and communication are considered important conditions for the success of strategic alliances (Schuh, 2012, pp. 44–48). Possible benefits include synergies, distribution of risks and costs, greater adaptability than markets, greater incentives than hierarchies, access to complementary resources or new markets (Aaldering et al., 2018, p. 18;

Kapoor & Lee, 2013, p. 277; Schuh, 2012, pp. 44–48). However, unintended sharing of knowledge and core competences and opportunism of partners are possible risks of strategic alliances (Basole et al., 2015, p. 539; Kapoor & Lee, 2013, p. 277).

5) Joint venture

Although sometimes the term is used to describe strategic alliances in general, joint ventures can only be seen as a special type of strategic alliances (Webster, 1992, p. 8). Their main characteristic is that they are legally autonomous enterprises that are commonly founded, owned and strategically led by two or more cooperating organizations on the basis of a formal agreement (Aaldering et al., 2018, p. 19; Schuh, 2012, pp. 44–48). The most prominent reasons for engagement in joint ventures are cost minimization through synergies, sharing of financial, material, immaterial and personal resources, improved competitive positioning, risk reduction, knowledge sharing and organizational learning (Aaldering et al., 2018, p. 19; Schuh, 2012, pp. 44–48). In contrast to many other kinds of interorganizational relationships, joint ventures are not always set up voluntarily as in some countries they are the only way to enter domestic markets. For this reason, joint ventures are a bare necessity in pursuing internationalization strategies that include the expansion to those countries. Joint ventures do not really represent dyadic relationships in the classic understanding, as they rather include three parties – the two cooperating mother companies and the commonly founded venture itself. (Duschek & Sydow, 2011, p. 108) As partners in joint ventures often are competitors, interaction also includes many competitive elements. For this reason, the concept of coopetition is especially applicable to these relationships (Gnyawali et al., 2016, p. 15). In recent years, the number of joint ventures has increased rapidly, fulfilling many different functions from R&D to supply and market entry (Ritter & Gemünden, 2003, p. 691).

6) Integration / internal R&D / hierarchy

Integration and internal technology sourcing is the exact opposite of market relationships. Organizations that are directly integrated into a superordinate mother organization are not governed by market mechanisms but by strict adherence to hierarchical directives and instructions. Instead of isolated procurement decisions and ex post regulation through the price mechanism, coordination is managed through organizational rules, culture and norms. The exact scope of exchange does not have to be specified beforehand, but is defined in the course of the exchange process. (Duschek & Sydow, 2011, pp. 43–44) Depending on the initial state, hierarchy can be effected through merger, fusion, majority or full acquisition or simple internal technology sourcing in traditional R&D-departments, integration teams, internal, autonomous or independent ventures (Iansiti & Levien, 2004b, p. 177). According to Phillips et al. (2006, p. 455), mergers and acquisitions are not an appropriate strategy in the face of discontinuous technological change. The advantages of internal technology sourcing are independence, autonomy and an advantage in customer perception. Additionally, hierarchy forms of organisation benefit from better adaptability which at least partly compensates the higher organizational costs (Kapoor & Lee, 2013, p. 276). Disadvantages are high risk, costs and efforts regarding time and resources (Schulte-Gehrmann et al., 2011, pp. 72–73). Prevailing trends nowadays point towards disintegration and specialization as an industry and its products mature instead of integration of all functions into one organization (Fixson & Park, 2008, p. 1307; Parhi, p. 4; Sovacool et al., 2019, p. 11). The same shift is referred to as the outsourcing trend, allowing companies to concentrate on core competences (Kampker et al., 2018, pp. 44–45).

The technology sourcing typology proposed for the purpose of this thesis can be seen in Table 8. It is based on the above mentioned typologies and generic types and most closely resembles the typology used by Schuh & Klappert (2011, p. 73). Adaptations have been made in order to be able to fully cover all relationship types discovered during development of the case studies while at the same time allowing an easy categorisation with only a minimum of needed information. All relationship categories can involve vertical and horizontal ties. “Interorganizational relationships” or just “relationships” are the words used as hypernyms to refer to all different types in the following chapters of this thesis.

Type	Time horizon	Relationship scope	Focus	Ownership/ legal autonomy
Market transaction	Short and long term	Supplier or customer	Predefined scope of exchange	Complete legal autonomy of involved parties
Partnership	Long term	Research & development, manufacturing, marketing, installation and/or operation	Common goal	Complete or almost complete legal autonomy of involved parties
Strategic alliance	Long term	Research & development, manufacturing, marketing, installation and/or operation	Strategically relevant common goal	Legal autonomy of involved parties or reciprocal investments
Joint venture	Long term	Research & development, manufacturing, marketing, installation and/or operation	Strategically relevant common goal	Common ownership by cooperating organizations
Internal R&D / Integration	Long term	Possibly covers all functions (R&D, Procurement, Manufacturing, Installation, Operation and Marketing).	Full hierarchical control	Complete ownership and/or integration into mother organization

Table 8: Typology of interorganizational relationships for technology sourcing (own creation)

At this point it has to be mentioned, that also internal research and development activities are considered an interorganizational relationship type for sourcing of technology for the scope of this thesis although they do not fulfil the basic requirement of being interorganizational. This is justified by the fact that internalization and externalization dependencies of technology sourcing can only be examined by also considering internal activities.

6 General Aspects of E-Mobility

This chapter covers the technological basics of electric mobility. Besides shedding light on the definition of the term, different types of electric vehicles are distinguished, differences to vehicles with internal combustion engines are shown, and by outlining the central characteristics of powertrain and energy storage technology, a background is provided for the empirical part of this thesis.

6.1 Definition of the Term

There is no unambiguous definition of the term “e-mobility” (Scheurenbrand et al., 2016, p. 2). “E-mobility” can be seen as either abbreviating the words “electromobility”, “electro mobility” or “electric mobility”; all exist. Sometimes electrified driving is even referred to as “electrical mobility” by non-native speaking scholars although the term rather describes the physical process of a movement of charged particles that are pulled by an electric field. The first word describing electric vehicles when they initially were invented at the end of the 19th century was “electromobile” which most probably is of French origin (Durkin & Philip, 2009, pp. 73–74). In general, electric mobility or electromobility is a *“road transport system based on vehicles that are propelled by electricity”* (Grauers et al., 2013, pp. 10–11). This definition especially stresses the systemic nature of all involved components, which also includes electricity supply. The needed electricity can either be supplied from outside the vehicle or generated by electricity production equipment incorporated into the vehicle. Another definition proposed by Scheurenbrand et al. (2016, p. 10) sees electric mobility or electromobility *as “a highly connective industry which focuses on serving mobility needs under the aspect of sustainability with a vehicle using a portable energy source and an electric drive that can vary in the degree of electrification”* (Scheurenbrand et al., 2016, p. 10). As can be seen, this rather focuses on the business side than on the technological aspects. Sustainability in this context refers to the independence on finitely available resources like crude oil or natural gas. What all definitions have in common is the electric propulsion system that transforms electric energy in mechanical energy and some kind of energy storage system in order to allow independent mobility.

Despite a dramatic rise in sales figures in the last couple of years, electric vehicles are not a new development, as the first examples already were invented as early as 1881 (Achleitner et al., 2013, p. 161; Kampker et al., 2018, p. 4; Nieuwenhuis & Wells, 2015, p. 197). However, the beginning of the 20th century brought the decision in favour of the internal combustion engine, most probably because of the higher energy density of fossil fuels and lower costs of the involved technology (Gupta-Chaudhary et al., 2018, p. 8; Kampker et al., 2018, p. 5). It was not before the end of the 20th century, when the limitedness of resources, strategic considerations regarding the dependence on crude oil, legislation and climate concerns finally led to the revival of interest in the technology (Kampker et al., 2018, p. 30; Mazur et al., 2013, pp. 1056–1057; Moore, 1996, p. 100; Strathmann, 2019, p. 24). Depending on the source of electric energy, electric vehicles allow a dramatic reduction of CO_2 emissions and emissions of other potentially toxic or ecologically harmful substances, which makes them an attractive alternative to internal combustion engines (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 21–22; International Energy Agency, 2018, p. 56). However, the energy-intensive manufacturing of the battery leads to CO_2 emissions that equal the amount that is emitted while driving some hundred thousand kilometres in a conventionally powered car (Heerwagen, 2019, p. 13).

6.2 Technological Overview of Electric Vehicles

The current trend towards electric mobility is propelled not only by huge investments and efforts in one single technology, but in a myriad of different concepts that all incorporate an electric motor to transform electric into kinetic energy (Lienkamp et al., 2012). However, the concepts differ significantly regarding the technology used for energy storage and the system architecture.

1. Hybrid electric vehicles (HEVs)

   Hybrid electric vehicles combine an electric motor with an internal combustion engine. The internal combustion engine is the primary source of propulsion, with the electric motor only serving auxiliary purposes. For this reason, HEVs feature two energy storage systems: a tank containing fossil fuels for the internal combustion engine and a small battery that can be charged by the combustion engine or via recuperation when braking. Those concepts include mild hybrid vehicles that do not allow driving propelled by the electric engine only and full hybrid concepts where fully electric driving is possible, although speed and distance are very limited due to the small amount of energy stored in the battery. (Achleitner et al., 2013, pp. 145–148; Amsterdam Round Tables & McKinsey & Company, 2014, pp. 21–22; Enrietti & Patrucco, 2011, pp. 12–13; Gupta-Chaudhary et al., 2018, p. 9)

2. Plug-in hybrid electric vehicles (PHEVs)

   In contrast to HEVs, where charging of the battery can only be accomplished via recuperation or using the internal combustion engine, PHEVs' batteries can also be charged using an external interface (Enrietti & Patrucco, 2011, pp. 12–13). Consequently, a PHEV can be considered as a combination of a conventional HEV and a fully electric BEV. PHEVs usually allow full electric driving over distances between 10 and 60 kilometres (Achleitner et al., 2013, pp. 145–148). A further categorization of plug-in hybrid drives according to the configuration of internal combustion engine and electric motor can be made. In parallel arrangements, torque can be delivered to the axles by both the internal combustion engine and the electric engine at the same time. In series configurations, one of the two motors does not have a direct connection to the driven axle. (Achleitner et al., 2013, pp. 187–192; Lowry, 2012, pp. 19–21) The most prominent example for a serial architecture are range-extended electric vehicles, where an electric powertrain is complemented by an internal combustion engine. (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 21–22)

3. Battery electric vehicles (BEVs)

   BEVs only incorporate a rechargeable traction battery for energy storage, and an electronically controlled electric motor for propulsion. (Gupta-Chaudhary et al., 2018, p. 9; Lowry, 2012, p. 19). Consequently, BEVs' traction batteries most often feature high capacity and lithium-ion technology (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 21–22). As besides recuperation during braking there is no way of generating energy on-board, BEVs are dependent upon energy transfer from an external electricity source or by exchanging the whole battery module (Enrietti & Patrucco, 2011, pp. 12–13). In contrast to HEVs and despite huge investments made by OEMs, the diffusion of BEVs historically lagged behind HEVs as a consequence of their smaller range, high battery costs and insufficient charging infrastructure (Achleitner et al., 2013, pp. 145–148). Nowadays, there is a variety of different BEVs that are able to almost travel 500 kilometres on one charge (Heerwagen, 2019, p. 10). As a consequence, BEVs accounted for two-thirds of electric vehicle sales in 2017 (International Energy Agency, 2018, p. 21).

4. Fuel cell electric vehicles (FCEVs)

   In contrast to other types of electric vehicles, where the energy is stored in a traction battery, FCEVs use an on-board fuel cell to convert chemical energy into electric energy that is used to power the electric engine. Although the technology is also suitable for the use with other fuels, most of them run on hydrogen that is stored in a high-pressure tank. The biggest advantage of FCEVs is their high range and fast recharging process in comparison to BEVs and their level of efficiency that is almost twice as high as in internal combustion engines. (Achleitner et al., 2013, p. 170; Amsterdam Round Tables & McKinsey & Company, 2014, pp. 21–22)

The focus of this thesis only lies on BEVs, without further consideration of all other concepts. Of course, not all effects can be unambiguously affiliated to only this specific type of drive train arrangement. However, concentration on BEVs should allow a closer limitation of scope when needed.

6.2.1 Differences to Vehicles with Internal Combustion Engine

Generally speaking, two different approaches for designing BEVs exist. The first approach is a conversion design, where a vehicle that was initially developed for being equipped with a conventional engine is adapted in order to accommodate an electric powertrain. In comparison to vehicles featuring an internal combustion engine, only minor modifications are necessary, allowing a retention of existing production facilities and procedures. (Strathmann, 2019, p. 34) The same innovation style can also be described as *"conservative sustaining"* as it originates from an attitude of maintaining existing value rather than a radical strategy with the goal to achieve a profitable breakthrough (Sovacool et al., 2019, p. 4). The opposite concept are purpose designs, which allows full exploitation of the potential advantages of BEVs (Barthel et al., 2015, p. 16; Kampker et al., 2018, p. 20). Those designs evolve from scratch in a development process that fully considers the different characteristics of all components that are part of electric powertrains (Kampker et al., 2018, p. 20; Strathmann, 2019, p. 34). Consequently, a purpose design necessitates the adaption of production processes, which might look economically unjustifiable in light of the low production figures expected in early stages. A possible reaction to this issue might be different body structures and materials that allow manufacturing without investing in capital-intensive tools and machines and at least partly compensate the high weight of the battery (Amsterdam Round Tables & McKinsey & Company, 2014, p. 13; Kampker et al., 2018, p. 20; Strathmann, 2019, p. 36). However, a cost-competitive electric vehicle can only be realized by choosing such transformative change-shaping innovation style (Kampker et al., 2018, p. 20).

Independently from the chosen design approach, many parts distinguish electric vehicles from conventional ones, leading to a shift in the needed technology and supplier base. From a technical standpoint, three different categories of parts can be found (Kampker, 2014, p. 17; Kasperk et al., 2018, p. 147):

1) Components that become obsolete for electric vehicles.
2) New components.
3) Components that need to be adapted.

A thorough overview over differences on component level can be taken from Table 9. As can be seen from the table, the most important changes can be determined in the areas of the drivetrain and suspension. The single most important new components are electric motor and traction battery parts, which furthermore incorporate technology that historically was not needed by vehicle manufacturers (Kalaitzi et al., 2019, p. 257). For this reason, battery producers and tier-one suppliers are the holders of core skills needed for EV production (Hensley et al., 2009, p. 92).

In contrast to an internal combustion engine's 1400 to 2000 moving parts, an electric powertrain only contains approximately 200 moving parts (Barthel et al., 2015, p. 21; Gupta-Chaudhary et al., 2018, p. 46). As a consequence, the production of electric vehicles is less labour-intensive, maintenance intervals can be extended, spare parts reduced and thus revenue streams in the downstream parts of the value-added chain and the number of assembly line jobs are dramatically decreased (European Commission, 2014, p. 2).

Category	Function	System	Component
Obsolete components	Drivetrain	Internal combustion engine	• Crankcase • Crankshaft • Piston • Connecting rod • Bushings • Cylinder head • Valves • Camshaft • Plain bearings • Cooling circuit • Turbocharger/compressor • Engine control unit • Oil pump
		Fuel system	• Tank • Fuel pump • Fuel injection system
		Exhaust system	• Exhaust manifolds • Three-way catalyst • NOx catalyst • SCR system
		Clutch	• Disc clutch • Torque converter
Adapted components	Drivetrain	Transmission	• Housing • Gear wheels • Lubrication • Differential gear
	Suspension	Steering	• Power steering pump • Actuator
		Brake	• Brake booster • Actuator • Control unit
	Bodywork	Interior and exterior	• Structure • Materials
	Various	Thermal management system	• Isolation • Air conditioning • Heating system • Cooling circuit
New components	Drivetrain	Electric motor	• Stator/rotor • Power electronics
		Traction battery	• Cells • Battery management • Housing • Charging unit
		High voltage system	• Fuse protection/wiring • DC converter

Table 9: Differences between electric and conventional vehicles (based on Kampker, 2014, p. 17; Kasperk et al., 2018, p. 147)

6.2.2 Powertrain Technology

In general, the electric drivetrain mechanically connects the traction battery to the driven axle of the vehicle and transforms the electrochemical energy stored in the battery into mechanical energy that is used to drive the wheels (Röth et al., 2018, p. 310). The main components of this system are the electric motor, the gearbox and a power inverter that allows control over the engine's torque and speed by converting the electric energy's current, voltage and frequency (Kampker, 2014, p. 117). Electric drivetrains do not need a conventional gearbox and clutch, because torque can be delivered even at standstill and is modulated by the inverter (Strathmann, 2019, p. 36). However, a single-ratio gear is still needed, as most engine type's optimum number of revolutions is too high for directly driving the wheels (Lowry, 2012, p. 224).

Three different topologies exist for the arrangement of electric motor unit, differential gears and driven wheels. These components can either be implemented by using a single central electric motor that is connected to the driven wheels via a differential like in conventional ICE-powered vehicles. However, the simplicity of this arrangement is bought dearly by efficiency losses and high weight. The second option are two or more electric motors that are connected to the driven wheels through a single-ratio gear. This way, much space within the vehicle can be cleared as differential gears can be omitted, and each wheel's torque can be electronically controlled individually. Lastly, the electric motors can be connected to the wheels directly, as part of the hub assembly. This option shows the highest transmission efficiency, but is expensive and necessitates large and heavy motors that allow continuous operation at low engine revolutions. These in turn lead to a considerable increase of unsprung masses. (Achleitner et al., 2013, p. 162; Lowry, 2012, p. 224; Morche et al., 2018, p. 194)

Generally speaking, all types of electric engines are suitable for the use in electric vehicles (Röth et al., 2018, p. 316). Relevant criteria for the choice of engine type are costs, weight, package space, noise emission, production effort, maintenance, recycling, efficiency, selection of materials, power density and durability (Achleitner et al., 2013, pp. 163–164; Röth et al., 2018, p. 316). In comparison to internal combustion engines, all electric motors operate very quietly, have a high level of efficiency and show an advantageous torque-speed characteristic (Achleitner et al., 2013, pp. 163–164). However, it has to be mentioned, that engine efficiency and power density do not mainly depend on the motor type but on other factors like size, speed, operation point and cooling method (Lowry, 2012, pp. 179–181; Lowry, 2012, pp. 181–182). The most widely spread examples in this context are conventional and brushless DC motors, synchronous motors, induction motors and switched reluctance motors (Röth et al., 2018, p. 330).

1. DC motor

   The brushed DC motor is the simplest and oldest form of electric engines (Kampker, 2014, pp. 130–132). It is most often used in toys, portable tools and other consumer applications and consists of a coil that rotates in the magnetic field created by a magnetic stator (Lowry, 2012, pp. 145–146). A commutator is used to switch the direction of the current flowing through the coil every half turn, so that the direction of the forces exerted to it leads to a continuing rotation (Kampker, 2014, pp. 130–132). The torque created in this kind of electric motors is highest at stand still and drops with increasing speed (Lowry, 2012, p. 149). Although DC motors convince through their simplicity and associated low costs, their main disadvantages are the commutator's brushes which need regular maintenance and the fact that the main losses occur at the rotor which is located at the motor's centre (Achleitner et al., 2013, p. 164; Lowry, 2012, p. 156). Consequently, the generated heat can hardly be removed, which leads to the limited efficiency and power density of this engine type (Achleitner et al., 2013, p. 164). Early electric vehicles were mostly equipped with DC motors. However, due to huge advancements in other engine types, their relevance as a traction engine is marginal nowadays. (Achleitner et al., 2013, p. 164; Röth et al., 2018, p. 316) Depending on the arrangement of the electric circuits of rotor and stator, DC motor compounds, shunt-wound, series-wound, and separately excited DC motors can be distinguished. The torque-speed characteristics of the respective types can be taken from Figure 15.

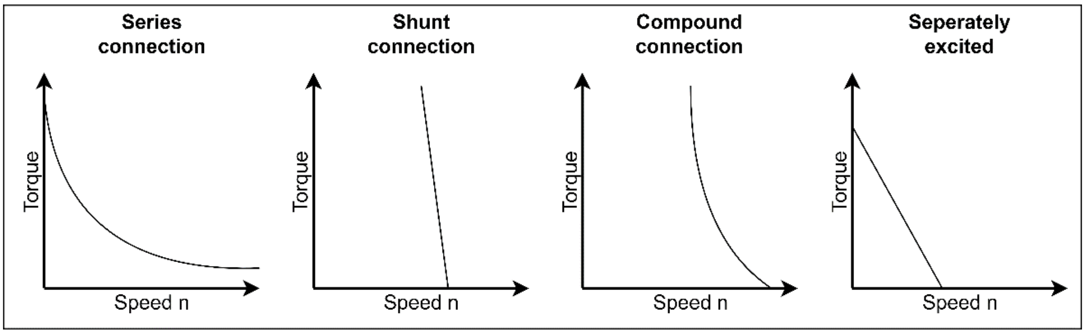


Figure 15: Torque-speed characteristics of DC motors in stationary operation at constant terminal voltage (based on Kampker, 2014, p. 132)

2. Brushless DC motor (BLDC)

   Those are similar to permanent magnet DC motors but do not incorporate a commutator for changing the direction of the current. Instead, commutation is performed electronically by an inverter that transforms the electric energy from a DC source to an AC current with variable frequency. (Achleitner et al., 2013, p. 165) In contrast to a conventional DC motor, the coil is accommodated at the stator and the rotor only consists of a permanent magnet (Lowry, 2012, p. 170). As a result, brushless DC motors avoid the conventional DC motor's disadvantages of internal heat generation and friction at the brushes of the commutator (Lowry, 2012, p. 169). For this reason, they represent an improvement in efficiency, maintenance intensity and power density. Small brushless DC motors with integrated power electronics are used in computer equipment. Higher power applications also include traction motors for electric vehicles, where the coil current is varied by more sophisticated controllers in order to control the torque. (Lowry, 2012, p. 171) The brushless DC motor's torque-speed characteristics very closely resemble those of conventional DC motors (see Figure 16) (Lowry, 2012, p. 170).

3. Synchronous motor (SM)

   As batteries always deliver electric energy in DC, an inverter has to be used to transform this energy into a three-phase current with variable frequency and amplitude in order to power and control AC motors (Achleitner et al., 2013, p. 165). The stator of these machines consists of three coils that create a rotating magnetic field in which the rotor turns. In synchronous AC motors, the rotor turns synchronously with the stator's magnetic field, but with a lag angle that depends on the engine load. (Kampker, 2014, pp. 126–130) Two different rotor designs exist for this type: In separately excited synchronous motors, the rotor's magnetic field comes from a DC current that flows through a coil. These machines have hardly been deployed in electric vehicles so far. (Achleitner et al., 2013, p. 165) Permanently excited synchronous machines feature a rotor that consists of a permanent magnet which leads to very high overall efficiency, power density and small package space. The design of these machines is very similar to the brushless DC motors', the only difference being the sinus-shaped current in synchronous AC motors in contrast to the block-shaped current in brushless DC motors. Permanently excited synchronous machines are the first choice for driving electric vehicles if efficiency and power density are considered. Additionally, they show a high efficiency over a wide speed range which makes them suitable for directly driving wheels as wheel hub motor. (Röth et al., 2018, p. 317) However, their costs are quite high due to the expensive high energy permanent magnetic materials (Kampker, 2014, pp. 126–130; Röth et al., 2018, p. 317). The synchronous AC motor's torque-speed characteristics can be taken from Figure 16.

4. Induction motor or asynchronous motor (ASM)

   Induction motors are very similar to synchronous motors except for the design of the rotor (Achleitner et al., 2013, p. 165). Both are AC powered, but in induction motors, the rotor does not feature an own source of electric current, which means that the current has to be induced through the stator's rotating field. For this reason, the rotation of the rotor is slower than the frequency of the three-phase current in the stator. The torque generated by the motor is dependent on the relative slip between those two, which necessitates a more complex controller architecture. (Kampker, 2014, p. 123; Lowry, 2012, pp. 177–179) As in synchronous motors, two different designs exist for the rotor: The first one is the wound type, where the rotor contains coils that are connected to the outside via brushes. Similar to conventional DC motors, the friction inherent in these brushes demands regular maintenance, which is the reason why this engine type did not prevail in electric vehicles. The second type are squirrel-cage rotors which consist of metal bars that are short-circuited at the sides. Because this type manages without brushes, it possesses a higher robustness and compactness. (Achleitner et al., 2013, p. 165) Induction motors with squirrel-cage rotors are mature, widely available, very reliable and reasonably priced due to high production volumes. For this reason, they are widely used in industrial applications and electric vehicles. Their main disadvantages are the higher volume that results in low power density and the losses that result from the current that has to be induced in the rotor, leading to a slightly lower efficiency than in other electric engine types. (Lowry, 2012, pp. 177–179; Röth et al., 2018, p. 318) The induction motor's torque-speed characteristics can be taken from Figure 16.

5. Switched reluctance machine (SRM)

   The stator and control electronics of switched reluctance machines is quite similar to that used in induction motors (Lowry, 2012, pp. 173–176). Both stator and rotor feature a toothed profile, the stator teeth being equipped with coils. The underlying principle is a magnetic flux' endeavour to always minimize its magnetic resistance and covered distance. If one coil is perfused by an electric current, the rotor will consequently turn until reaching the optimum position. In order to keep the resulting rotation going, opposite coil pairs are cyclically turned on and off in response to the rotor's position. (Kampker, 2014, p. 133; Röth et al., 2018, pp. 318–319) As this machine type manages without magnets or rotor coils, it is robust and cheap at the same time. Its disadvantages are higher sound emissions caused by forces in axial direction. Nevertheless, switched reluctance machines are very well suited for the deployment in electric vehicles due to their high power density in areas of high speed, their high torque-to-volume ratio and their high efficiency over a wider speed range and torque than any other electric motor. (Röth et al., 2018, pp. 318–319) Switched reluctance machines will probably become more widely spread in the future, mostly in cost-sensitive mass produced products which allow an economically justifiable manufacturing of the needed high-precision control electronics. (Lowry, 2012, pp. 173–176) The torque-speed characteristics can be taken from Figure 16.

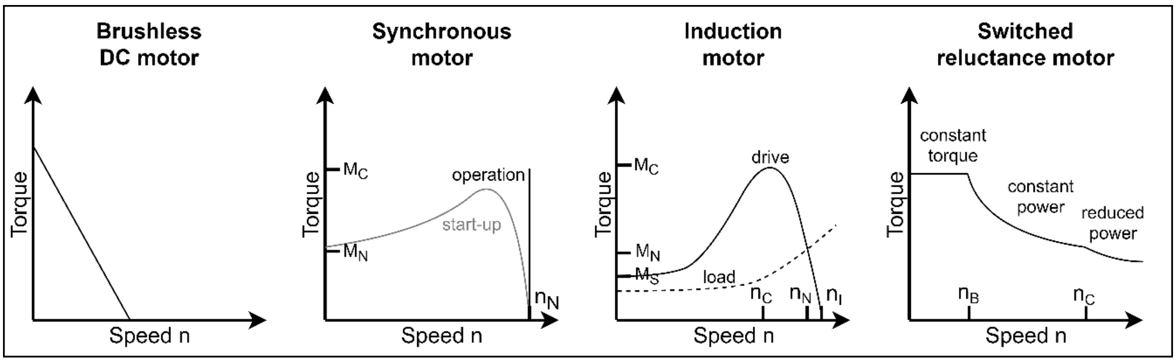


Figure 16: Torque-speed characteristics of EV motors in stationary operation at constant terminal voltage (based on Chan & Cheng, 2019, p. 13 and Kampker, 2014)

An overview over advantages and disadvantages of the presented types of electric engines for electric vehicles can be seen in Table 10.

	DC machine	BLDC machine	SM	ASM	SRM
Power density	--	++	++	+	+
Efficiency	--	++	++	o	+
Max. speed	--	++	++	++	++
Noise emission	-	+	++	+	--
Reliability	-	+	+	++	++
Machine costs	--	-	-	+	++
System costs	+	+	o	++	+
Technological maturity	++	++	++	++	o
Controllability	++	+	+	o	+

Table 10: Comparison of different engine types for EVs (based on Kampker, 2014)

6.2.3 Energy Storage Technology

In comparison to electric engine technology, energy storage technology is still technologically immature (Kampker, 2014, p. 22). In general, options for energy storage in electric vehicles are batteries, supercapacitors, flywheels and hydrogen tanks for the use with fuel cells (Lowry, 2012, pp. 32–33; Röth et al., 2018, p. 345). Due to the focus of this thesis, only battery technology will be covered in this section.

Electric batteries are systems of electric cells that are connected together to transform chemical energy into electric energy. Each cell consists of a positive and negative electrode that are kept in an electrolyte. When the battery's electrodes are connected to an electric load, a chemical reaction between the electrodes and the electrolyte generates DC electricity. Generally speaking, primary, secondary and tertiary batteries can be distinguished. (Lowry, 2012, p. 29) Primary batteries can only be discharged once and have to be exchanged and reprocessed after being used. Secondary batteries can be recharged multiple times, whereas the energy carrier in tertiary batteries or fuel cells is not stored within the battery but supplied continuously from the outside. (Achleitner et al., 2013, pp. 166–168; Morche et al., 2018, p. 245) In some applications, batteries are not recharged, but exchanged in order to reduce the time required for necessary stops (Kampker et al., 2018, p. 18). The term traction battery that is used to describe the battery systems utilized in electric vehicles creates a clear differentiation from starter batteries that are employed in vehicles powered by internal combustion engines. The main components of traction battery systems are battery cells, a protective housing with cooling/heating functions and the battery management system. Although this periphery increases the system's weight and volume, a secure and controlled operation is impossible without (Morche et al., 2018, p. 228).

Three different designs for battery cells that are used in electric vehicles exist: cylindrical, prismatic and pouch cells (Kampker et al., 2018, pp. 18–19; Röth et al., 2018, pp. 349–350). Cylindrical cells are the most common type today and feature a metal cylinder as their outer shell (Kampker, 2014, p. 56). They are standardized and most often used in applications where battery size is not a big concern, can be manufactured at low costs and withstand high internal pressures which leads to high safety and expected lifespan (Choi et al., 2011, 21-22). However, cylindrical cells show a low package density and poor heat dissipation properties which makes necessary an advanced cooling concept. (Kampker, 2014, p. 56; Röth et al., 2018, pp. 349–350). Pouch cells are not covered by a rigid shell but sealed in a multi-layer foil instead; the contacts consist of a conductive foil that is welded to the electrode. This leads to cost and weight savings and allows the best package, energy density and cooling. (Choi et al., 2011, 21-22) However, the cost and weight reduction is at least partially recouped by the need for a rigid casing on module level. Further disadvantages of this design are a swelling in the case of internal pressure build-up, bad stackability of electrodes, possible leakages and higher production costs. (Kampker, 2014, p. 54). Pouch cells are widely spread in portable consumer electronics (Choi et al., 2011, 21-22). Prismatic cells combine the advantages of both cylindrical and pouch cells. They can consist of ovally winded or piled-up layers that are covered by a cuboid housing. This allows high package density, easy module assembly, high flexibility regarding the cell's physical size and high bending stiffness at the same time. However, pressure is necessary to join cells into a package and temperature gradients might be a problem during charging and discharging. (Kampker, 2014, p. 56) Prismatic cells are widely spread in consumer applications (Choi et al., 2011, 21-22).

For application in electric vehicles, a certain number of battery cells is connected in series in order to reach the needed voltage. This assembly is known as battery module, which also includes cooling channels and an individual housing. Similar characteristics of all cells contained in a battery module is vital, as otherwise the behaviour of the whole battery assembly is compromised. A certain number of battery modules is then wired in parallel configuration in order to meet the needed power specifications of the whole battery pack. The connected battery cells are equipped with sensors that measure electric energy, voltage and temperature. The installation of periphery electronic devices like power electronics, battery management and cooling system constitutes the final step of battery assembly. (Kampker, 2014, pp. 56–58)

Many different combinations of electrode and electrolyte materials exist, which have a dramatic influence on a cell's characteristics (Röth et al., 2018, p. 347). The most important criteria for the selection of a specific cell chemistry are durability (in charging cycles until the capacity falls to 80% of the nominal capacity or the life expectancy in years), operating temperature, general performance (e.g. peak power at low temperatures, thermal management and state-of-charge measurement), the specific energy (energy of a battery in watthours divided by its weight in kilogrammes; defines a vehicle's range), energy density (energy of a battery in watthours divided by its volume in cubic metres), the specific power (power that can be taken from a battery at 80% charge level in watt divided by the battery's weight in kilogrammes; defines a vehicle's acceleration, maximum speed and minimum recharge times), costs (most often in € or $ per kilo-watthour; depend on materials, design and production figures), voltages (usually between 200 and 1000 volts), recharge rates, amp hour efficiency and self-discharging rates. (Achleitner et al., 2013, pp. 166–168; Dinger et al., 2010, p. 2; Lowry, 2012, p. 33; Röth et al., 2018, p. 343)

The cell types most often used in electric vehicles are lead acid, nickel-cadmium, nickel-metal hydride, sodium-based, lithium-ion and metal air batteries:

1. Lead acid batteries

   Lead acid batteries have been in use in automotive applications for a long time, especially as starter batteries for internal combustion engines and in micro-hybrid vehicles (Röth et al., 2018, p. 344). They are by far the cheapest rechargeable batteries per kilowatt-hours. However, their low specific energy and resulting high weight in combination with their low life expectancy makes them very unappealing for modern long-range vehicles. Nevertheless, they are a reasonable choice for hybrid drives, where specific energy is less important than specific power. Due to the low pricing of their basis materials, lead batteries will still hold their commercial significance for the foreseeable future, in spite of their inherent technological limitations. (Achleitner et al., 2013, p. 168; Kampker, 2014, p. 47; Lowry, 2012, p. 41; Röth et al., 2018, p. 344)

2. Nickel-cadmium batteries (NiCd)

   The nickel-cadmium was once considered the main contestant of the lead acid battery for use in electric vehicles due to its higher specific energy and number of charging cycles before its capacity falls to 80% of the nominal capacity. However, the potentially occurring memory effect, which leads to faster degradation in case of regular partial discharges and the toxicity of cadmium make them almost irrelevant for the use in modern electric vehicles. Additionally, they are significantly more expensive than lead acid batteries. (Achleitner et al., 2013, p. 168; Kampker, 2014, p. 47; Lowry, 2012, p. 41)

3. Nickel-metal hydride batteries (NiMH)

Nickel-metal hydride batteries' cathode reaction is very similar to that of nickel-cadmium batteries. However, its negative electrode features hydrogen absorbed in a metal hydride instead of the toxic cadmium. The cell type was introduced commercially at the end of the twentieth century and ended the nickel-cadmium battery's dominance in many applications. (Achleitner et al., 2013, p. 169; Lowry, 2012, p. 44) Nickel-metal hydride batteries have a power density that is high enough to make cooling necessary at charging (Lowry, 2012, p. 45; Röth et al., 2018, p. 344). They have an almost twice as high specific energy and superior life expectancy than nickel-cadmium batteries and the technology is considered very sophisticated (Kampker, 2014, p. 47). However, market prices of the involved materials are considerably high, and the cell's self-discharging properties are their biggest disadvantage (Lowry, 2012, p. 45). Nevertheless, batteries of this type are employed in almost all medium and full hybrid electric vehicles that are available today. A use in plug-in hybrid or BEVs cannot be realized expediently as the specific energy and cost reduction potential are not sufficiently high. In the medium term, nickel-metal hydride batteries will probably be substituted by lithium-ion technology in most applications. (Röth et al., 2018, p. 344)

4. Sodium-based batteries

Examples of this battery type were first developed in the 1970s. Their main difference to other battery types is that they need a temperature between 270 and 350 degree Celsius for operation. As a consequence, they have to be enclosed in an insulated evacuated case, making an application in small systems very impractical. (Achleitner et al., 2013, p. 169; Lowry, 2012, pp. 46–47) Early types were sodium-sulfur cells which showed a six times higher energy density than lead acid cells and an extraordinarily high energetic efficiency but their huge weight compensated much of this advantage (Lowry, 2012, p. 47). The more sophisticated types are sodium-metal chloride or ZEBRA batteries, which are quite similar to sodium-sulfur batteries except for their improved safety level, which finally satisfied the safety concerns associated with the application in electric vehicles. (Lowry, 2012, p. 48) ZEBRA batteries are commercially available and underwent many field tests in electric vehicle prototypes from the end of the 20th century on (Daimler AG, 2013). However, the fact that their operation necessitates extensive heat-insulation measures and a permanent connection to a mains supply in standstill in order to keep the battery at working temperature has minimized their significance in EV applications in recent years, although they are considered cheaper than lithium-ion batteries. (Kampker, 2014, p. 48)

5. Lithium-ion batteries (LIB)

This is an umbrella term for a myriad of different material combinations that lithium-ion cells can be comprised of. Their characteristics regarding safety, electric properties and life expectancy are highly dependent on the respective materials. They all have in common that the cell's anode contains lithium and that the ionic conduction between the electrodes is accomplished through lithium ions. Those cells contain between 3 and 5 weight percent lithium, which is the lowest-density metal in existence and has a very high electronegative potential. Lithium-ion cells are the most promising cell types for use in electric vehicles as they combine outstanding performance in life expectancy, efficiency, specific power, specific energy and safety. (Achleitner et al., 2013, p. 169; Kampker, 2014, p. 49; Röth et al., 2018, p. 345) Many different cathode materials exist, which all lead to different specific energy, voltage and expected life. Nowadays, the most popular cathode materials are $LiCoO_2$ (LCO), $LiNiO_2$ (LNO), $LiNiCoAlO_2$ (NCA), $LiNiMnCoO_2$ (NMC), $Li_4Ti_5O_{12}$ (LTO), $LiFePO_4$ (LFP) and $LiMn_2O_4$ (LMO). Due to the high costs for cobalt, producers of lithium-ion cells try to replace this element with other metal oxides. Those cells combine higher specific power and energy with lower thermal stability. (Dinger et al., 2010, p. 3; International Energy Agency, 2018, pp. 12–13; Röth et al., 2018,

p. 346) The disadvantage of lithium-ion batteries – besides their high prices – is that operation necessitates a protective circuit in order to limit peak voltages. Lithium-ion cells were originally marketed for premium portable consumer electronics but their low weight led to wide application in modern series-production electric vehicles. Further research is expected to improve production processes and therefore reduce costs. (Lowry, 2012, pp. 51–52) At the same time, endeavours to introduce ultra-fast charging will increase the costs and decrease the energy density of those batteries (International Energy Agency, 2018, p. 63).

6. Metal-air batteries

   Metal-air batteries are primary batteries which means that they cannot be recharged by simply reversing the direction of the flowing electrons. Instead, the whole electrodes and electrolyte have to be replaced after the cell is discharged. The used electrodes are then reprocessed for reuse, which resembles some kind of manual charging. As a consequence to the fact that this recharging is accomplished outside of the vehicle, the vehicle is ready for continuing its journey within a couple of minutes – just like in vehicles running on fossil fuels. Examples for this technology are the aluminium-air and zinc-air batteries. Aluminium-air batteries have the huge disadvantage of showing an absolutely intolerable specific power of just 10 watt per kilogramme. Zinc-air batteries' specific power is ten times higher, which makes them suitable for the use in vehicles. They are already commercially available as of now and are used in hearing aids due to their very high specific energy. However, their self-discharging properties and the lack of expensive reprocessing infrastructure impair their future prospects in EV applications. (Achleitner et al., 2013, p. 169; Lowry, 2012, p. 52)

It has to be mentioned that not a single one of all the existing battery technologies is superior in all relevant dimensions (Dinger et al., 2010, p. 3). Additionally, none of them has the potential to compete with the long range of fuel-powered vehicles (Amsterdam Round Tables & McKinsey & Company, 2014, p. 35; Lowry, 2012, p. 77). In the distant future, many concepts are claimed to bring the decisive change in favour of the BEV. Exemplary technologies are lithium-air and lithium-sulphur cells. (International Energy Agency, 2018, p. 63) Another possible improvement might come from solid-state batteries, in which all components are solid. This leads to improved specific power and specific energy (Gupta-Chaudhary et al., 2018, p. 48). However, all potential successor technologies' readiness level is low, which means that lithium-ion batteries are likely to remain the main energy storage technology incorporated in electric vehicles for the short to medium term (International Energy Agency, 2018, p. 11).

Table 11 shows a comparison of all battery technologies described above.

6.3 Definition for the Scope of this Thesis

For the scope of this thesis, the term e-mobility will be narrowed down to BEVs (BEVs) as defined in section 6.2. Generally speaking, this includes all different types of electric powertrains, as long as they are powered by rechargeable batteries only. For the timelines of the case studies in chapter 9, only BEVs featuring ZEBRA and lithium-ion batteries will be considered. This selection is made due to the low driving range offered by other battery types, making usage on an everyday basis impossible.

The above mentioned definitions do not further specify the types of vehicles included in terms of their purpose, size and number of wheels. In order to narrow down the scope of this thesis, only four-wheeled BEVs for the transport of passengers are considered. This corresponds to the category M1 specified in the Austrian and German legal regulations (Bundesrepublik Österreich, 1967, §3; Morche et al., 2018, p. 185).

In the further parts of this thesis, the term electric drivetrain will be used to describe the electric motor and its power electronics only, without including parts to transfer torque to the wheels or the battery system.

Cell Type		Lead acid	NiCd	NiMH	ZEBRA	LIB	Zinc-Air	Fuel for ICEs
Specific energy $\left[\frac{Wh}{kg}\right]$		20-35	35-55	60-75	100-120	120-200	100-230	13000
Energy density $\left[\frac{Wh}{l}\right]$		54-95	70-90	≈ 150	150-160	200-620	100-270	9800
Specific power $\left[\frac{W}{kg}\right]$		200-300	≈ 125	200	150	300-1500	105	Almost unlimited
Nominal cell voltage $[V]$		2	1.2	1.2	≈ 2	3.5	1.2	-
Amphour efficiency $[\%]$		≈ 80	Good	Quite good	Very high	Very good	-	-
Internal resistance		Extremely low	Very low	Very low	Very low	Very low	Medium	-
Commercial availability		Several manufacturers	Good only in smaller sizes	Good only in smaller sizes	Very few suppliers	Standard	Very few suppliers	Very good
Costs $\left[\frac{€}{KWh}\right]$		100-150	250	300-350	< 250	140-330	60	≈ 0.00012
Operating temperature$[°C]$		Ambient	-40 to +80	Ambient	300-350	Ambient	Ambient	Ambient
Self-discharge $\left[\frac{\%}{day}\right]$		≈ 2	0.5	< 5	Equivalent to 10	≈ 0.33	High	None
Life expectancy	Cycles	300-1500	> 2000	> 2000	> 1000	1000-2000	> 2000	-
	Years	2-3	3-10	10	5-10	8-10	?	8-10
Recharge time $[h]$		8	1	1	8	2-3	≈ 0.167	≈ 0.167

Table 11: Parameters of different battery cell types (according to Achleitner et al., 2013, p. 168; Dinger et al., 2010, p. 4; International Energy Agency, 2018; Lowry, 2012)

Part III: **EMPIRICAL RESEARCH**

7 Actors in the Automotive Business Ecosystem for BEVs

This chapter aims at identifying the most relevant actors in the automotive business ecosystem for BEVs. First, the general value-added chain layout in the automotive industry is outlined. Next, a databank analysis allowed the identification of relevant actors in the different ecosystem spheres described by Moore (Moore, 1996, p. 27; see Figure 6). As it is not possible to define exact boundaries of business ecosystems, there is no way of listing all relevant actors within such an ecosystem (Müller, 2014, p. 24). For this reason, this chapter should rather be understood as an attempt to identify the most relevant actor groups and assign them to the different spheres of the business ecosystem framework. This way, the results of this chapter should give an answer to the first research question:

R1: Which are the most relevant groups of actors in the automotive business ecosystem for BEVs?

For answering this question, no specific focus was set with regard to geographic region or company type in order to allow the best possible identification of all relevant actor groups in the business ecosystem of BEVs without any bias. The insights gained in this chapter allow a more exact formulation of research questions R2 and R3 and will be further discussed in the following chapters.

7.1 General Layout of the Value-Added Chain

In order to allow a thorough understanding of the contact points between individual actors along the supply chain, an exemplary overview over value-added steps for BEVs is given in this section. An exact representation of all value-added steps for the creation of a final product would by far exceed the scope of this thesis. However, a general layout of the value-added chain of a product class can be given. It is most often split up in an upstream and downstream part. The upstream part includes all activities up to the final assembling of the finished product. The adjacent downstream part includes all activities that are left before the product reaches the end of its lifecycle. (Strathmann, 2019, p. 31) Figure 17 shows an exemplary value-added chain of BEVs as proposed by Kampker et al. (2018). Its upstream part contains procurement, development and production activities on component, part, module and system level which are assembled to the complete vehicle. Downstream activities in this sequence of steps are marketing, sales, financing, servicing and other activities associated with the usage of the finished product. (Kampker et al., 2018, pp. 44–45)

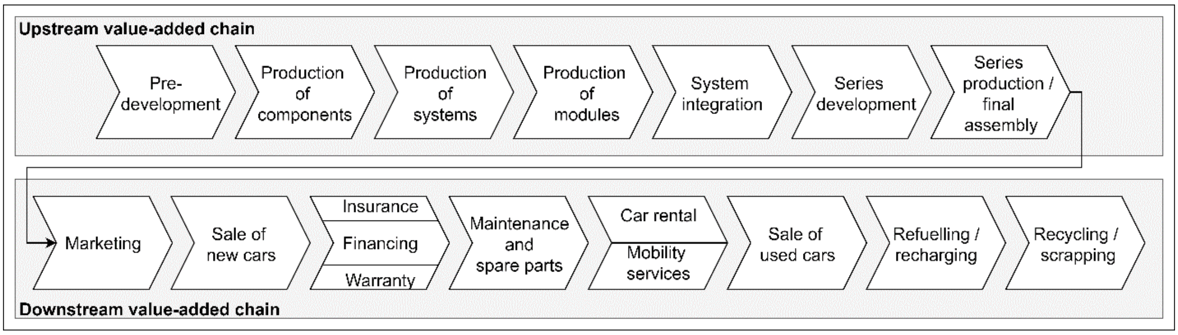


Figure 17: Value-added chain of EVs (based on Kampker et al., 2018)

7.2 Research Procedure

GlobalData's Company Profiles database was used for collecting a representative list of individual companies and organizations active in the business ecosystem for BEVs. The database was accessed via the Nexis Uni service by choosing "Company and Financial" content and narrowing down the search to the sub-database "GlobalData Company Profiles" as the only source of information. This service covers - among others - companies from the automotive, construction, consumer, foodservice, mining, oil and gas, packaging, power, retail, technology and tourism industry. Further narrowing down was done by limiting the timeframe to the years 2009 to 2019. The used keyword for searching was “electric mobility”. This did not allow the defined focus of BEVs, but led to a higher number of results that could be confirmed to actually be matching the scope of this thesis than “BEV” or other criteria.

The search resulted in a number of 334 entries of companies that are or were active in the area of electric mobility. In a following step, each company was attributed to its actual products according to company information found on its website or other published materials. Additionally, duplications, subsidiaries of other considered enterprises, companies that were not part of the business ecosystem of BEVs as defined for this thesis, and companies that have ceased operations in the meantime were deleted from the list. The companies were then assigned to actor groups that were defined in an iterative process during review of all companies. It has to be pointed out that each company could be accounted to one or more different categories if necessary through its wide field of activities. These categories allowed a classification according to the different aggregated categories mentioned in Moore’s business ecosystem spheres (Moore, 1996, p. 27). The final step was complementing the categories with actor groups mentioned by Moore that are no business entities and therefore do not appear in any company database (see Table 12). Those were individual customers, employees and labor unions, environmentalists and the media.

Role	Actor Group	Aggregated Category	Ecosystem Sphere
Battery components producer	Suppliers of battery technology	Direct suppliers	Core business
Battery producer	Suppliers of battery technology	Direct suppliers	Core business
Car distributor	Vehicle distribution organizations	Distribution channels	Core business
Electric components producer	Suppliers of battery technology; suppliers of drivetrain technology	Direct suppliers	Core business
Electric engine components producer	Suppliers of drivetrain technology	Direct suppliers	Core business
Electric powertrain supplier	Suppliers of drivetrain technology	Direct suppliers	Core business
Electronic components producer	Suppliers of battery technology; suppliers of drivetrain technology	Direct suppliers	Core business
Electronics producer	Suppliers of battery technology; suppliers of drivetrain technology	Direct suppliers	Core business
Engineering software publisher	Suppliers of manufacturing equipment	Direct suppliers	Core business

General component producer	General component suppliers	Direct suppliers	Core business
Producer of fluids for EVs	General component suppliers	Direct suppliers	Core business
Research and development provider	Engineering service providers and research institutions	Direct suppliers	Core business
Strategy consultant	Engineering service providers and research institutions	Direct suppliers	Core business
Supplier of manufacturing equipment and facilities	Suppliers of manufacturing equipment	Direct suppliers	Core business
Technical consulting	Engineering service providers and research institutions	Direct suppliers	Core business
Cell producer	Suppliers of battery technology	Direct suppliers	Core business
Developer of BEVs	OEMs	Core contributions	Core business
Vehicle manufacturer	OEMs; competitors	Core contributions, competing organizations	Core business
Battery recycling, reuse and remanufacturing	Recycling, reuse and remanufacturing companies	Suppliers of complementary products and services	Extended enterprise
Charging infrastructure distributor	Charging infrastructure manufacturers, distributors and operators	Suppliers of complementary products and services	Extended enterprise
Charging infrastructure equipment manufacturer	Charging infrastructure manufacturers, distributors and operators	Suppliers of complementary products and services	Extended enterprise
Charging infrastructure operator	Charging infrastructure manufacturers, distributors and operators	Suppliers of complementary products and services	Extended enterprise

Electricity distributor	Electricity producers, distributors and retailers	Suppliers of complementary products and services	Extended enterprise
Electricity producer	Electricity producers, distributors and retailers	Suppliers of complementary products and services	Extended enterprise
Electricity supplier	Electricity producers, distributors and retailers	Suppliers of complementary products and services	Extended enterprise
Fleet operator	Fleet operators	Direct customers	Extended enterprise
Producer of compound materials	Suppliers of raw materials	Suppliers of my suppliers	Extended enterprise
Provider of financial services	Provider of financial services	Suppliers of complementary products and services	Extended enterprise
Provider of maintenance and service	Providers of Maintenance and Service	Suppliers of complementary products and services	Extended enterprise
Provider of mobility services	Mobility service providers	Suppliers of complementary products and services	Extended enterprise
Raw materials producer	Suppliers of raw materials	Suppliers of my suppliers	Extended enterprise
Standardization body	Standardization bodies	Standards bodies	Extended enterprise
-	Individual customers	Direct customers	Extended Enterprise
Certification and training	Stakeholders	Stakeholders	Business ecosystem
Developer of HEVs	Competitors	Competing organizations	Business Ecosystem
Investor	Shareholders	Stakeholders	Business ecosystem
Producer of fuel cells	Competitors	Competing organizations	Business ecosystem
Public funding	Governments and their institutions	Government agencies	Business ecosystem

Regulatory body	Governments and their institutions	Government agencies	Business ecosystem
-	Employees and Trade Organizations	Stakeholders	Business ecosystem
-	The media	Stakeholders	Business ecosystem
-	Environmentalists	Stakeholders	Business ecosystem

Table 12: Actor's roles, categories, groups and ecosystem spheres

7.3 Results

The search resulted in a number of 334 companies that were attributed to electric mobility. However, this list contained 69 double entries, 41 companies that could not be identified as being involved in activities correlated to electric vehicles, two companies that have already ceased operations and 12 companies that belong to another business ecosystem, like for example producers of trucks, buses or motorcycles. After the steps outlined in section 7.2 were performed, the final list consisted of 210 individual actors and holding companies that were classified in 38 different roles, originated from 38 different backgrounds and 35 different countries (see Table 21 on page A14 in the appendix). At this stage, the list only included companies that demonstrably are involved in activities associated with BEVs.

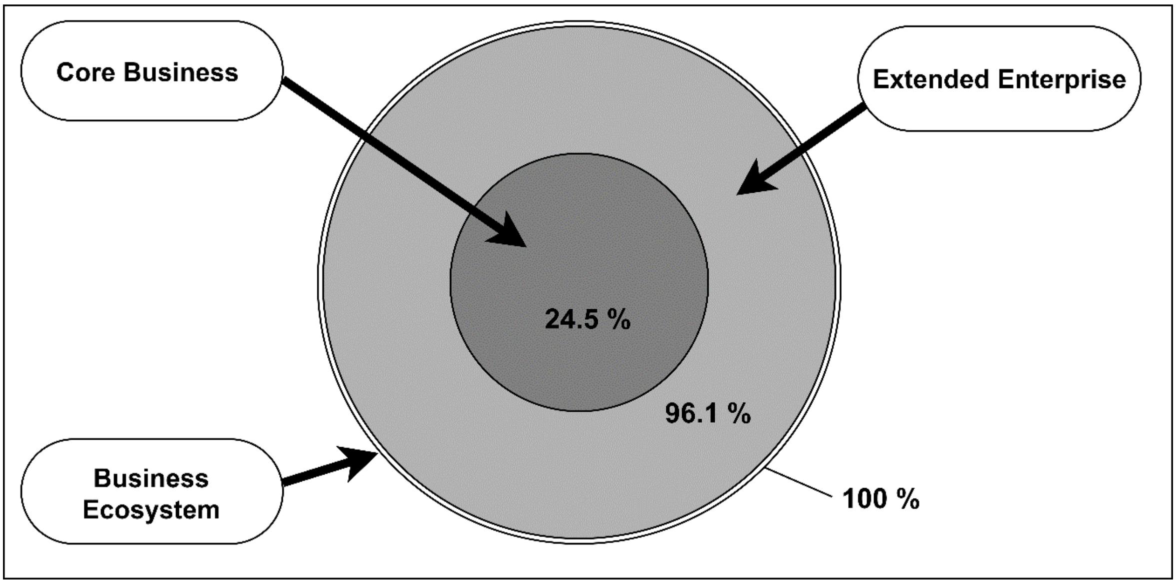


Figure 18: Distribution of actors between business ecosystem spheres (own creation)

Answering research question R1, the most relevant actor groups can be found in Table 12 and Figure 19. Those are suppliers of manufacturing equipment, stakeholders, recycling, reuse and remanufacturing companies, suppliers of battery technology, OEMs, electricity producers, distributors and retailers, financial service providers, maintenance and service providers, charging infrastructure manufacturers, operators and distributors, suppliers of drivetrain technology, suppliers of raw materials, standardization bodies, governments and their institutions, engineering service providers and research institutions, competitors, mobility service providers, fleet operators, vehicle distribution organizations, general component suppliers, environmentalists, employees and labor unions, individual customers and the media.

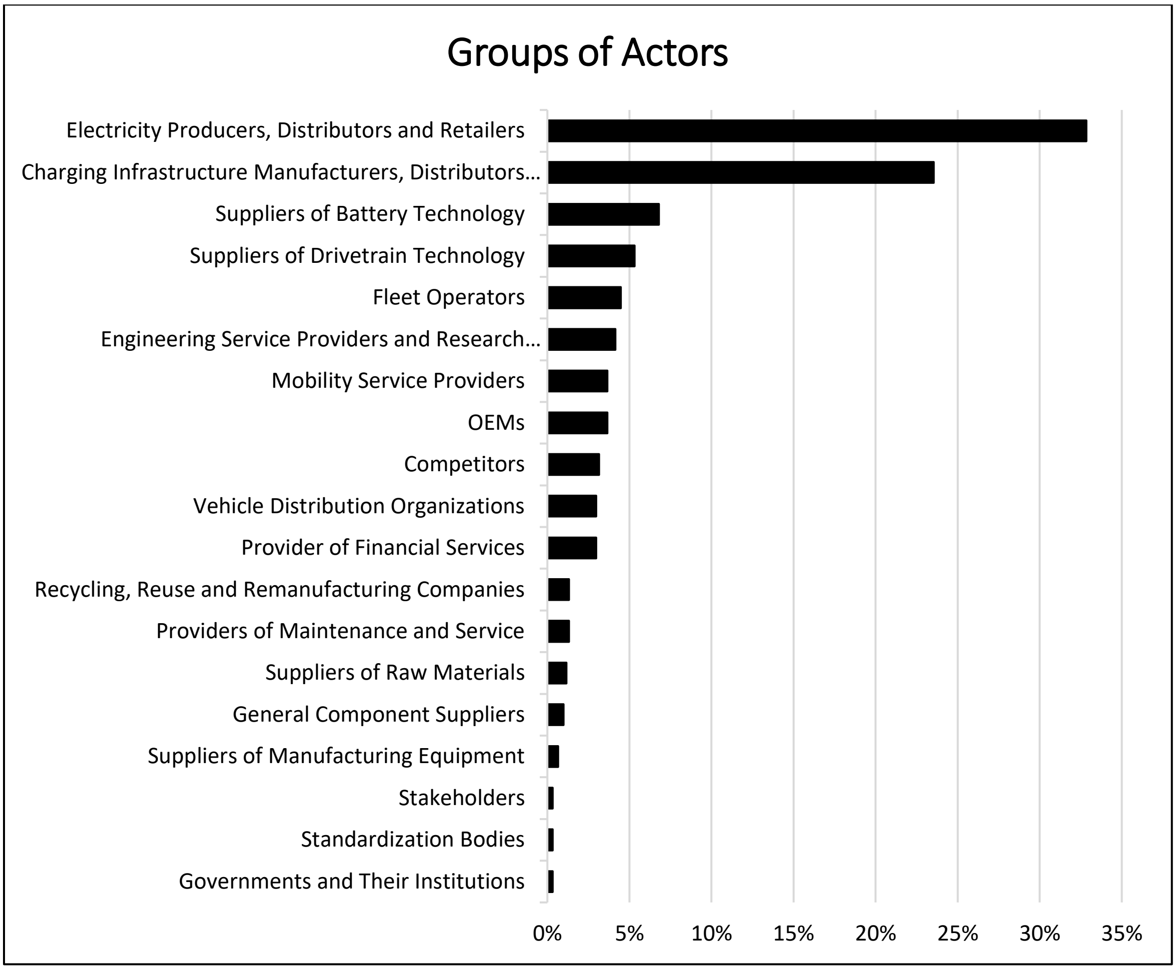


Figure 19: Identified groups of actors (own creation)

The highest share of players can be found in the extended enterprise sphere, which is due to the high number of providers of complementary products and services, mainly charging infrastructure and electricity companies (see

Figure 18 and Figure 19). The second largest group are direct suppliers of all components needed in BEVs, whilst OEMs only constitute a small share of all actors. However, this is in full accordance with Iansiti and Levien's (2004b, p. 79) definition of keystone players. According to them, they only constitute a small physical share of the whole ecosystem, although their influence is dramatically higher than that of niche companies. It has to be mentioned, that besides actors not covered by the database due to their characteristics as non-business entities, also governments and standardization bodies are most probably underrepresented in this analysis as well as the remaining stakeholders. The highest number of direct suppliers of OEMs either acts in the supply chain of electric powertrain technology or battery technology.

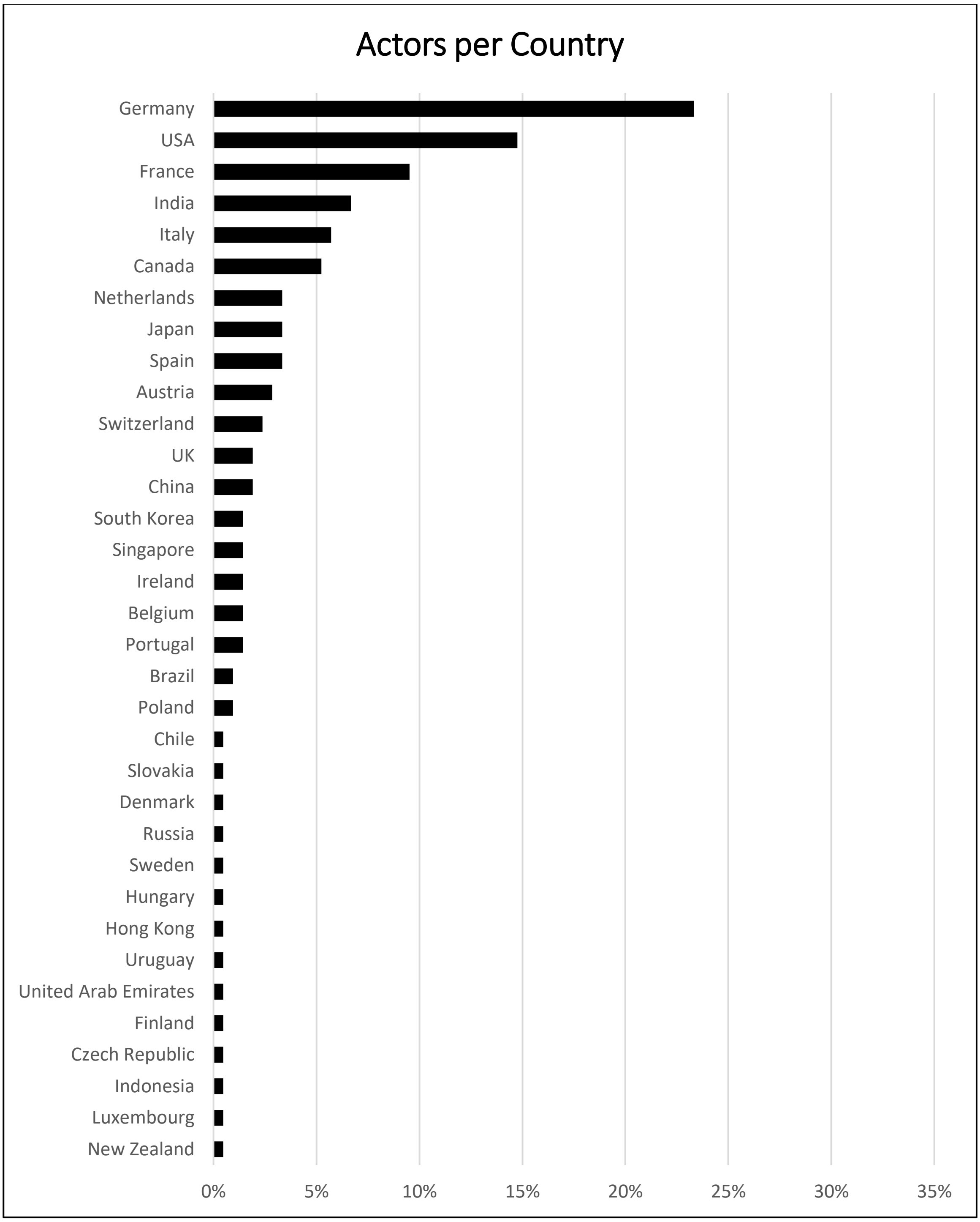


Figure 20: Country of origin of identified actors (own creation)

The highest number of identified ecosystem players originates from Germany, which is leading in front of the USA. Companies from the European Union account for the majority of all actors (see Figure 20). For this reason, the focus for answering research question R2 in chapter 8 will be laid on Europe alone. Additionally, the high presence of German companies allows a narrowing down of research focus only on German OEMs when answering research question R3 in chapter 9. Interestingly enough, the share of Chinese companies is low in comparison. Although the used database covers all worldwide areas, this surprising result might be caused by under proportionate presence of the undoubtedly high number of Chinese EV companies on international markets and language barriers.

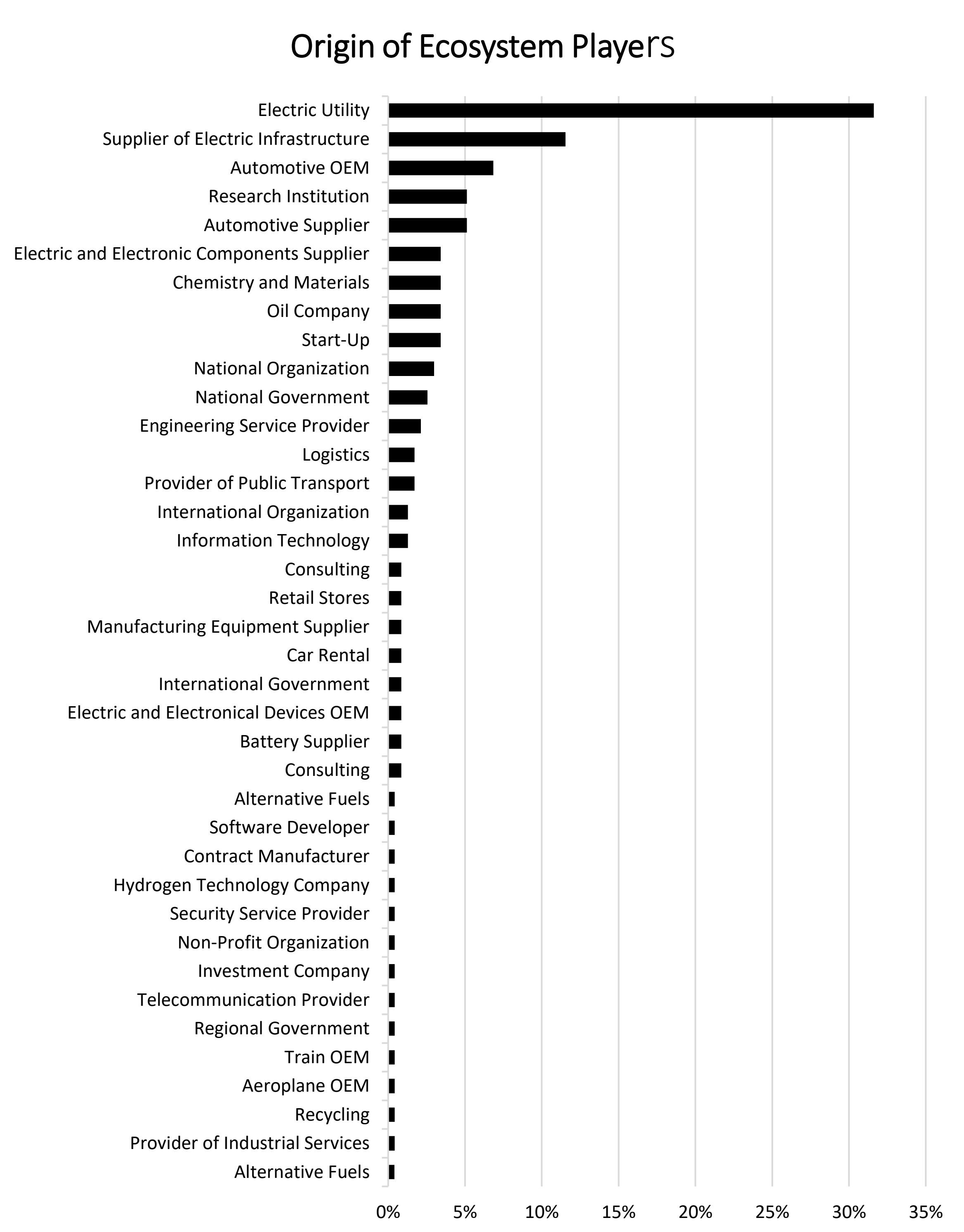


Figure 21: Industry of origin of identified ecosystem players (own creation)

Regarding the industrial origin of companies involved in the newly created business ecosystem for BEVs, electric utilities embody the highest share. This is a clear consequence to the high number of electricity suppliers and charging infrastructure operators, which most often are electric utilities. The same holds true for suppliers of electric infrastructure, which often develop and manufacture charging infrastructure equipment. Many suppliers of drivetrain technology have already been established as automotive suppliers for a long time. However, most suppliers of battery technology are completely new to the automotive business ecosystem. A number of categories are of special interest due to their strangeness to the automotive industry. One security service provider is listed as operator of charging infrastructure, retail stores and logistics providers use their fleets of vehicles for pioneering electric mobility, a considerable share of companies has started business as start-up in the newly created business ecosystem for BEVs and an airplane and train OEM has entered the charging infrastructure business (see Figure 21 and Table 21 on page A14 in the appendix).

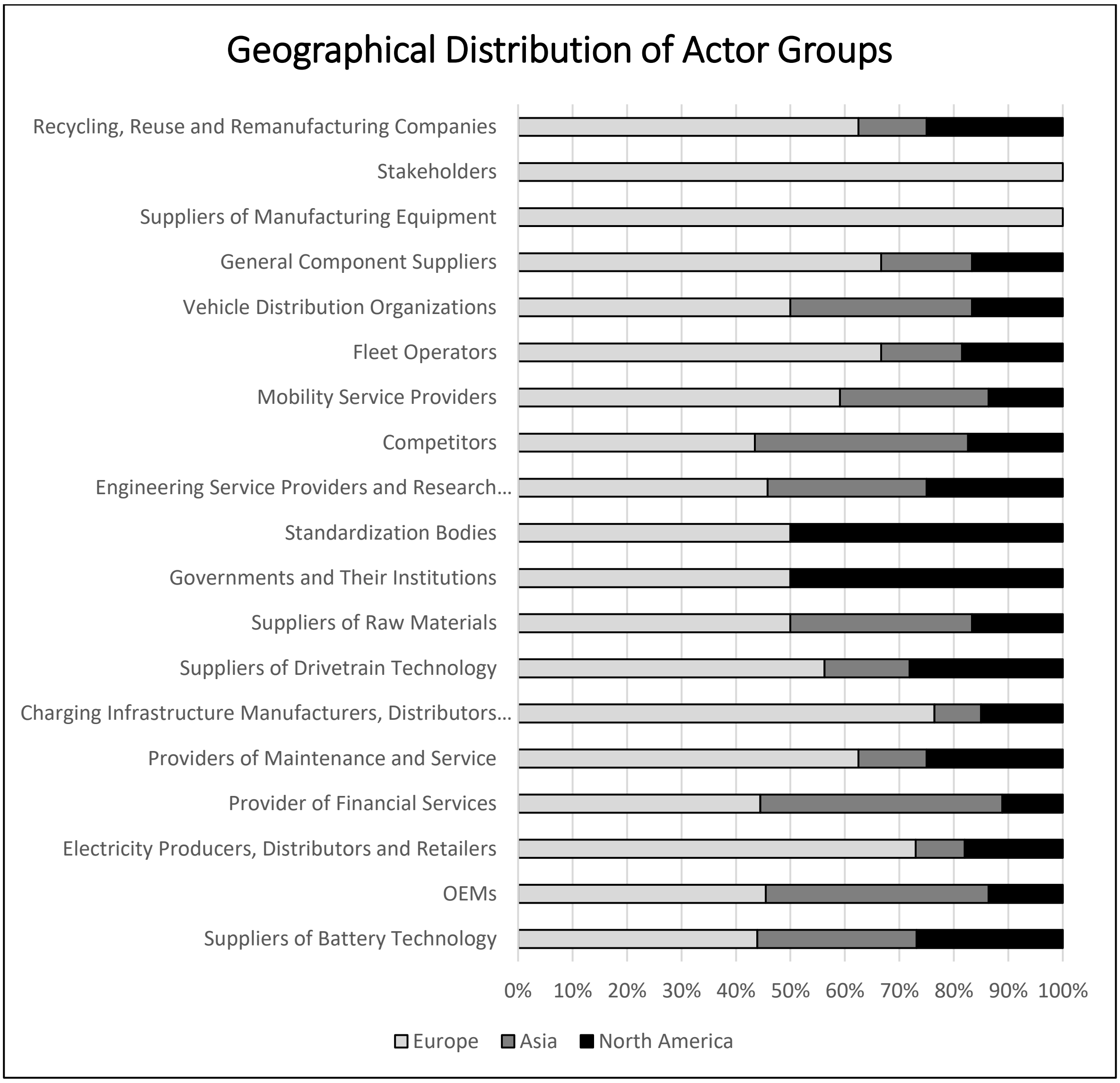


Figure 22: Geographical distribution of actor groups(own creation)

Figure 22 shows the geographical distribution of actors on continent level. Here, the predominant position of European enterprises in the business ecosystem for BEVs can be clearly seen. Most interesting is the high share of European companies in the actor groups of stakeholders and suppliers of manufacturing equipment. However, this might as well be caused by the low number of respective entries found in the database. The same holds true for standardization bodies and governments and their institutions, where only European and North American actors could be identified. The share of Asian actors is especially high in vehicle distribution organizations, competitors, suppliers of raw materials, providers of financial services, OEMs and suppliers of battery technology.

The used method has some clear limitations that have to be considered when assessing the results. These limitations are outlined in section 11.3.

8 Impact on Actors in the Automotive BE for BEVs

This chapter is aimed at showing the impact the trend towards electric mobility has on the identified actors of research question R1 (see chapter 7). For this purpose, the identified players of chapter 7 were supplemented by actor groups, which were not represented in the database but still are relevant. Those are individual customers, employees and labour unions, environmentalists and the media. Additionally, general components suppliers were not considered as their relevance is low and not much information was found about the impact of electric mobility to their business. The analysis is based on secondary data stemming from scientific papers, books, business and industry reports as well as companies' own publications. Data was collected until theoretical saturation was reached. As a consequence of the gained insights in chapter 7, the analysis is focused on the European business ecosystem for BEVs. This way, the results of this chapter should give an answer to the second research question:

R2: Which impact does e-mobility have on the identified actor groups in this business ecosystem?

Furthermore, the findings of this chapter should allow further narrowing down of the research focus in research question R3. It has to be mentioned that electric vehicles are not the only trend that currently impacts automotive companies and suppliers alike. Additional challenges are a new understanding of individual mobility, highly connected and autonomously driving vehicles, the emergence of markets in developing countries and other alternative drivetrains (Achleitner et al., 2013, p. 170; Griffiths et al., 2015; Kuhnert et al., 2018). For this reason, it often is very hard to identify the exact cause of single effects and to separate two or more influences from each other. In this thesis, it has been tried to fulfil this task as good as possible. However, analysis of the available literature sources did not allow a clear identification of individual influences at all times and therefore also some consequences of other trends might be contained in this analysis.

8.1 Core Business

As can be seen in Figure 6, the core business constitutes the inner sphere around the core company of a business ecosystem. Besides the core contributing company, this includes direct suppliers and distribution channels.

8.1.1 Core Contributions

The core contributing companies in the business ecosystem of BEVs are original equipment manufacturers (OEMs), which at the same time are often considered its keystone players due to their role as coordinators in widely dispersed supply networks (Kasperk et al., 2018, p. 149; Kersten et al., 2014, p. 434; Rong et al., 2017, p. 234). Key product innovations are most often driven by OEMs in response to external pressure and executed by suppliers (Dodourova & Bevis, 2014, p. 259; Mazur et al., 2013, p. 1060). Nowadays, almost all major OEMs have shown interest in the production of their own BEV (International Energy Agency, 2018, p. 38).

However, OEMs' own contributions to the value added have been reduced in recent years as a consequence of increased product variety. Together with shortened product development cycles this has resulted in a concentration of OEMs on their core competences and an increased outsourcing of activities to suppliers or engineering service providers. In the face of the switch to electric vehicles, OEMs are now forced to reconsider these outsourcing efforts if they are to retrieve their share of value added. They have to work with new categories of suppliers, rework their business models, address customer concerns, react to government regulations and cooperate for the development of standards (Accenture, 2014, p. 10; Accenture, 2014, p. 14; Amsterdam Round Tables & McKinsey & Company, 2014, p. 51). As most automotive OEMs' core competencies are the development and manufacturing of gearboxes, internal combustion engines, exhaust systems and oil pumps, they perceive electric vehicles as a serious threat to their business (Hensley et al., 2009, p. 91; Sihn et al., 2012, p. 132). In order to keep their level of value added, automobile manufacturers have to internalize at least half of the value added in the development and manufacturing of electric engines and battery systems (Kampker et al., 2018, pp. 44–45; Kasperk et al., 2018, p. 145). However, this necessitates highly expensive automated production equipment, different machines for mechanical machining, highly flexible powertrain and vehicle assembly plants and advanced logistics (Abrams Kaplan, 2018, p. 2; Amsterdam Round Tables & McKinsey & Company, 2014, p. 49; Kampker et al., 2018, pp. 63–64). For this reason, many companies invest heavily in this area or form alliances with suppliers that have already been able to build up knowledge in associated technologies like electronics, battery chemistry, compound materials, laser and nano production technology and integrated circuits. (Kampker et al., 2018, pp. 44–45)

Many manufactures have to combine these efforts with continued work on the improvement of conventional drives which still constitute their main business (Gupta-Chaudhary et al., 2018, p. 16; Strathmann, 2019, p. 3). This double burden and the uncertainty regarding the drivetrain technology that will prevail in the future explains the high number of alliances that can be observed among OEMs (Barthel et al., 2015, p. 16; Kampker et al., 2018, p. 49). In response to the changing understanding of individual mobility and the need for appropriate infrastructure for electric vehicles, OEMs are - besides forming alliances - increasingly involved in complementary activities. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 53) This can be understood as part of OEMs' perception of electric mobility as an opportunity and not just as a thread and is in accordance with the fact that systemic innovation necessitates the coordination of a whole bundle of interdependent innovations. Thus, OEMs have to stimulate the creation and enduring development of the new ecosystem needed for a sustainable shift from internal combustion engines to battery electric drivetrains in cars. (Pinske et al., 2014, p. 45) A major task comes to OEMs as well in having to educate customers on the advantages held in the new technology. In order to address customer concerns and allow development of a mass market for battery electric cars, they have to make increased use of all of their marketing channels in the future. (Accenture, 2014, pp. 10–15)

By exploiting new business segments and business models and proactively adapting their core competences and activities to the new reality, they are seeking to establish themselves as an integral part of this newly created business ecosystem for BEVs. (Kasperk et al., 2018, p. 145) Consequently, they are moving away from their pure existence as traditional car producers and develop towards system integrators and providers of mobility as a whole. Further details on these efforts will be presented in the respective sections of this chapter. Information on all BEVs available in Austria can be found in Table 22 on page A15 in the appendix.

8.1.2 Direct Suppliers

Suppliers of components, parts, modules and systems that are to be implemented in cars are organized in a tier-structure. This pyramid-like supplier structure consists of three or four different levels of suppliers. Generally speaking, the number of suppliers in each level is lower the closer the supplier cooperates with the OEM. The OEM itself coordinates its supplier base and is responsible for major R&D activities. Tier 1 suppliers are integrators who integrate the modules produced and delivered by tier 2 suppliers into fully functioning systems that are implemented into the whole vehicle. Tier 2 suppliers most often are specialized niche companies that are the technology leaders in their respective field. Tier 3 suppliers produce simple parts, components and raw materials which necessitates excellence in processes or costs leadership. Sometimes, tier 1 suppliers are even so closely integrated into an OEM's research and development activities that they are called tier 0.5 suppliers. (Barthel et al., 2015, p. 12; Kampker et al., 2018, p. 43; Strathmann, 2019, p. 33) Figure 23 illustrates the traditional pyramid-shaped supply chain structure of the automotive industry.

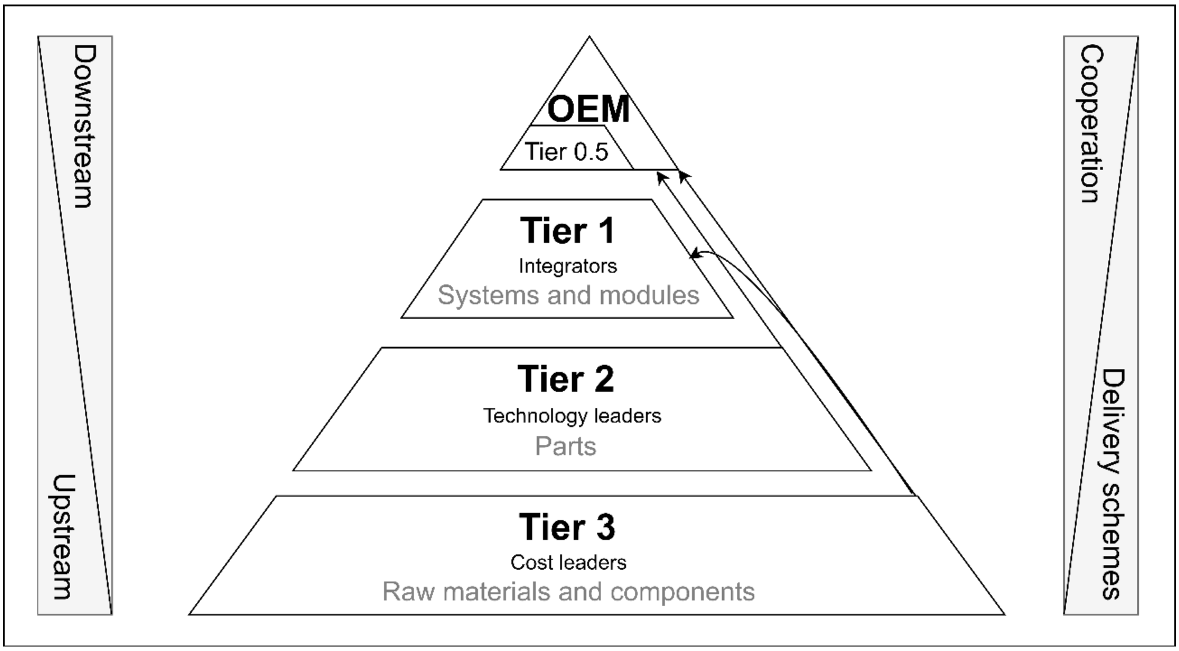


Figure 23: The structure of the automotive supply chain (according to Kampker et al., 2018, p. 43; Strathmann, 2019, p. 34)

In theory, tier 1, tier 2 and tier 3 suppliers can serve as direct suppliers to an OEM as depicted in Figure 23. However, for the scope of this thesis, tier 1 and tier 2 suppliers are considered to be direct suppliers to OEMs, whilst tier 3 suppliers are concluded to be indirect suppliers and therefore are covered in section 8.2.1.

Direct suppliers are the most prominent relationship partners of OEMs in many areas (Bratzel et al., 2013, p. 75; Parhi, p. 4). The level of cooperation in these relationships differs and reaches from simple market-governed relationships to highly integrated partnerships that even include capital investment or spatial consolidation (Lettice et al., 2010, pp. 310–311; see Section 5). Especially when covering the supply of strategically important products and services, these relationships can be a sustainable source of competitive advantage, as they can hardly be imitated by competitors (Ritter et al., 2004, pp. 176–177).

Many tier 1 suppliers operate globally and the most important companies act on the same economic level as OEMs themselves (Barthel et al., 2015, pp. 11–12; see also Table 27 on page A18 in the appendix). In recent years, many OEMs have shifted large development and integration tasks to their tier 1 and tier 0.5 suppliers respectively. As a consequence, these companies have developed advanced supplier management capabilities on their own. (Barthel et al., 2015, pp. 11–12; Lettice et al., 2010, p. 310) Strategic supply chain management has been implemented by many OEMs and tier 1 suppliers in recognition of the increased complexity that is associated with the involvement in an increased number of such cooperative efforts (Paulraj & Chen, 2007, p. 29). In the future, OEMs will probably reconsider this outsourcing strategy in the most critical domains of battery, electric motor and electronics technology in order to keep their share of value added. (Germany Trade and Invest, 2018, p. 6) In this scenario, tier 1 suppliers would have to concentrate on the development and production of standardized systems and modules for the supply to several OEMs, which would allow them to reach economies of scale and therefore reduce production costs. As standardized components do not hold the potential for product differentiation and therefore do not have a particular customer value, tier 1 suppliers would not directly have to compete with OEMs in this scenario. (Barthel et al., 2015, p. 20)

As a consequence to the increasing trend towards battery electric cars, companies from other industries like for example from the chemical and electronics industry have the chance to become suppliers of OEMs. At the same time, incumbent automotive suppliers try to strengthen their own market position. (Kampker et al., 2018, p. 45) They are forging alliances with tier 2 or tier 3 suppliers that allow them to offer highly sophisticated products (Dinger et al., 2010, p. 11). Whereas in the traditional automotive business the big tier 1 suppliers used to be the main drivers of innovation and held the most powerful position within the automotive business ecosystem together with OEMs, this is likely to change for electric vehicles. According to industry experts and researchers, the power will shift upstream along the supply chain, away from traditional manufacturers and suppliers towards the newcomer small and medium enterprises that nowadays are technology leaders in EV technology: suppliers of battery cells, electric motors and power electronics. (Kalaitzi et al., 2019, p. 266)

Of course, the shift towards BEVs will also lead to reduced production volumes of vehicles with internal combustion engines in the long run. Suppliers of components that will become obsolete in electric vehicles, like those only used in fuel systems, internal combustion engines, conventional gearboxes, exhaust systems and clutches (see Table 9) will have to find alternative business models and fields of activities in order to still play a role in the business ecosystem for BEVs. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 49) Not all big tier 1 suppliers have been successful in shifting their activities from research, production and development of conventional powertrain technology to electric or electrified powertrain technology so far. (Orlowski et al., 2019)

8.1.2.1 Suppliers of Battery Technology

Battery technology is the single most expensive and important competitive factor for BEVs (Eddy et al., 2019, pp. 3–4; Heerwagen, 2019, p. 11). It dictates a vehicle's range and therefore its main limitations in comparison to conventional cars. The supply chain that follows from the structure of battery systems can be seen in Figure 24 and consists of suppliers of key materials like lithium, cobalt and manganese, producers of cell components like electrodes and electrolyte, manufacturers of integrated battery cells or packs and companies that accomplish the final assembly of battery modules to battery packs that are ready for the installation in the vehicle's chassis (Kampker et al., 2018, p. 51; see also section 6.2.3). Despite its high relevance as a core competence and the rapidly rising demand, almost all OEMs, especially in the US and Europe, have to purchase battery technology from third parties (Dijk et al., 2013, p. 138; Eddy et al., 2019, p. 2; Morche et al., 2018, p. 242). Most often, this includes battery cells or packs and control electronics, which are then assembled to complete battery systems by the OEMs themselves (Eddy et al., 2019, p. 4). Whilst innovations in diesel and gasoline technology were only developed partly by suppliers, this picture has completely changed for battery technology: research in this area was initially almost exclusive to networks of suppliers (Dijk et al., 2013, p. 138). Battery cell chemistry is simply too far away from the vehicle manufacturers' traditional core competences for them to directly engage in research and development in this area (Eddy et al., 2019, p. 4).

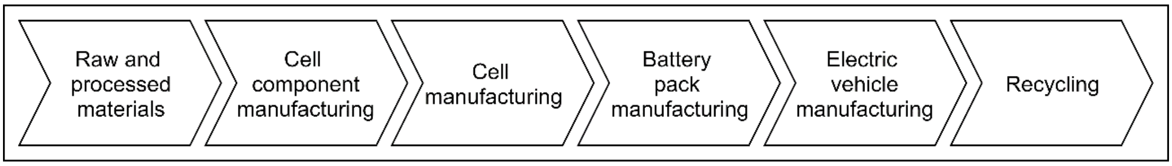


Figure 24: Automotive traction battery supply chain (according to Drabik & Rizos, 2018, p. 4)

Asian companies have been building up knowledge in battery technology for portable consumer electronics for almost 25 years. For this reason, almost all of the few manufacturers that are currently able to industrially produce battery cells suitable for the application in BEVs are located in Japan, China or South Korea (Eddy et al., 2019, p. 2; Heerwagen, 2019, p. 11; see also Table 23 on page A16 in the appendix). Due to their geographical proximity, Asian vehicle manufacturers prefer joint ventures with local battery producers for sourcing battery technology (Dijk et al., 2013, p. 138). However, the geographic concentration of battery cell production plants on the Asian continent poses a worrying problem for all other vehicle manufacturers. The resulting dependency of BEV producers on these global technology leaders is not just an issue for strategic but also for geopolitical and trade balance-related reasons. According to calculations by McKinsey & Company (2019, p. 6), an established European battery cell production would hold the potential to create about 250 000 jobs by 2040. Additionally, the large-scale intercontinental transportation of batteries presents a serious challenge due to their heavy weight and vulnerability to corrosion under saline conditions (Abrams Kaplan, 2018, p. 2).

As a consequence of the above mentioned reasons, setting up a battery cell factory in Europe is the aim of many consortia consisting of Asian battery producers, start-ups, various industrial enterprises, OEMs and even government agencies (Eddy et al., 2019, pp. 3–4; Enrietti & Patrucco, 2011, p. 6; Onstad et al., 2018; Spieth & Meissner, 2018, p. 19). However, the manufacturing process – especially of lithium-ion cells – is so complex that up until now these endeavors have only led to the establishment of industrial production facilities on the European continent which allow manufacturing of insufficiently low volumes at competitive costs (Onstad et al., 2018). This should change in the future, as the number of such initiatives is increasing (International Energy Agency, 2019, pp. 89–90).

The production process itself is even so technologically demanding, that many producers of production equipment concentrate on one processing step only. Holistic production concepts are a rare object of research and development, which is caused by interface problems and the heterogeneity of process steps. The result is the virtual inexistence of whole production facilities that are suitable for series production. (Kampker, 2014, p. 44) In reaction to this knowledge monopoly of only a handful of companies, other car manufacturers signed long-term agreements with the existing battery cell producers in order to gain control and exclusive access to technology that allows differentiation of their vehicles from other companies' products. However, these agreements lead to limited flexibility and a reduction of possible scale effects. (Dinger et al., 2010, pp. 10–11; Eddy et al., 2019, p. 2; Enrietti & Patrucco, 2011, p. 15; Hensley et al., 2009, p. 91)

In addition to the above mentioned difficulties, the established manufacturers of battery cells sell their cells at very low prices almost matching their expenses in order to undermine all efforts of entrants and increase entrance barriers. This is also the reason why a reduction of the already low battery costs below €100 per kilo-watthour cannot be expected in the close future. (Gupta-Chaudhary et al., 2018, p. 36; Heerwagen, 2019, p. 11) However, existing manufacturers of battery cells also face a couple of other serious challenges. As production and sales numbers of electric vehicles will rise, their products might become standardized commodities, and differentiation might be shifted to battery pack or battery management level. (Hensley et al., 2009, p. 92) Moreover, the timing of an increase in battery cell production capacity is critical, as it has to happen in full accordance with EV production ramp-up (Eddy et al., 2019, p. 5). Another unresolved issue are the warranty risks associated with the introduction of batteries to vehicles which traditionally have a far longer lifecycle than most consumer electronics devices. As battery cells are not their proprietary product, car producers do not want to build up necessary financial reserves to cover potential warranty claims, while most battery cell producers simply do not have the balance sheets to bear risk-associated costs. (Hensley et al., 2009, p. 93) Additionally, battery cell producers are highly dependent upon suppliers of raw materials. Growing battery demand has already led to significant increases in scarce resources like lithium, cobalt and manganese – a trend which is likely to continue as the forecasted production figures of some elements will not be sufficient to satisfy future global demand (also see section 8.2.1). For this reason, competitive advantage for battery cell manufacturers does not only come from technological leadership but also from well-negotiated long-term contracts with suppliers of these materials. (Eddy et al., 2019, p. 5)

On the other hand, battery manufacturers can also potentially profit from the possibilities offered by the scale reached through the increasing demand for their products. They might adapt the technology developed for electric cars for other applications in the transport sector, fast charging or systems to cover peak loads in the energy grid. (Hensley et al., 2009, p. 94) Finally, battery cell manufacturers could team up with tier 1 suppliers directly which would allow them to build up automotive-specific knowledge and gain access to a broad portfolio of already established relationships to OEMs. (Dinger et al., 2010, p. 11)

8.1.2.2 Suppliers of Electric Drivetrain Technology

Electric motors are the second biggest technological advancement that differentiates electric vehicles from conventionally driven cars. It is this very technology that lays the cornerstone for the viable chance of minimizing the emissions of pollutant and noise in individual mobility. (Spieth & Meissner, 2018, p. 12) The whole motor assembly does not only include the traction motor and all its components, but also the periphery like the high voltage onboard power supply system, power electronics to control the electricity's voltage, frequency and current and the cooling system needed for the motor (Röth et al., 2018, p. 315).

Quite in contrast to traction battery technology, however, electric motor technology can be considered very mature (Kampker, 2014, p. 22). Neither does it impose any dramatic limitations to electric vehicles nor allow clear differentiation of one vehicle manufacturer's products from its competitors' like it is the case with internal combustion engines which are considered a core competence by many OEMs or battery packs which significantly influence the range of BEVs. (Hensley et al., 2009, p. 91; Morche et al., 2018, p. 242).

Although the production of electric motors is marked by the deployment of diverse highly sophisticated technologies and comprehensive quality management measures, knowledge in this area is by far more geographically dispersed than for battery cells (Röth et al., 2018, p. 330; see also Table 24 on page A17 in the appendix). This allows car makers to enter into e-motor production themselves (Amsterdam Round Tables & McKinsey & Company, 2014, p. 49). In fact, many OEMs already develop and produce their own electric engines for application in their series production BEVs. Others have formed alliances and joint ventures with tier 1 suppliers to share know-how, build production facilities or simply ensure long-term supply reliability. Due to the fact that the technology is not too far away from their original field of expertise, the most prominent European suppliers of electric motor and powertrain technology are the large corporations that already are established tier 1 suppliers for internal combustion engine technology (see Table 24 on page A17 in the appendix).

Another fact that facilitates OEMs' decision for high investments in electric motor development and production equipment is the fact, that those are quite independent from the exact configuration of the powertrains prevailing in the future. Hybrid, battery electric and fuel cell-powered vehicles all incorporate electric engine technology. Additionally, the supply risk of needed raw materials is far less severe than for battery cell chemistry, as the needed materials like copper and rare earth are more widely available than lithium, cobalt and manganese (International Energy Agency, 2018, p. 84).

8.1.2.3 Suppliers of Manufacturing Equipment

Another group of highly relevant actors are suppliers of production equipment. This includes companies providing OEMs and suppliers with machines, tools and enterprises that engineer whole production plants. (Barthel et al., 2015, p. 12)

The production facilities for electric vehicles differ greatly from those used for manufacturing conventional vehicles (Amsterdam Round Tables & McKinsey & Company, 2014, p. 13). For this reason, many core processes need to be revamped to allow large-scale production of electric vehicles (Accenture, 2014, p. 14). However, the differences do not affect all process steps to a similar degree. Paint shops and interior assembly plants will not have to undergo comprehensive adaptations whilst powertrain assembly plants and final assembly lines will have to be transformed in order to allow the machining and assembly of new components and accommodate enhanced occupational safety measures for handling high-voltage components. (Abrams Kaplan, 2018, p. 2; Kampker et al., 2018, p. 66) The reduction of powertrain parts from between 1400 and 2000 to 200 parts leads to a dramatic decline of machined manufacturing steps like turning, milling, drilling and sanding. In exchange, the significance of mechanical forming and joining procedures like pressing, drawing, bending and punching will rise. In addition, knowledge in special welding applications like for joining electric motor's stator metal sheets or contacting of battery cells will gain in importance. For this reason, special tools for ultrasonic welding, winding of motor coils, wire drawing and impregnating offer high chances for suppliers of production equipment to profit from the ongoing changes in the automotive business ecosystem. (Barthel et al., 2015, p. 21; Kampker et al., 2018, pp. 63–64)

The changed requirements in the production process finally lead to an increased replacement of manual workforce by automated systems while at the same time maintaining a high degree of flexibility. Although highly integrated automated production systems for mass production of electric vehicles are not yet widely applied in consequence of their difficult amortization at initially low production volumes, a future increase of EV production figures is likely to reduce the number of assembly line jobs in favor of a higher degree of automation as a consequence of the safety risks inherent in handling high-voltage electronics. (European Commission, 2014, p. 2; Kasperk et al., 2018, pp. 148–149) Thus, companies that demonstrate knowledge in engineering flexible automated production systems will most probably be able to benefit in the medium and long term.

New lightweight materials like carbon fiber hold great potential for compensating for the heavy weight of batteries needed in electric vehicles. Unfortunately, production processes are not yet mature enough to allow a production at economically justifiable costs. (Kampker et al., 2018, pp. 63–64) However, optimizations in this area would allow huge benefits as a weight reduction of one kilogram already entails a cost reduction of a single-digit euro value in battery capacity (Morche et al., 2018, pp. 225–226). For this reason, production equipment that makes a cost-efficient production of exterior parts from these materials possible would be highly appreciated by OEMs and tier 1 suppliers alike.

Investing in purpose-built production platforms holds the potential to decrease production costs and therefore allows a market price reduction of electric vehicles that might be rewarded by customer behavior (Amsterdam Round Tables & McKinsey & Company, 2014, p. 13). However, the timing of scaling up always is critical (Eddy et al., 2019, p. 5). For this reason, it is not fully clear, when OEMs and suppliers will seek to make the high investments needed for complete remodeling of their production facilities (Amsterdam Round Tables & McKinsey & Company, 2014, p. 49). In the meantime, facilities in many cases are just adapted to accommodate the assembly of conventional and electric vehicles in the same plants or even production lines (see Table 25 on page A17 in the appendix). Smaller OEMs sometimes even outsource production to contract production companies (Kalaitzi et al., 2019, p. 265; see Table 25 on page A17 in the appendix). Regardless of the exact strategy chosen, all lead to orders and increased turnover for suppliers of production equipment.

8.1.2.4 Engineering Service Providers and R&D Institutions

The increased technological uncertainty and complexity of automobiles that is not caused by their electrification only, but also by other trends like digitalization, individualization, connectivity and autonomous driving have an influence on the depth and intensity of relationships between OEMs and engineering service providers or other external R&D providers (Barthel et al., 2015, p. 12; Reiners, 2018, p. 7). Engineering service providers are privately-held companies that perform paid research and development activities on a contractual basis. Publicly funded or private institutions to perform similar tasks can be universities, public laboratories or other similar institutions. Both engineering service providers and R&D institutions can be considered direct suppliers in a wider sense as they are a source of intellectual property and immaterial goods and services for vehicle manufacturers. They grant access to new competencies and resources and facilitate institutional learning. (Enrietti & Patrucco, 2011, p. 8; Schuh, 2012, p. 24)

Instead of outsourcing the development, testing and production of single components, OEMs increasingly concentrate outsourcing activities in strategically relevant areas on research and development purposes only. As a consequence, they do not consider these subcontractors as subordinate service providers of single tasks, but order whole packages or systems that combine bundles of individual tasks. Thus, the concerned companies have to adapt their capabilities to these changed requirements in order to win important major contracts. (Reiners, 2018, p. 7)

The basis of the resulting intensified relationships, especially between engineering service providers and OEMs is increasingly provided by trust, which is considered even more important than pure competence alone. Although orders are still governed by individual contracts, OEMs consider engineering service providers as equal partners that even fulfil project management and coordination tasks between other involved companies. (Reiners, 2018, p. 8)

Universities and public laboratories are competence centers for a variety of technological innovations incorporated in BEVs and therefore a valid choice for sourcing of research and development work. They offer basic research and pave way for many technological advancements in their role of pioneers of applied sciences. As a consequence, they have close ties with OEMs, suppliers and other companies in the automotive business ecosystem. (Yuanjian & Mkhitaryan, 2017; also see Table 26 on page A18 in the appendix) Some manufacturers of BEVs even emerged from beginnings as university initiatives (e.Go Mobile AG, 2017).

8.1.3 Distribution Channels

In general, distribution channels connect producers of products or services to their end customers (Szopa & Pekala, 2012). In the automotive business ecosystem, these channels include a number of different organizations covering wholesale and retail (see Figure 25).

Changes in the distribution channels of BEVs are not entirely founded on the differences between those cars and conventional gasoline- or diesel-powered automobiles. In fact, the technological capabilities leveraged in newly established distribution channels for BEVs have already been existing for the last 20 years (Selz & Klein, 1998). However, traditional vehicle manufacturers are mostly still pursuing traditional distribution channels for the sales of their new vehicles, independently from the kind of propulsion system. The only adaptations many companies have made in response to the extended technological capabilities and changing customer needs are complementary websites and online configurators as well as flagship stores that allow easier access to information on their products and direct contact with customers. (Morrissey et al., 2017, p. 3; Srivastava et al., 2018, p. 7) Dealing with newly produced cars is not considered a profitable business but a costly strategic necessity. Car manufacturers try to exert close control over their distribution channels in an attempt to build and maintain customer relationships which in turn should ensure their loyalty. The business is hardly sustainable and profit is mainly made with financing, selling spare parts and maintenance services. (Selz & Klein, 1998, p. 3)

However, the picture is very much different for newcomers that entered the market with the advent of BEVs (Selz & Klein, 1998, p. 2; see Figure 25). They do not have the conflicting situation of having to praise the advantages of electric mobility while still heavily depending on sales of conventionally-powered vehicles. As a consequence, distribution of such companies' products through already existing conventional channels would be contra productive, as their advantage of credibility would be impaired when sold at dealerships that at the same time have to sell vehicles featuring internal combustion engines. (Musk, 2012) Due to the fact that many customers already make their choice for a specific brand or even model before entering a dealership for the first time, setting up an own network of dealerships holds the great risk of not even being noticed by customers (Morrissey et al., 2017, pp. 6–7; Musk, 2012). For this reason, the most viable choice for new entrants are online stores that are combined with showrooms in shopping malls or pedestrian areas. In this distribution concept, vehicles can directly be ordered online and are delivered through service stations that can be widely spread over an area. Signing the purchase contract and paying for a product without ever having spoken to sales personnel or seen the actual product might seem bewildering to some. Nevertheless, according to information of Boston Consulting Group and Bain and Company, most potential car buyers start their search online, the number of dealer visits drops constantly and more than 25% of customers would buy their new car online if possible (Morrissey et al., 2017, pp. 4–7; Srivastava et al., 2018, p. 4). Additionally, direct sales hold the great advantage of skipping one step in the value-added chain which increases the profits of vehicle manufacturers. However, the strategy is quite capital intensive, as companies have to build and operate showrooms and service stations on their own (Musk, 2012).

In the long run, incumbent OEMs will have to invest considerable effort in adapting their distribution channels accordingly (Accenture, 2014, p. 12; Morrissey et al., 2017, p. 3; Selz & Klein, 1998, p. 1). Many possible solutions can be chosen in the face of the uncertainties associated with the future of individual mobility. What is most important in order to at least retain market shares is extending the online offerings by introducing a full-featured online store that allows direct purchase of new vehicles. This also necessitates consistent pricing schemes and increased collection and analysis of user data (Morrissey et al., 2017, p. 10). At the same time, the efficiency and productivity of existing distribution channels has to be dramatically increased (Srivastava et al., 2018, p. 6). The consultants of Bain & Company estimate a potential cost reduction by 20% if the correct measures are applied (Morrissey et al., 2017, p. 4). Other possible scenarios include intermediary platforms provided by third parties that allow comparison of vehicles and forward customers to dealers' websites in exchange for a finder's fee (Srivastava et al., 2018, pp. 5–6). Additionally, big online retailers have already carried out experiments with fully automated car-vending systems and could also take up online car sales (Srivastava et al., 2018, pp. 3–6).

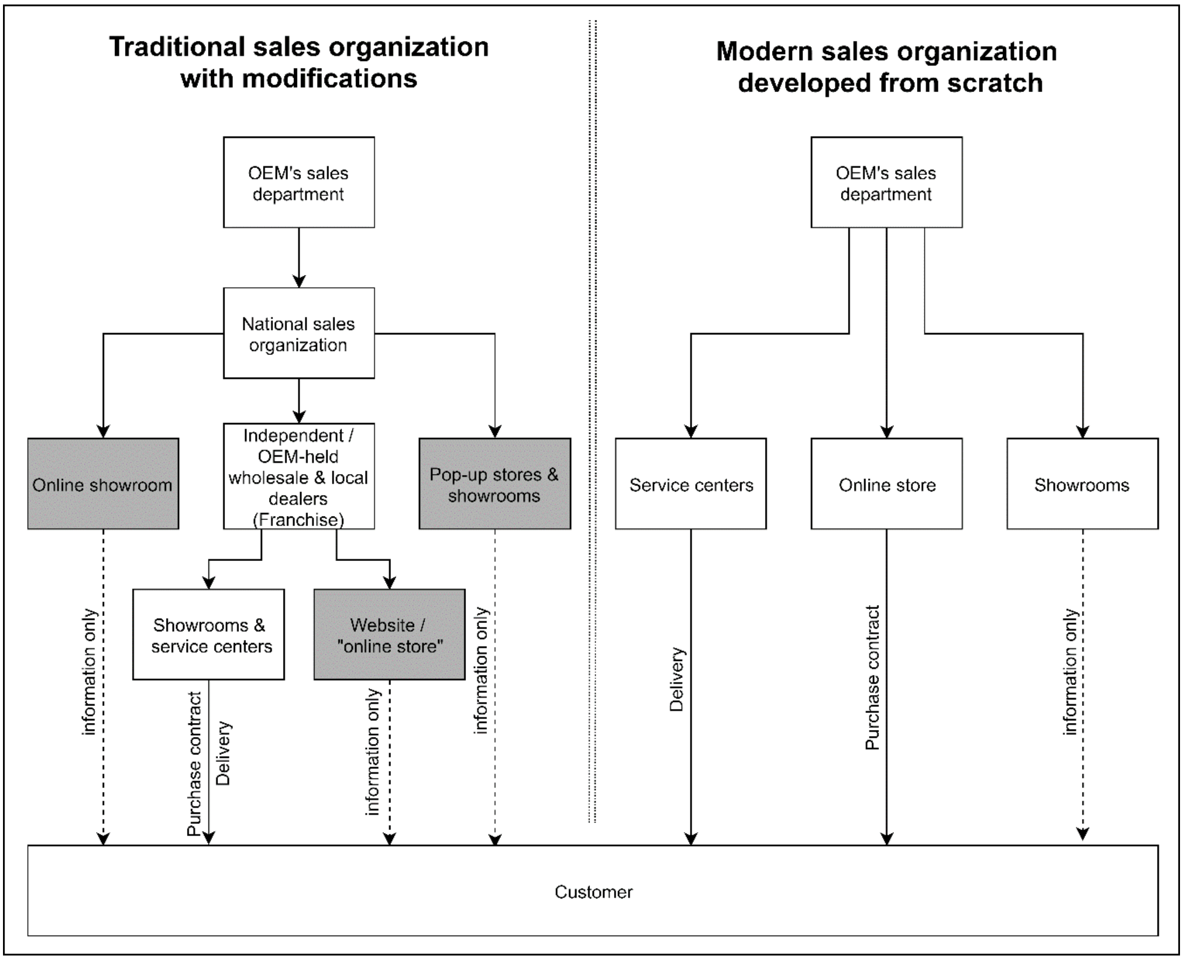


Figure 25: Differences of typical distribution channels for new vehicles (Modifications in grey, based on Selz & Klein, 1998, p. 2)

The first OEMs have already initiated steps to update their distribution structures. They have recognized the need for individualized offerings, closer customer contact and change the requirements they apply on their dealerships in an attempt to increase efficiency. Some even intend to introduce online direct sales and showroom stores in close coordination and with monetary involvement of existing dealers that are most often bound to vehicle manufacturers through long-term exclusive franchising contracts. (Morrissey et al., 2017, p. 12; Srivastava et al., 2018, p. 10; Volkswagen AG, 2018b, p. 9) In order to not antagonize dealers, OEMs could also create electric sub-brands that are only marketed via online channels (Srivastava et al., 2018, p. 5). The main goal of these efforts is to convince sceptical customers of the merits of electric mobility and rapidly increase its market penetration in order to reach economies of scale. Consequently, manufacturers even contractually oblige their dealers to aggressively market electric vehicles. (Volkswagen AG, 2018b, p. 10)

Another question discussed by many OEMs and car dealers is, if batteries or even whole vehicles should be sold or only leased/rented to customers. All concepts have already been tested under market conditions but at the moment no concept seems to be prevailing for batteries. (Accenture, 2014, p. 12; Srivastava et al., 2018, p. 10; Strathmann, 2019, p. 40; Vallée et al., 2018, p. 100) Additionally, bundles with free use of charging infrastructure or membership in charging infrastructure networks are offered by some OEMs (Musk, 2012; Sovacool et al., 2019, p. 6). Newly created distribution channels for electric vehicles include OEMs' offerings as mobility providers and operators of car sharing fleets (see sections 8.2.5.3 and 8.2.2).

8.2 Extended Enterprise

The extended enterprise is a business ecosystem's second sphere, consisting of enterprises that are only indirectly connected to the core contributing company. This includes suppliers of suppliers, direct customers, customers of customers, standardization bodies and suppliers of complementary products and services.

8.2.1 Suppliers of Suppliers

Of course, many indirect suppliers are involved in the production of a BEVs' many thousand parts and components and the mining of the needed raw materials. In reference to the typical automotive supply chain (see Figure 23), the most important ones are companies belonging to tiers 2 and 3. In contrast to the big globally-operating suppliers of tier 1, those rather are small and medium-sized enterprises which most often are technology leaders in their specific areas. (Barthel et al., 2015, pp. 11–12) For this reason, some scholars even purely distinguish the different levels of the supply pyramid by the number of employees (Barthel et al., 2015, p. 12).

However, the most critical indirect suppliers for BEVs are suppliers of raw materials that are difficult to extract, only occur on our planet in very limited quantities and therefore are produced in insufficient amounts for full-scale diffusion of BEVs. The most relevant changes in material demand through the trend towards electric mobility are copper, rare earth, lithium, cobalt and nickel (International Energy Agency, 2018, p. 84). Ensuring the supply of these scarce materials will become a key competitive factor for suppliers and OEMs in the future.

The most widely-spread battery types in modern BEVs are lithium-ion and nickel-metal hydride cells which contain lithium, graphite, nickel, manganese, aluminium, titanium, phosphor and cobalt in varying weight proportions depending on the exact cell chemistry (International Energy Agency, 2019, p. 22; see section 6.2.3). Of these elements, nickel, lithium and cobalt are the most critical, as the required quantities exceed those of all others (Debarre & Gilek, 2018, p. 3; International Energy Agency, 2018, pp. 12–13; International Energy Agency, 2018, p. 85). The supply chain of nickel is well-developed as a consequence of its wide use in an array of different applications. Approximately two million tonnes of nickel are extracted each year, its primary purpose being high-grade steel alloy production. Usage in battery cells only accounts for an unproblematically small proportion of total demand. (International Energy Agency, 2018, p. 85)

The situation is much different for lithium and cobalt, which will be increasingly demanded through the shift to BEVs (Debarre & Gilek, 2018, p. 3; International Energy Agency, 2018, pp. 12–13). Lithium production is mostly concentrated in Asia, South America and Australia. Although global lithium reserves are sufficient for increasing volumes of lithium-based battery cell production, lithium supply is constraint by production rates of approximately 35000 tonnes in 2016 and a virtual market oligopoly by a handful of corporations. (Debarre & Gilek, 2018, p. 3; International Energy Agency, 2018, p. 85; Kampker et al., 2018, pp. 51–52) Demand is rising more rapidly than global production capacities, which has already led to a manifold increase in prices of raw lithium over the last couple of years (Debarre & Gilek, 2018, p. 3; Eddy et al., 2019, p. 5; International Energy Agency, 2018, p. 85). However, lithium costs alone only contribute marginally to the costs of batteries on cell and system level (Dinger et al., 2010, p. 7). Additionally, lithium resources exist in countries that are relatively stable politically. For this reason, lithium shortages and the resulting increased expenses for sourcing it do not dramatically affect market prices for lithium-based batteries. (Debarre & Gilek, 2018, p. 3; Dinger et al., 2010, p. 7)

Supply of cobalt holds the greatest future risks. The world reserves that are economically extractable with existing technological capabilities are only estimated to last for a little over 50 years at current consumption rates of over 100000 tonnes a year. Even with high shares of recycling, an increased demand through high adoption rates of BEVs would inevitably lead to exhaustion of reserves without even considering the demand created by other industries. The production volume of cobalt has not changed over the last years, which together with low volumes of cobalt demand in the past have led to dramatic price increases. The produced quantities are likely to stay relatively constant in the future, as cobalt occurs in the same ores as nickel and copper and therefore is structurally linked to the markets of these materials. Additionally, cobalt is only mined in a handful of mostly politically unstable developing countries under questionable working conditions. Other than that, processing facilities are almost exclusively located in China. (Debarre & Gilek, 2018, p. 3; Eddy et al., 2019, p. 5; International Energy Agency, 2018, p. 85; International Energy Agency, 2018, pp. 12–13) As a consequence, the transparency and traceability of material sourcing is an important issue that has to be addressed in the future. Although there already are standards for the responsible sourcing of raw materials, traceability gaps still are hindering initiatives to avoid conflicts and human rights violations associated with their mining. (International Energy Agency, 2019, p. 23; International Energy Agency, 2019, p. 172)

As a consequence to these issues, battery manufacturer are currently developing cell chemistries that exchange cobalt through oxides of other metals. Furthermore, many battery manufacturers are already engaged in or consider vertical integration into extraction and supply of key materials (Eddy et al., 2019, p. 5; Hensley et al., 2009, p. 94). Even some OEMs have negotiated long-term contracts with suppliers of raw materials that they allocate to cell manufacturers of their BEVs (Kalaitzi et al., 2019, p. 264; Kampker et al., 2018, pp. 51–52).

Other materials that have not been specifically needed for road transport in the past are rare earth materials and high amounts of copper contained in electric motors (Amsterdam Round Tables & McKinsey & Company, 2014, p. 49). However, neither of those two poses serious risks to the deployment of electric vehicles. Copper is so widely used in a vast array of different applications that increased demand caused by the shift to BEVs is insignificantly low. Rare earth can be substituted by other materials in modified engine designs according to some sources. (International Energy Agency, 2018, p. 84) Other experts state that the strategic significance of rare earths like dysprosium and neodymium in electrified drivetrains is worryingly high as they can hardly be substituted, are highly demanded and almost exclusively supplied by Chinese mines. (Kampker et al., 2018, pp. 51–52)

Carbon-fibre reinforced plastics and other compound materials have the potential to be applied more extensively in the bodywork of electric vehicles in an effort to compensate the high weight of batteries (Amsterdam Round Tables & McKinsey & Company, 2014, p. 13; Morche et al., 2018, pp. 225–226). As a consequence, producers of these materials were considered strategically relevant enough to strive for partnerships for long-term sourcing (Sovacool et al., 2019, p. 6). However, the anticipated high costs in the medium two-digit euro range for a weight reduction of one kilogramme exceed potential single-digit euro-value cost reductions that result from the lower battery requirements (Kampker et al., 2018, pp. 63–64; Morche et al., 2018, pp. 225–226). For this reason, most OEMs have abandoned experiments to implement these materials into series production BEVs in most market segments (Sovacool et al., 2019, p. 10).

8.2.2 Direct Customers

As for conventional vehicles, the two main direct customer groups for battery electric cars are individual customers, who can either buy or lease/rent their vehicle through the distribution channels outlined in section 8.1.3 and institutional buyers that operate whole fleets of vehicles. This latter group includes public institutions, large companies' corporate fleets or also car sharing communities, car rentals and mobility providers. Whilst individual early adopters are mainly environmentally conscious consumers willing to try the new technology, fleet operators are very sensitive to small reductions in the total costs of ownership. (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 11–12)

Many individual customers are still sceptical regarding the potential of electric vehicles as a proper means of individual mobility. Main reservations exist regarding the reduced range of BEVs in comparison to conventional cars (Bratzel et al., 2013, p. 41). However, the range of many BEVs would be fully sufficient for most people on their daily routes, as those are covering only up to 100 kilometres. The average distance travelled per car ride is even as low as 15 kilometres in Germany. (Vallée et al., 2018, p. 94) Thus it can be concluded that this concern mainly is created through the subjective fear of having to stop with an empty battery and no recharging possibilities in consequence of unplanned congestions or diversions. Additionally, people do not want to lose the flexibility of spontaneous long journeys although they hardly ever put this situation into practice. (Bratzel et al., 2013, p. 41) Lacking charging infrastructure, higher acquisition costs and the unclear longevity of batteries are other problems that discourage potential buyers from preferring a BEV over a conventional one. (Gupta-Chaudhary et al., 2018, p. 13; Gupta-Chaudhary et al., 2018, p. 33) Although the mentioned problems are addressed by offers including battery warranties and increased efforts of OEMs to improve battery capacity, the density of charging networks and production costs, sales figures of BEVs are still highly dependent on incentives granted by governments due to their otherwise higher total costs of ownership in comparison to conventional cars for individual users (Gupta-Chaudhary et al., 2018, p. 65; International Energy Agency, 2019, p. 165). This can be seen as an indicator for the fact, that a sustainable industry transformation is only possible by educating customers to an accordingly high environmental consciousness (Bormann et al., 2018, p. 28). An additional impediment of EV market diffusion is the fact that the new technology's problems are far more prominent in the perception of consumers than the advantages it offers (Gupta-Chaudhary et al., 2018, p. 13). In order to reach mass adoption, OEMs must therefore also address customer concerns by fully exploiting the potential of their marketing channels (Accenture, 2014, p. 10). Until now, few manufacturers have taken proactive actions to market the potential of electric vehicles like lower maintenance and fuel costs and the avoidance of local emissions (Accenture, 2014, p. 15; Accenture, 2014, p. 10).

Nevertheless, if the customer concerns can be addressed rightly, electric vehicles hold a great market potential. Increasing urbanization across the globe leads to the rising demand for small vehicles with efficient powertrains for personal transportation that feature low emissions of pollutants or noise. This is exactly where BEVs can come into play. (Griffiths et al., 2015, p. 14) Autonomously driving vehicles are considered to hold the potential to bring major improvements to the customer perception of electric drivetrains, as through the reduced involvement of the driver into vehicle operation and control, the emotional value of internal combustion engines will be diminished. (Kampker et al., 2018, p. 20)

Fleet operators are the main focus of attention for many OEMs when they first enter the market with BEVs. The operation of whole vehicle fleets offers many attributes that perfectly match the characteristics of BEVs like the easy installation of an own charging infrastructure, high utilization rates, homogeneous and regular usage patterns and low required range. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 54; Dijk et al., 2013, p. 139; Kampker et al., 2018, p. 40) Additionally, the total costs of ownership (TCO) of BEVs are at the same level as those of petrol- or diesel-powered vehicles in the long run for fleet applications (Dijk et al., 2013, p. 145; International Energy Agency, 2018, p. 102). By employing BEVs in highly publicly exposed fleets like for example postage services, the visibility of the new technology can be raised and the technological capabilities demonstrated. This way, market diffusion of BEVs can be facilitated. (Vallée et al., 2018, p. 91)

The understanding of individual mobility and the mobility needs, especially of customers belonging to younger age groups, differ significantly from the requirements of the customers traditionally targeted by car manufacturers. Many inhabitants of urbanized areas simply do not have the actual want to own a car any more. (Barthel et al., 2015, p. 7) Many OEMs and other enterprises answer to this increasing trend by offering concepts like car sharing and other mobility services that complement their range of offerings in order to open up these market segments. (see also section 8.2.5.3)

Market penetration of BEVs in Europe varies significantly between countries. This is mainly caused by the different stimulation activities performed by local and state governments (Hensley et al., 2009, p. 90). Norway shows the highest market shares of BEVs across Europe, with almost 30 % in 2018. However, this high figures are not even closely matched by the second-biggest markets. The number of BEVs sold in Europe showed a constant growth rate of more than 50 percent in the last years. (International Energy Agency, 2019, p. 214; see Table 28 on page A19 in the appendix) In 2017, more than 130000 BEVs were sold on European markets, accounting for roughly one percent of overall new car sales. (Gupta-Chaudhary et al., 2018, p. 65) On global average, the market share was 0.8 % in the same period or 745330 BEVs in absolute numbers (Gupta-Chaudhary et al., 2018, p. 10; International Energy Agency, 2019, p. 214). Predictions for future adoption rates vary significantly depending on the underlying assumptions (Debarre & Gilek, 2018, p. 2; Gupta-Chaudhary et al., 2018, p. 8; Hensley et al., 2009, p. 90). According to McKinsey & Company, BEVs would enter the mainstream market if about 10 % of all cars globally would share this technology (Hensley et al., 2009, p. 91). The global stock of BEVs lied a little over three million vehicles in 2018 and is not expected to exceed one to two percent of total cars in 2020 (International Energy Agency, 2019, p. 210; Kampker et al., 2018; see Table 29 on page A19 in the appendix).

8.2.3 Customers of Customers

Identified groups of indirect customers can either be buyers of pre-owned cars or customers of fleet owners like car sharing communities, car rentals or other mobility services (see section 8.2.5.3). Used BEVs only constitute a small share of all used vehicles sales (Cox Automotive, 2019). For buyers of those BEVs, the same holds true as for direct customers (see section 8.2.2).

8.2.4 Standardization Bodies

The speed of the market diffusion of BEVs is highly dependent on standards concerning the involved technology and the adherence of the involved actors to them (Brown et al., 2010, p. 3798). Standards are clearly defined specifications of interfaces that facilitate interoperability (Iansiti & Levien, 2004b, p. 162). They are of particularly high importance for complex innovative systems, they give access to new knowledge and are an important factor in international trade which also is the reason for their high strategic relevance (Dossett, 2015, p. 20; Gerst & Jakobs, 2012, pp. 1–10). In contrast to regulations, which are legally binding documents issued by governments, standards only provide a voluntary basis for coordination. However, many standards become mandatory by being adopted as regulations. (Pereirinha & Trovao, 2011, p. 5)

Standards are defined by technical committees that consist of experts and representatives of all relevant stakeholder groups like industry, government and academia (Pereirinha & Trovao, 2011, p. 5). They do not act under direct control by governments but are coordinated by Standards Development Organisations (SDOs), which initiate the creation of standards in reaction to needs expressed by its stakeholders (Brown et al., 2010, p. 3798). On an international level, the most important SDOs are the International Electrotechnical Commission (IEC), which is responsible for the standardization of all electrotechnical appliances and the International Organization for Standardization (ISO), which deals with the same duties for all other technologies (German National Platform for Electric Mobility, 2017, p. 13; van den Bosschen et al., 2007, p. 2). A third body is the International Telecommunication Union (ITU) (Gerst & Jakobs, 2012, p. 7). Their European equivalents are the European Commission for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI) (Pereirinha & Trovao, 2011, p. 2). These organizations' activities are further complemented by national standardization organizations in many countries, like for example the Deutsches Institut für Normung (DIN) and the Deutsche Kommission Elektrotechnik Elektronik Informationstechnik (DKE) in Germany (Gerst & Jakobs, 2012, p. 7.; also see Table 13).

As electric vehicles are integrated systems combining automotive with electric technology and therefore unite both responsibilities of ISO and ICE, their standardization landscape is complex. This situation is further illustrated when considering the different backgrounds of the two organizations. Standardization in the electricity industry traditionally was aimed at interoperability of all components of systems that are possibly to be combined in mostly industrial applications. For this reason, many systems like electric motors are covered by extensive IEC standards on all different aspects like safety, environmental impact, quality and interfaces. The rather industrial background of customers of these products also explains the need for standardization of detailed specifications that allow interchangeability and outstandingly long periods of system use. Automotive companies in contrast are used to standardization that covers aspects dictated by government regulations like safety, performance testing and environmental impact. However, as interchangeability of components is only relevant in certain areas in consequence of different usage patterns, the existing standards covering automobiles traditionally concern the whole vehicle rather than all parts individually. (van den Bosschen et al., 2007, pp. 2–3)

As a result, the collaboration formed by ISO and ICE in the 1970s for standardization of electric vehicles is marked by conflicts about responsibilities and division of work. Both SDOs finally were able to agree on a memorandum of understanding and a clear division of work in 1990 which can be taken from Table 13. (van den Bosschen et al., 2007, p. 3) According to Pereirinha & Trovao (2011, p. 2), the responsible active working groups for electric vehicles working under ISO TC22/SC21 – *"Electronically propelled road vehicles"* and IEC TC69 *"Electric road vehicles and electric industrial trucks"* are:

1. ISO TC22/SC21 WG 1: *Vehicle operation conditions, vehicle safety and energy storage installation*
2. ISO TC22/SC21 WG 2: *Definitions and methods of measurement of vehicle performance and of energy consumption*
3. ISO TC22/SC21 WG 3: *Lithium-ion traction Batteries*
4. IEC TC69 WG 2: *Motors and motor control systems*
5. IEC TC69 WG 4: *Power supplies and chargers*

In reaction to a lack of interoperability of some interfaces standardized by IEC and ISO, in 2010 the European Commission (EC) requested the responsible European standardization bodies to develop own European standards or adapt international standards in a way that avoids these issues. (Dossett, 2015, p. 10; Pereirinha & Trovao, 2011, p. 4)

		Background		
		General	**Electric**	**Communication**
Responsibility	**International**	ISO	IEC	ITU
	Europe	CEN	CENELEC	ETSI
	Germany	DIN	DKE	DKE
Distinction		*"Work related to the electric vehicle as a whole"*	*"Work related to electric components and electric supply infrastructure"*	

Table 13: Standardization bodies for EVs (according to Gerst & Jakobs, 2012, p. 7; van den Bosschen et al., 2007, p. 3)

Already existing standards that have been created by these initiatives cover electric safety on general requirements, automotive engineering and charging infrastructure level, the specifications, performance and lifetime of wired charging systems, electric motors, power electronics, battery and high-voltage electric systems and lines as well as electromagnetic compatibility, interoperability of charging interfaces and platforms (German National Platform for Electric Mobility, 2017, pp. 17–21). Further standards are currently elaborated for high power charging, wireless charging, back feeding of energy to the electricity grid and different applications of information and communication technologies (ICT) (German National Platform for Electric Mobility, 2017, pp. 29–37). All standards have to be continuously adapted and complemented in order to keep pace with technological advancements, reach harmonization across different countries and avoid inhibition of innovations by outdated or conflicting norms (Brown et al., 2010, pp. 3802–3804). Future endeavors in the area of electric vehicles might include lifecycle assessment of sustainability, battery swapping, vehicle-to-grid applications and interoperability of different charging networks (Brown et al., 2010, p. 3805; Dossett, 2015, p. 13; International Energy Agency, 2018, p. 99).

Standardization has already led to cost reductions in charging infrastructure (Amsterdam Round Tables & McKinsey & Company, 2014, p. 13). This effect is likely to be repeated for other components in the future as standardization and interoperability are considered essential tools in ensuring a quick transition to electric individual mobility (International Energy Agency, 2018, p. 100). However, in order to reach this goal, published standards have to be internationally consistent and unambiguous and parallel work of rivaling SDOs that results in a wide range of conflicting standards has to be avoided (Brown et al., 2010, p. 3798; van den Bosschen et al., 2007, p. 7).

8.2.5 Suppliers of Complementary Products and Services

The business ecosystem for BEVs is an increasingly distributed value network that not only consists of the product itself, but also leverages several other company's products and services (Accenture, 2014, p. 12; Dodourova & Bevis, 2014, p. 253). A systemic innovation like a battery electric car needs complementors in order to successfully take the hurdle of commercialization (Kapoor & Lee, 2013, p. 278; Pinske et al., 2014, p. 45). For BEVs, the most important identified groups of suppliers of complementary products and services are utilities, charging infrastructure suppliers, owners and operators, mobility providers, providers of maintenance and service, financial and leasing companies and recycling companies.

8.2.5.1 Producers, Distributors and Retailers of Electricity

Of course, the adoption of BEVs increases electricity demand. The global electricity consumed for charging EVs was 54 tera-watthours in 2017, which is a little bit more than Greece's electricity demand (International Energy Agency, 2018, p. 53). Thus, the technology holds the potential for considerable additional revenue streams for electric utilities, transmission system operators, distribution system operators and retailers which produce, distribute and sell this energy (see Figure 26). In order to fully benefit from this potential, partnerships are necessary that enable them to control market development. (International Energy Agency, 2018, p. 55; Kampker et al., 2018, p. 29)

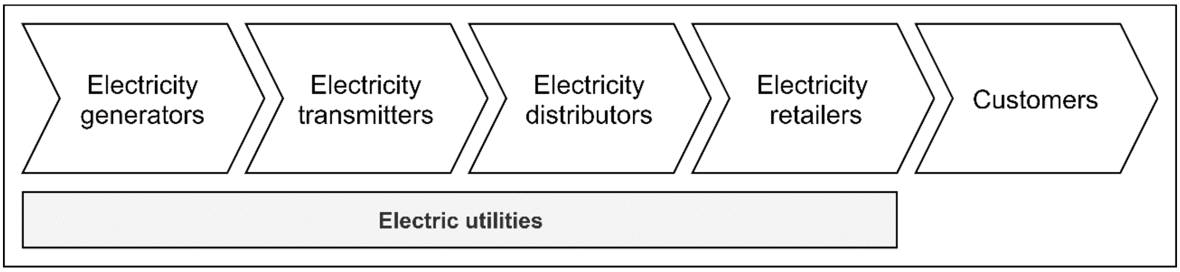


Figure 26: Supply chain of electricity (based on Wrigley & Matthews, 2016, p. 51)

Although a high market diffusion of BEVs in Europe would roughly double household demand of electricity, this would only result in a 3-4% increase of required overall energy volume and could theoretically be accommodated by the power supply system without significant modifications to the existing infrastructure (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 41–42). However, the key challenge for the power sector rather is the resulting peak loads (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 41–42; Dijk et al., 2013, p. 142; Kampker et al., 2018, p. 30). Peak loads are determined by the speed, moment and location of simultaneous consumption of electric energy. In the course of the day, base demand for energy has two characteristic peaks in the morning and afternoon. The exact moment when a high number of electric vehicles are connected to the electricity grid can either level out these peak loads or further intensify them up to a point where the grid is no longer able to bear them, which would result in a collapse. Another factor that influences the impact on the power grid is the speed of charging; fast charging exerts far higher stress than slow charging due to the higher power demanded. For this very reason, unrestrained EV charging of private users at their home charging stations when they arrive home from work in the afternoon would necessitate expensive upgrades of the cables and transformers that constitute the grid, especially in areas with high numbers of electric vehicles or low-voltage distribution grids. (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 41–42; Vallée et al., 2018, pp. 116–117)

The uptake of BEVs is only meaningful if the energy used to power them is produced sustainably through photovoltaic arrays, wind turbines or biomass. However, those sources are not capable of delivering similar high and constant amounts of energy as conventional power plants. On the one hand, the resulting high number of dispersed sources feeding energy to the grid applies additional stress to it. On the other hand, an intelligent management of these decentralized sources and loads might be a possible option to prevent grid updates. Such concepts are known as smart grids and comprise of a distributing grid that connects a high number of flexibly controllable energy sources, storage systems and loads that communicate indirectly or directly in order to optimize utilization. (Dijk et al., 2013, p. 142; Kampker et al., 2018, p. 30; Vallée et al., 2018, p. 118) This way a higher grid stability can be achieved. The batteries of electric vehicles that are connected to the electricity grid for a longer time than necessary can be included in smart grid management as a source of power reserves and buffer capacity when needed, which is called *"vehicle-to-grid"* (Amsterdam Round Tables & McKinsey & Company, 2014, p. 45; International Energy Agency, 2018, p. 103). Another application is to use a connected BEV's battery for powering a household. This enables shifting of energy demand that has to be sourced from the grid to periods of lower prices and is called "*vehicle-to-building"* (Amsterdam Round Tables & McKinsey & Company, 2014, p. 46; International Energy Agency, 2018, p. 103). A smart demand-side management (DSM) could use the existing electricity overcapacities at times of low base demand – for example at night – for cheaply recharging an EV's battery. This strategy does not only save money but also helps grid operators to level out demand. (Hensley et al., 2009, p. 95; International Energy Agency, 2018, p. 55)

Many utilities have teamed up with other enterprises and are engaged in the construction and operation of recharging infrastructure for electric vehicles in an effort to reposition themselves as enablers of an environmentally sustainable economy (Amsterdam Round Tables & McKinsey & Company, 2014, p. 33; Dijk et al., 2013, p. 139). Unfortunately however, the regulatory environment in many countries limits utilities' efforts to establish in the newly created business. The reason are regulated revenues they receive from public organizations, municipalities and governments for providing the public with their vital services and which are a considerable competitive advantage when competing with companies that do not enjoy this amenity. Nevertheless, many solutions for this conflict have been found, like for example sharing of infrastructure costs between all network users and regulatory relaxations. (International Energy Agency, 2018, p. 49)

In spite of the obvious high potential it holds for them, the new technology also exposes utilities to the risk of being pushed out of the profitable business ecosystem for BEVs by other service providers like for example large IT companies or other market entrants. (Hensley et al., 2009, p. 95)

8.2.5.2 Charging Infrastructure Manufacturers, Distributors, Owners and Operators

As a consequence of their different propulsion technology, conventional refuelling infrastructure has to be complemented by facilities for charging electric vehicles. In fact, a sufficiently dense network of charging infrastructure is one of the key success factors for a large-scale adoption of BEVs (Accenture, 2014, p. 8). For this reason, owners and operators of charging infrastructure were identified as relevant actor groups together with suppliers of charging equipment and needed parts like couplers, power converters, cords, attachment plugs and other components (Brown et al., 2010, p. 3804).

Three different ways of recharging BEVs exist:

1. Wired charging

   This includes plugging the EV's internal or external charging device into a socket at home or at a public / semi-public charging station. Today, different charging interface standards exist globally for fast and slow charging, depending on the geographical region. In Europe, the type 2 "Mennekes" plug has been introduced as a standard for slow charging and the CCS "Combo" plug for fast charging. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 32; see Table 30 on page A20 in the appendix)

2. Induction / wireless charging

   Induction charging uses the magnetic field between two independent coils for charging. One coil has to be mounted in the surface underneath the car, whilst the other one is part of the vehicle's on-board charging device. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 30)

3. Battery swapping

   For this technology, the battery has to be mounted to the underfloor of the vehicle in a way that allows easy access. Nevertheless, handling of the battery in the swapping process is complex due to its heavy weight and electric hazards. For an economically viable solution, battery interfaces would have to be standardized. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 30)

Today, wired charging is by far the most widely applied charging procedure (Amsterdam Round Tables & McKinsey & Company, 2014, p. 30). Battery swapping was piloted on a small scale in Denmark and Israel by a company called Better Place and was praised as the future technology by some. However, the technology was abandoned following bankruptcy of the company so that nowadays not a single modern BEV features a battery swapping capability although this would allow far faster charging. A hen-and-egg-type problem was the reason for the unsuccessful pilot project, as nobody wants to buy a vehicle without a high enough number of charging stations. At the same time, construction and operation of these expensive facilities were uneconomical for the low number of actual vehicles sold. (Noel & Sovacool, 2016, p. 379) Induction charging is a technology that is not yet commercially available and only used in pilot projects (Amsterdam Round Tables & McKinsey & Company, 2014, p. 30; Rong et al., 2017, p. 237).

Most early adopters charge their electric vehicle primarily at home, which can be accomplished by using normal household sockets or residential charging devices. The same charging process is also possible at work, which is the second most popular charging location. (International Energy Agency, 2018, p. 10) Public charging stations only rank third in this list, although their strategic relevance for BEV diffusion is high (Amsterdam Round Tables & McKinsey & Company, 2014, p. 35). Publicly accessible fast charging stations are necessary for long distance travels and in areas where private parking lots are seldom due to land availability constraints (Gupta-Chaudhary et al., 2018, p. 27; International Energy Agency, 2018, p. 10; Vallée et al., 2018, p. 93). An EU directive recommends the installation of one public charging station per ten electric cars, which will probably be achieved in 2020 (International Energy Agency, 2018, p. 12; International Energy Agency, 2018, p. 46). Those stations often belong to networks operated by alliances of OEMs, utilities or other private sector companies with financial support by municipalities or governments (Amsterdam Round Tables & McKinsey & Company, 2014, p. 32; International Energy Agency, 2018, p. 10). A problem is the lack of interoperability between the charging networks operated by different providers due to different billing and communication systems. EU-wide regulations have already been proposed to target this issue and achieve harmonization that would allow charging point roaming. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 37)

The high costs associated with the installation of charging stations can hardly be recouped from the revenue streams of power sales to customers only. For this reason, many companies are cooperating closely with other enterprises involved in the business ecosystem for BEVs. Some have concentrated on operation of charging infrastructure only, which is known as the role of Charge Point Operator (CPO). They offer their services as turnkey solutions to stakeholders like businesses and municipalities that have an interest in fast deployment of electric vehicles or just want to offer this as a service premium to their customers. Others run billing systems and platforms that allow access to charging points operated by CPOs. Those are called E-Mobility Service Providers (EMSP). The different roles of companies in EV charging are depicted in Figure 27. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 39; Virta, 2019) Due to the similar character of charging infrastructure to petrol stations, some companies are even making the shift from this traditional business to offering EV charging services (see Table 31 on page A22 in the appendix). The whole charging industry shows increasing signs of consolidation through acquisition of smaller companies by major companies, some of them stemming from the energy sector or traditionally are focussed on oil (International Energy Agency, 2019, p. 15).

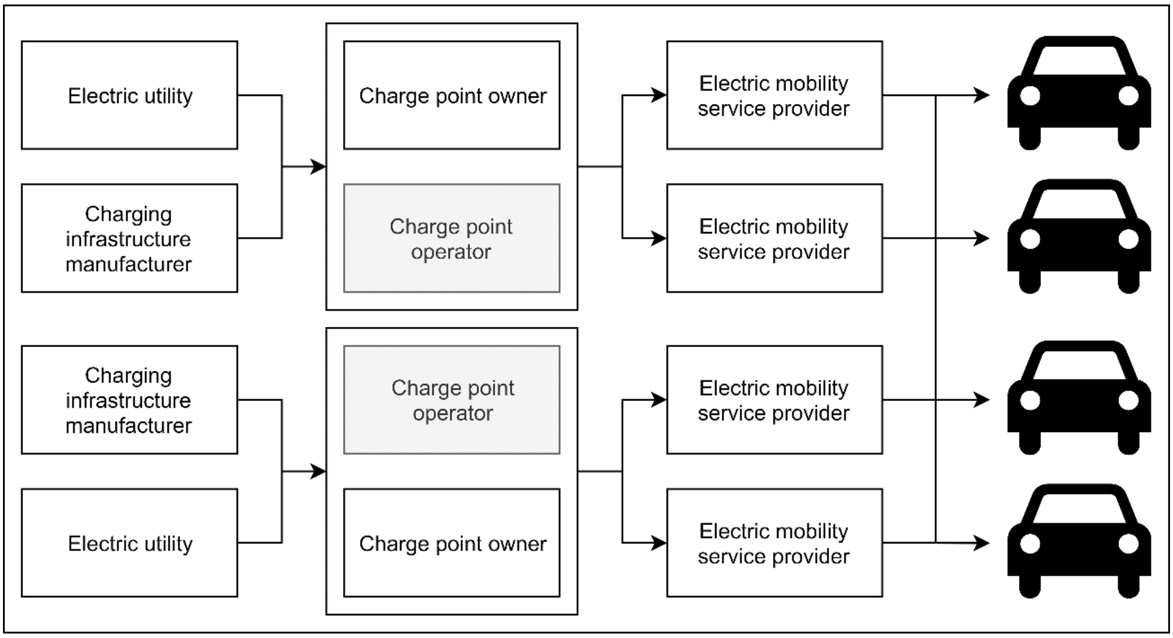


Figure 27: Different roles of companies engaged in EV charging infrastructure(based on Virta, 2019)

Electric vehicles hold the potential to disrupt large parts of the oil industry, as more than a quarter of oil demand stems from the operation of passenger cars (Kah, 2018, p. 1; Perkins, 2016) Especially in Europe, where EV adoption rates are most likely to grow, this will probably lead to shut down of refining facilities as a consequence of low utilization rates in the long run (Monzon et al., 2018, p. 8). However, the displacement of conventional vehicles will take many years and additional demand for oil comes from a variety of other sectors (Kah, 2018, pp. 1–4; Monzon et al., 2018, pp. 8–9). For this reason, global oil demand could still grow, even if individual mobility would be powered entirely by sustainably produced electricity. Nevertheless, oil companies do play a role in the business ecosystem for BEVs, as many have recognized the strategic importance of readying for a carbon-free future. By making use of their vast infrastructure and capital resources for offering charging points and engaging in the development of charging infrastructure equipment, they try to compensate the loss of their position as exclusive energy suppliers of individual mobility (see Table 31 on page A22 in the appendix). (Monzon et al., 2018, p. 10)

8.2.5.3 Mobility Service Providers

As many of their core competences are becoming obsolete for battery electric cars and a high share of competence and value creation lies in the hands of specialized suppliers, OEMs try to find new sources of revenue. Additionally, they look for ways to increase the adoption rate of electric vehicles in order to benefit from economies of scale. One possible option is the transition from being product-centered manufacturers to competing with existing providers of mobility as a whole service. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 53) Today, mobility involves a high number of different means of road and rail transport like taxis, buses, trains, bicycles and many others that can all be combined on a journey from A to B. Mobility services are aimed at closing the gaps between the different steps in order to improve the overall travelling experience. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 55; Vallée et al., 2018, p. 91)

Electric cars can play an important role in this concept, especially in densely populated metropolitan areas (Barthel et al., 2015, p. 16; Bratzel et al., 2013, p. 43). In contrast to the traditional customers of car manufacturers, individual ownership is not considered a prestigious necessity among many – especially younger – city residents any more (Amsterdam Round Tables & McKinsey & Company, 2014, p. 53). Against this background, offering mobility on demand holds great potential on both the customer as well as the provider side. Customers can profit from lower investment and operating costs, whilst providers benefit from additional revenue streams and higher utilization of vehicles. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 54) Mobility services possibly include a whole bundle of individual solutions: examples are car sharing, ride hailing, parking services, charging and multi-modal platforms. All of them have the ability to contribute to the breakthrough of electric mobility, since they remove some of the barriers inherent in early BEV technology (Amsterdam Round Tables & McKinsey & Company, 2014, p. 54).

Car sharing is a concept that combines the advantages of individual mobility with the flexibility and cost efficiency of car rentals. The customers do not hold ownership of a vehicle but can dispose over the vehicles that belong to the car sharing service's fleet when needed. In exchange for this service, they have to be registered and pay a base fee that covers overhead costs like organization, insurance and proportional financing of vehicles. Additional fees have to be paid for actual usage of vehicles, most often depending on the travelled distance. (Dijk et al., 2013, p. 139; Vallée et al., 2018, p. 100) Three different models of car sharing exist, depending on the location of the vehicles and the ownership of the vehicle fleet (Amsterdam Round Tables & McKinsey & Company, 2014, p. 54). In free sharing, vehicles are bound to be returned at defined stations. The fleet usually consists of a high number of various types in order to cover all possible needs of customers. In flex sharing, cars can be parked at freely chosen spots within a certain area. As a consequence, these fleets most often consist of a low number of different vehicle types. (Vallée et al., 2018, p. 101) Whilst car sharing traditionally was mainly happening in smaller communities or based on public or private initiatives and independent platforms, OEMs have now recognized their chances in increasing sales volumes by entering the fast-growing market (see Table 32 on page A23 in the appendix). (Amsterdam Round Tables & McKinsey & Company, 2014, p. 53; Barthel et al., 2015, p. 17; Deloitte, 2017, p. 2; Dijk et al., 2013, p. 139; Rong et al., 2017, p. 238; Vallée et al., 2018, p. 102) Additionally, employment of electric vehicles in car sharing allows easy promotion of the advances of electric vehicles and getting a deeper understanding of customers' needs. Financial interests often take a back seat in these efforts in favour of strategic concerns. (Deloitte, 2017, p. 3)

Ride hailing is a different concept, where individual drivers use their privately-held vehicle for offering paid transportation services, usually of passengers, via online-platforms. The business is dominated by a small number of established platforms, although some OEMs have already started their own platforms in an attempt to increase the adoption rate of their electric vehicles. (AlixPartners, 2018; Srivastava et al., 2018, p. 5)

Other offerings belonging to the same category of mobility services mainly are platforms that allow making use of a number of different mobility-related individual services through a single customer interface – usually a website or mobile application. Their main aim is to facilitate use and improve processing, availability, flexibility and payment processes. (Spieth & Meissner, 2018, p. 17) The services bundled under the roof of these platforms might reach from parking, ticketing of means of public transport, navigation to and billing of charging stations and similar activities. Possible providers of these services are utilities, public transport companies, OEMs or independent organisations. (Dijk et al., 2013, p. 139; Hall et al., 2017, p. 4)

What many of those mobility solutions have in common is that they lower the barriers for wider adoption of BEVs and make the life of their users easier. This is also what makes them especially appealing to car manufacturers. The main limitations of electric vehicles are their limited range and higher total costs of ownership in regular usage. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 57) However, thorough information on the next charging opportunity, simple billing, a possible switch to a readily charged car or even a car featuring a wider range when needed are valid solutions for extending the actual travelling range when using electric mobility. Higher purchase costs can be addressed by alternatives that do not include full vehicle purchase and bring high utilization rates which can even lead to an advantage in total costs of ownership of BEVs. (Dijk et al., 2013, p. 139; International Energy Agency, 2018, p. 102) Further concepts are full-service leasing schemes that include maintenance and repair work, mobility packages which combine EV purchase with vouchers or price reductions for car rentals. These allow customers to travel for longer distances when needed. However, although all presented concepts lower the barriers of stepping into electric mobility for end customers, the pivotal question still stays the same: if a majority of car users can be convinced to adapt their vision of individual mobility to the different frame conditions inherent in electric mobility. (Barthel et al., 2015, p. 17; Strathmann, 2019, p. 41; Vallée et al., 2018, p. 91)

8.2.5.4 Providers of Maintenance and Service

As a consequence of an electric vehicle's lower number of moving parts, maintenance intensity and spare parts demand will decrease. For this reason, potential after-sales revenue will decline for battery electric cars. (Accenture, 2014, p. 12; Amsterdam Round Tables & McKinsey & Company, 2014, p. 49; Heerwagen, 2019, p. 12; Strathmann, 2019, p. 38) Thus also the whole concept of exclusive car dealerships will be questioned, whose business models are based upon after sales in order to compensate for the low margins common in dealing with new cars (Selz & Klein, 1998, p. 3). However, EVs will give rise to a number of additional services, like for example battery installation, capacity monitoring and exchanges, maintenance of electric components and charging devices and EV roadside assistance (Accenture, 2014, p. 12). Training of maintenance and repair stuff is needed for ensuring that dealerships and repair shops have the needed capabilities and knowledge to manage the tasks they have to tackle. Further qualification will be needed for hazard prevention when handling high voltage components. Independent testing organizations will have to find testing procedures to certify these capabilities. (Accenture, 2014, p. 14; Vallée et al., 2018, p. 127)

Another trend, that can also be seen independent from electric cars are over-the-air updates like introduced to automotive maintenance by Tesla. Those services not only enable easier maintenance without physical presence of the vehicle but also the comprehension of OEMs themselves in repair and maintenance work. Technology like this will become reality in the automotive business ecosystem for BEVs soon, as a number of OEMs already published their strategic plans on these topics. (Accenture, 2014, p. 12; Bratzel, 2016, p. 2; Vallée et al., 2018, p. 128; Volkswagen AG, 2018b, p. 6)

Providers of maintenance and service will have to be integrated more closely to other steps in the value-added chain. In order to lower the barriers of EV adoption, some OEMs are offering bundles that include both the vehicle and cost reductions in maintenance plans or warranties for components and batteries. (Strathmann, 2019, p. 41)

8.2.5.5 Financial Services and Leasing Companies

Leasing of cars has already been a viable business branch for a number of years. A financing organization buys the vehicle on order of the customer and lets the customer freely dispose over it against payment of an initial and regular leasing fees. Those fees are adapted to the depreciation of the vehicle that arises from the distance travelled in it. After termination of the contract, the customer can either buy the vehicle by paying the residual value or return it to the financing organization, which is in many times a commercial bank owned by or cooperating with the vehicle manufacturer or car dealer. (Vallée et al., 2018, p. 100) In fact, the importance of leasing and financing revenues for OEMs and car dealers has increased in the last years and nowadays embodies one of the most profitable services offered by car manufacturers (Selz & Klein, 1998, p. 3; see Table 33 on page A23 in the appendix).

Although leasing is especially appealing for business customers, it also is a valid strategy for lowering the high initial purchase costs of BEVs. For this reason, OEMs have introduced concepts that bundle leasing offers with full-service repair and maintenance (Accenture, 2014, p. 12). Others let their customers only purchase the vehicle without a battery, which has to be leased. This way, the high costs for expensive batteries can be excluded from the vehicle's purchase price and the customer does not have to care about battery degradation or longevity. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 51; Kampker et al., 2018, p. 18; Rong et al., 2017, p. 237) Similar packages could also be offered by utilities or other stakeholders in order to reach higher market penetration of electric vehicles (Strathmann, 2019, p. 40; Vallée et al., 2018, p. 128). Alternatives to conventional leasing of a single vehicle might be subscription models like for example for car sharing services (Vallée et al., 2018, p. 91; see section 8.2.5.3).

8.2.5.6 Recycling, Reuse and Remanufacturing Companies

Another identified group of relevance are companies that occupy with recycling and reuse of components included in electric vehicles. Especially the batteries that are an integral building block of the drivetrain of battery electric cars underlie degradation and have to be replaced after a certain period of usage (see Table

11). After a maximum lifetime of ten years, the capacity of most battery types has fallen below 80 percent of their nominal specification, which impairs performance, acceleration, efficiency and reliability. However, the high costs of battery production and the high prices of the included raw materials call for ways to realize their still existing economic potential. (Debarre & Gilek, 2018, p. 5) Additionally, government regulations in the European Union oblige producers and distributors to take back batteries free of charge. They also dictate a mandatory minimum recycling rate for industrial and automotive batteries and prohibit landfilling and incineration. However, the policy is already outdated, as the considered battery technology does not reflect the current state of the art. As a consequence, many companies do not concentrate on the environmental impact of material extraction or its criticality but just recycle those materials which allow the cheapest recycling processes. (Brown et al., 2010, pp. 3803–3804; International Energy Agency, 2019, p. 182; Morche et al., 2018, pp. 251–252)

Three ways of dealing with used batteries exist: recycling, reuse and remanufacturing. As batteries can still be used until their capacity falls below 50 % of nominal specifications, a very viable solution is their deployment in stationary energy storage systems, where the requirements are lower than for electric vehicles. In fact, second use of old lithium ion batteries does not only have the advantage of lower battery costs, but also high versatility in terms of application purpose. They are already being deployed in residential applications for energy storage and as back-up solution for levelling out energy peaks in electricity grids. Due to their responsibility to find a solution for battery lifecycle management and easy access to high numbers of old batteries through their customer contacts and distribution channels, especially companies with electrical and industrial knowledge like OEMs, electric utilities and suppliers are believed to lead the development of solutions in this area. First initiatives by these actors are already showing results. (Debarre & Gilek, 2018, pp. 5–8)

Remanufacturing or refurbishment of batteries is a different approach which requires adoptions already in the construction of battery cell and module assemblies. However, modular interfaces and a modified battery architecture would not only allow restoring the original state of the battery but also extension of the batteries' capacity through updates of cell chemistry. Remanufactured batteries could then be deployed in new vehicles, or be used as spare parts in older vehicles after series production of the original batteries has ended. Changeable modules would furthermore allow an increase of the original battery's life as its overall capacity can be negatively influenced by single faulty cells. A simple change of these cells could therefore lead to considerably higher capacities and extend the lifetime of the battery on system level. Due to the high value of periphery like housing, cooling and battery management system, the residual value of batteries that show a too low performance for use in BEVs still lies at approximately 70% of the original price. For this reason, remanufacturing would be a very reasonable concept. However, solutions for the required detachable connections which need to be stable enough for passing crash tests, as well as durable in spite of vibrations still have to be found. Additional problems might be changes in battery technology, electric isolation and electric hazards when handling with battery components and the different matching between supply of used batteries and demand of remanufactured ones. (Debarre & Gilek, 2018, pp. 7–8; Morche et al., 2018, pp. 266–268)

Recycling finally means dismantling of whole batteries in order to recover valuable chemical components like lithium and cobalt. In spite of the high value that used batteries still have, a true recycling industry for electric vehicle batteries barely exists. As a consequence, lithium ion batteries cannot even be recycled profitably in countries with cheap workforce as of now. Although the economics of this business might improve in the future following higher production volumes and rising material prices, currently recycling has to be enforced by government regulations. These have already resulted in the development of recycling processes and the installation of first recycling facilities. Existing approaches for battery recycling include pryometallurgical, hydrometallurgical, biometallurgical and direct recycling (see Table 14). Industrial application of these processes mainly happens in North America, Europe and Japan. All types are theoretically able to process a variety of different battery chemistries. However, the variety of existing sizes, fire hazards and different connection elements are challenging process reliability. Other than that, the quality of the retrieved materials often is impaired through the pyrometallurgical and hydrometallurgical processes which lowers their value significantly. Physical recycling offers advantages but would require standardized manufacturing in order to allow automated processes at a big scale. In the future, many manufacturers of batteries are expected to develop their own recycling processes in order to reprocess faulty cells when production volumes increase. (International Energy Agency, 2019; Kampker, 2014, pp. 89–93; Morche et al., 2018, pp. 253–257)

Name of process	**Description**	**Advantages**	**Disadvantages**
Pyrometallurgy	Metals are recovered via high temperature smelting. Separation is done by hydrometallurgy.	• Easy implementation. • High efficiency. • Results in marketable metals.	• Energy-intensive smelting. • Costly because of high energy use. • Production of harmful gases. • No recovery of aluminum or lithium.
Hydrometallurgy	Acids dissolve ions out of the metallic parts (nickel, cobalt, lithium) into a solution from which each metal can be recovered by precipitation or solvent extraction.	• Low energy process. • High recovery rate of battery materials. • High selectivity. • Low production of harmful gases.	• High consumption of harmful chemicals (waste acid sludge issues). • Long process (chemical reactions). • Bad efficiency.
Biometallurgy	Hydrometallurgy based on microbial activity to separate ions.	• Low energy process. • High recovery rate of battery materials. • Easily manageable temperature and pressure requirements.	• Long process (chemical reactions relying on microbial activity). • Requires bacteria culture.
Direct/Physical recycling	Use of physical processes such as gravity separation of shredded battery materials.	• Low energy process.	• Does not permit recovery of each cathode material separately.

Table 14: Different processes for battery recycling (according to Morche et al., 2018, p. 253; International Energy Agency, 2019, p. 182)

8.3 Business Ecosystem

The business ecosystem is the whole networked system of actors that concentrate around a certain product or service offering. In addition to all actors included in the core business and extended enterprise sphere, the business ecosystem also includes government agencies and other quasi-governmental regulatory organizations, competing organizations and all remaining stakeholders.

8.3.1 Government Agencies and Other Regulatory Organizations

Governments play a pivotal role in defining the pace of the shift to battery electric cars (Dijk et al., 2013, p. 142; Hensley et al., 2009, p. 90; International Energy Agency, 2018, p. 22; Rong et al., 2017, pp. 239–240). Although not matching the immense endeavours of the Chinese government, the most important driver for the changing focus towards this technology in Europe is not customer demand, but legislation and regulations introduced by governments (Dodourova & Bevis, 2014, p. 258; Gupta-Chaudhary et al., 2018, p. 16; Rong et al., 2017, p. 239). Additionally, incentives granted by governments are aimed at increasing customer demand. As a consequence, the ten countries with highest EV adoption rate all actively promote electric mobility by means of a whole palette of different initiatives. (International Energy Agency, 2018, p. 22) The reasons for these efforts are the desire for higher independence from oil imports, a reduction of emissions and the chance to gain a technological advantage over other countries, which is particularly relevant for countries with major OEMs. Additionally, governments want to ensure that large parts of value-added for the new technology can be kept inside the country. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 15; Kampker et al., 2018, p. 30)

Besides those measures, governments can also act as partners and coordinators of actors in the newly created business ecosystem in an attempt to solve the problem of collective action inherent in systematic innovations (Pinske et al., 2014, p. 46; Rice et al., 1998, p. 57). In the future, OEMs will have to find ways to manage growing interaction and negotiation with authorities (Spieth & Meissner, 2018, p. 16). In the long term, only a binding agreement between governments and vehicle manufacturers on the termination of ICE production and registration will ensure full commitment of all actors to extensive reduction of carbon emissions in the individual mobility sector in accordance with international targets. The created certainty would provide the needed assurance for OEMs and safeguard the termination of lobbying efforts to influence legislation. (Barthel et al., 2015, p. 6; Bormann et al., 2018, p. 23)

Currently existing government programs are either aiming at increasing customer demand or encouraging vehicle manufacturers and suppliers to advance investments in the development of improved technology (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 14–15; Bormann et al., 2018, p. 28). Possible measures to lower the adoption barriers for customers are tax exemptions or reductions, financing of abatements or charging infrastructure, regulations for adapting buildings to the needs of electric mobility, public procurement schemes or granting additional benefits that drivers of conventional vehicles do not have (Amsterdam Round Tables & McKinsey & Company, 2014, p. 16; APCO, 2010, p. 3; Dijk et al., 2013, p. 138; International Energy Agency, 2018, p. 13; Kasperk et al., 2018, p. 141; Pinske et al., 2014, p. 46). Supply-side provisions might reach from public funding of research and development to registration bans of ICE-powered vehicles and mandatory quotes for the number of electric models offered by OEMs (Accenture, 2014, p. 4; Amsterdam Round Tables & McKinsey & Company, 2014, p. 16; Barthel et al., 2015, pp. 17–18; Dijk et al., 2013, p. 138; International Energy Agency, 2018, p. 35; Kasperk et al., 2018, p. 141). External pressures seem necessary to trigger significant changes in the attitude of OEMs towards mass adoption of BEVs (Mazur et al., 2013, p. 1060).

First legally binding limits for worldwide emission of carbon dioxide were already set in the Kyoto protocol (Barthel et al., 2015, p. 8). Today, developing cleaner and more efficient cars is of growing relevance for European car manufacturers in the face of strict regulations that have been published by the European Commission to reach the goals dictated by this convention of international law (European Commission, 2014, p. 1). Europe even shows the strongest policy signals for zero- and low-emission vehicles worldwide besides California and China (International Energy Agency, 2018, p. 10). After a voluntary commitment of the automotive industry to reduce the average fleet emission of their produced cars below 140 grams per kilometre in 2008 was not fulfilled, in 2009 the first binding limits for CO_2 emissions of newly registered vehicles were passed in the European Union. The first stage put into action from 2015 on required all car manufacturers' fleets of produced models to not exceed an average emission of carbon dioxide of 130 grams per kilometre. Financial penalties were installed that were high enough to lead to a comfortable achievement of objectives. (Barthel et al., 2015, p. 9; Gupta-Chaudhary et al., 2018, p. 79) The next stage of these regulations will be phased in from 2020 to a target of 95 grams per kilometre in 2021, depending on vehicle weight and other factors on manufacturer level. These targets will first be based on the New European Driving Cycle (NEDC), before the Worldwide Harmonised Light-Vehicle Test Procedure (WLTP) will be used for testing from 2021 on. For this reason, the requirements will be converted between those two testing procedures for the future regulatory stage. OEMs will have to pay financial penalties for every gram of CO_2 that exceeds the limit. (European Commission, 2014, p. 1; Griffiths et al., 2015, p. 16; Gupta-Chaudhary et al., 2018, p. 79) *"Super credits"* were introduced for vehicles that emit less than 50 grams per kilometre. Those will count for two cars in 2020, a number that will be continuously reduced until counting for one car only in 2023. (Gupta-Chaudhary et al., 2018, p. 40) According to many experts, these regulations are one of the key drivers for the increasing engagement of OEMs in the battery electric car sector. The catalytic effect does not only affect European but also foreign companies that want to stay present on European markets. (Gupta-Chaudhary et al., 2018, p. 80; Strathmann, 2019, p. 23) Interestingly, none of these regulations explicitly prefers BEVs over other technologies like FCEVs, hybrid vehicles or even highly efficient internal combustion engines. However, the targets are believed to be very hard or impossible to meet for OEMs without equipping parts of the fleet with alternative drivetrain technologies (Strathmann, 2019, p. 22; see Figure 58 on page A24 in the appendix). Not even hybrid drives will be sufficient to fulfil the requirements, as they most often emit more than 50 grams per kilometre. A complementary incentive scheme rewards an overproportional uptake of production of low- and zero- emission cars by vehicle manufacturers with a reduction of emission thresholds by up to five percent. (International Energy Agency, 2018, p. 25) Future plans include further reductions of 2021 targets by 37.5% in 2030 (International Energy Agency, 2019, pp. 71–74).

Additionally, the European Union has introduced a row of other measures to facilitate the breakthrough of BEVs. Those include deployment targets for publicly available charging infrastructure, regulations for the installation of charging points in new or renovated residential buildings, binding requirements for the minimum percentage of clean vehicles in public procurement as well as funding of research and development and initiatives to create a European battery industry. (International Energy Agency, 2018, pp. 46–48; International Energy Agency, 2019, pp. 71–74)

European regulations and incentives are further complemented by national initiatives. In 2018, 33 member states of the European Union had national incentive schemes to foster electric passenger car adoption (examples see Table 34 on page A24 in the appendix). Those schemes most often are aimed at reducing the high up-front costs of electric vehicles. In some countries, additional taxes for conventional vehicles add to their effect. The most generous incentives in Europe are granted in Norway, which also explains its extraordinarily high BEV market share in recent years (see Table 28 on page A19 in the appendix). This country therefore also serves as the perfect example for the great influence incentives have on customer demand and at the same time raises the question of customers' reactions to a termination or reduction of those measures. (Amsterdam Round Tables & McKinsey & Company, 2014, p. 16; Gupta-Chaudhary et al., 2018, p. 82; International Energy Agency, 2018, p. 22; International Energy Agency, 2019, pp. 71–74; Kampker et al., 2018, p. 27; Rong et al., 2017, p. 242) Some countries also use exemptions and reductions of purchase, lease and road taxes to increase the appeal of environmentally friendly cars to customers. However, this solution might prove critical in the future, as additional sources of income will have to be found and tax schemes reworked in order to maintain the level of tax incomes derived from road traffic. (International Energy Agency, 2019, pp. 23–24) In the long term, many national governments pledge the complete termination of registrations for new internal combustion engine cars (International Energy Agency, 2018, p. 35; Kampker et al., 2018, p. 24).

Municipalities also contribute their share to the regulatory landscape of individual mobility. Some major cities have committed to zero-emission zones within their region, provide additional charging infrastructure, free parking spaces or other incentives like free usage of bus lanes for environmentally friendly cars. On the one hand, local regulations are potentially more aggressive than nation-wide agreements, which helps OEMs to increase sales numbers. On the other hand, local pronouncements might possibly fragment market demand due to different requirements which necessitate adaptions for market success in individual regions. (Bormann et al., 2018, p. 26; International Energy Agency, 2018)

In spite of their positive effects on the development of a whole electric mobility environment, governments are bound to act cautiously. In order to avoid the risk of only targeting the market diffusion of one specific technology while hindering efforts in all other technologies, policy makers have to lay their focus on only introducing technology-neutral regulations and incentives. (International Energy Agency, 2018, p. 98) Other than that, government initiatives might even increase the uncertainty associated with future individual mobility concepts if acting double-minded (Gupta-Chaudhary et al., 2018, p. 84) Consequently, close cooperation with all parties and observation of their responses to policy pressures are needed (Amsterdam Round Tables & McKinsey & Company, 2014, pp. 33–34; Mazur et al., 2013, p. 1055; Rice et al., 1998, p. 57). Long-term commitment of all involved actors has to be ensured in an attempt to create clear, harmonized, transparent and consistent guidelines that are not blurred by individual parties in an attempt to enforce their own interests.

Besides fostering the growth of the business ecosystem, governments also have to adapt general legislation for accommodating regulations regarding the operation of electric vehicles in road traffic (Kampker et al., 2018, p. 27).

8.3.2 Stakeholders

The term *"stakeholder"* was coined by Edward R. Freeman (1983, p. 25) and defined as *"any group or individual who can affect or is affected by the achievement of the firm's objectives."* Figure 28 shows an exemplary list of a firm's stakeholders. The relevant stakeholders in the business ecosystem for BEVs that have not been considered yet are environmentalists, employees, the media and owners. Competitors will be covered in section 8.3.3.

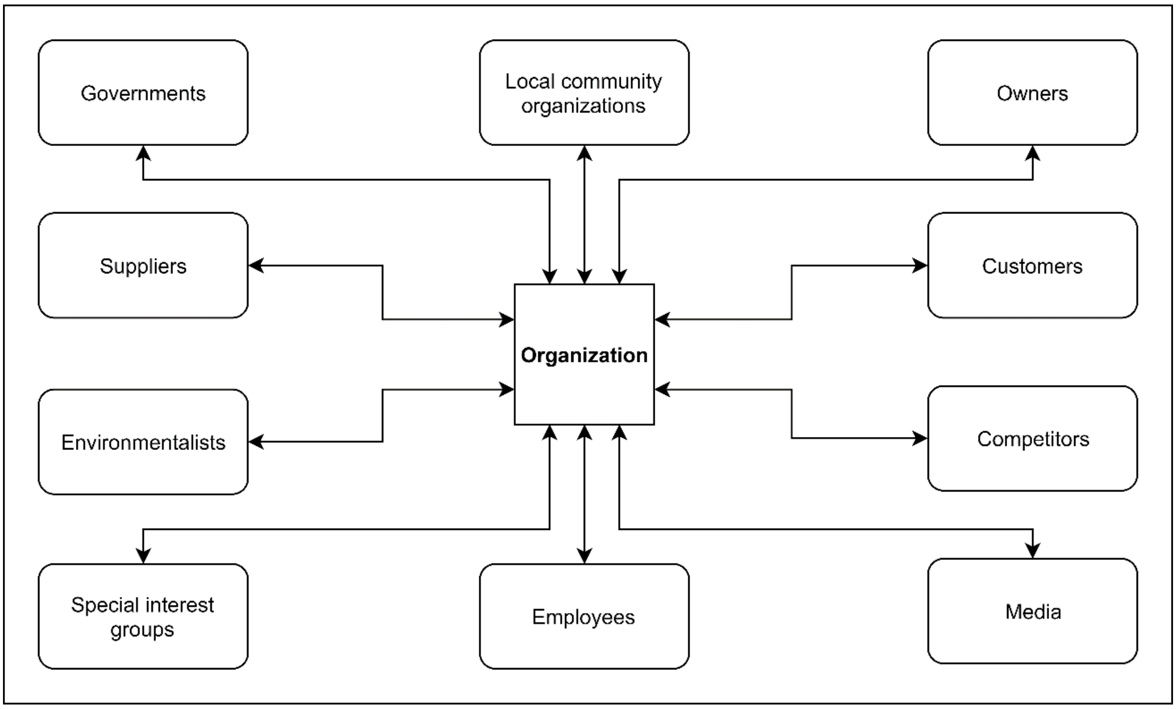


Figure 28: Stakeholders of an organization (based on Freeman, 1983, p. 25)

8.3.2.1 Environmentalists

The main advantage of BEVs in comparison with conventionally powered cars are their almost inexistent local emissions of carbon dioxide and other toxic gases (tank-to-wheel). However, a holistic calculation of CO_2 emissions has to consider CO_2 emissions along the whole lifecycle of a BEV together with the emissions created at the production of energy that is used to charge the vehicle (well-to-tank). Some sources state that for this reason, widespread adoption of BEVs might not bring the actual amount of CO_2 emitted through personal transportation below the level of ICE vehicles. (Debarre & Gilek, 2018, p. 1; International Energy Agency, 2018, p. 56) According to calculations carried out by the International Energy Agency (2018, p. 56) the real well-to-wheel reduction of CO_2 emissions through the utilization of battery electric cars is 50% in comparison to gasoline-powered cars and 60% when compared with diesel-powered cars. If the emissions associated with vehicle production are also taken into account, the reductions are far less significant. However, when considering the whole lifecycle and the actual European mix of energy generation, BEVs still allow a reduction of roughly 30% of greenhouse gas emissions of a comparable gasoline-powered vehicle. (International Energy Agency, 2018, p. 56) Other experts state that the level of CO_2 emitted for production and operation of BEVs and diesel vehicles roughly lies at the same level after 200000 driven kilometers (Heerwagen, 2019, p. 13). Irrespective of all numbers, it has to be clear that the adoption of BEVs on a large scale necessitates sufficiently high volumes of economically friendly produced electric energy in order for them to be part of a viable solution to reduce global greenhouse gas emissions (Grauers et al., 2013, pp. 10–11).

8.3.2.2 Employees and Labour Unions

Automotive companies are an important factor of employment in the European Union. In 2013, more than 2.3 million inhabitants of the 28 EU member states were working in the national motor vehicle manufacturing sectors, most of them in Germany. (European Commission, 2014, pp. 1–2) According to Deloitte (2017, p. 61), due to the higher degree of automation in the production of electric vehicles and the resulting decrease of involved human labor, workforce is very likely to be reduced (Helbig et al., 2017, p. 61). However, the burden of adapting to the structural changes triggered by the shift to BEVs must be fairly distributed. Trade unions, social partners and civil society will have to be involved in order to allow a high competitiveness of companies while at the same time staying committed to social standards. (Bormann et al., 2018, p. 27) Additionally, retraining of existing personnel in all areas of the value-added chain will become necessary as a consequence of the changing capabilities and knowledge needed for new processes (Brown et al., 2010, p. 3798; Srivastava et al., 2018, p. 11; Vallée et al., 2018, p. 127).

8.3.2.3 The media

Media also plays a role in the growth of a full-scale business environment for BEVs. The most prominent example is the high media presence of Tesla and its founder Elon Musk. (Mazur et al., 2013, pp. 1056–1057) Additionally, the high visibility of passenger vehicles and their relevance to the lives of many people leads to an inordinate proportion of media attention and therefore explains their perceived high importance in the reduction of fossil fuel consumption. (Kah, 2018, p. 1; Sheller & Urry, 2000)

8.3.2.4 Shareholders

Of course, the challenges posed to companies involved in the automotive business ecosystem by the trend towards BEVs also have implications on the shareholders and owners of these enterprises. High investments are necessary for the development and production of purpose-built vehicles, their systems and components, the needed tools and machines, infrastructure and other facilities. (Accenture, 2014; Amsterdam Round Tables & McKinsey & Company, 2014, pp. 41–49; International Energy Agency, 2019, p. 15; Sovacool et al., 2019, p. 9) Together with the high uncertainty regarding the drivetrain technology that will emerge as the prevailing standard in the future, this on the one hand creates a substantial thread to all companies involved in the automotive business ecosystem (Barthel et al., 2015, p. 20; Hensley et al., 2009, p. 91). On the other hand, however, it also offers enough chances for many venture capital investors and start-ups to try to get a foot in the door of this big industry sector (Debarre & Gilek, 2018, p. 6; Deloitte, 2017, p. 2; Sovacool et al., 2019, p. 10). Policy measures and standards contribute their share to reduce the risks for investors in the transition towards the new business reality (International Energy Agency, 2018, p. 22).

8.3.3 Competing Organizations

Besides technological competitors of battery electric cars like fuel-cell powered vehicles, hybrid vehicles or highly efficient internal combustion engine vehicles, the newly created business ecosystem for battery electric cars and its changed frame conditions also offer high chances for new entrants to add to the rivalry between existing core contributing companies (Strathmann, 2019, p. 37). Due to the heavy weight of their batteries, the bodywork of BEVs might be manufactured from lightweight compound materials like reinforced plastics. These parts can consequently be made without the need for stamps and dies used for forming the steel or aluminium body parts of conventional vehicles. Due to the fact that these tools require very high investments, their omission eradicates one of the major barriers to car production for possible new entrants. (Moore, 1996, p. 101)

Possible new market players are furthermore companies that originate from other countries like the emerging EV nation China, where electric mobility is boosted by broad government support (APCO, 2010, p. 13; Kampker et al., 2018, p. 49). Vertical integration of already existing automotive companies might also pose challenges to core contributing companies. Several suppliers, for example system integrators belonging to tier 1 of the automotive supply pyramid are reported to be ready to launch their own BEVs. (Heerwagen, 2019, p. 12) However, general entry barriers like production scale, distribution and servicing infrastructure, brand equity, customer relationships and capital still keep their relevance in spite of a transition to BEVs (Hensley et al., 2009, p. 91). Additionally, public and private *"protection levers"* like regulations, incentives and subsidies play an important role in aiding the new business ecosystem to protect its niche existence in the competition against the dominant design of internal combustion engines (Pinske et al., 2014, p. 46).

8.4 Results

The exact answer for research question R2 can be taken from the previous sections which cover all relevant actor groups identified in research question R1.

The analysis shows clearly, that for a couple of reasons, government organizations are the main parties to push the automotive business ecosystem towards alternative drivetrain concepts. Additionally, a variety of incentives and public funding initiatives serve as what Pinske et al. (2014, p. 49) call *"main public protection levers"* to foster the niche until the market is ready for mass adoption. The needed technological knowledge for taking up research and development as well as production and sales of the new technology necessitates cooperation with other organizations.

Besides the high significance of external pressures exerted on OEMs in order to force them into the adoption of new drivetrain concepts, the most interesting observation made is the growing involvement of OEMs in fields which originally did not belong to their areas of expertise. In order to retain their level of captured value and at the same time transform their business models for future success, most vehicle manufacturers that are part of the business ecosystem for BEVs are diversifying their offerings by vertically or laterally integrating into a number of different businesses. This does not just include strategically important technology that is part of the vehicle itself like electric powertrain and battery components as a direct consequence to the external pressures by governments. Additionally, OEMs' activities in parts of the downstream value-added chain like mobility services, battery end-of-life management, charging infrastructure and financing and leasing services also undergo massive changes. Whilst some of these efforts have already been in existence as part of their business for a long time and have only been adapted to the needs of electric mobility – like the financing sector – other offerings have only recently been introduced by OEMs, and are closely connected to BEVs.

Table 15 includes all OEMs that offer BEVs in Austria in 2019 and their activities in raw materials, battery cell technology, battery system technology, electric powertrain technology, direct sales, financial and leasing services, fleet operators, mobility services, charging infrastructure and battery recycling, reuse and remanufacturing. The overview is based on information collected from official company press releases, business reports, scientific papers and books in an attempt to illustrate the diversification of OEMs' e-mobility offerings which by far exceed development, production and distribution of cars. The different categories resulted from the activities in which OEMs were reported to be involved in the data collected for this chapter.

OEM	Raw Materials	Battery Cell Technology	Battery System Technology	Electric Drivetrain Technology	Direct Sales	Financial and Leasing Services	Fleet Operator	Mobility Services	Charging Infrastructure	Battery Recycling, Reuse and Remanufacturing
Volkswagen	✔	☑	✔	✔	✓	✔	☑	☑	☑	✔
BMW	✔	☑	✔	☑	✔	✔	☑	☑	☑	☑
PSA	✗	☑	✓	☑	✗	✔	✔	✔	✗	☑
Hyundai-Kia	✗	✗	✔	✔	✔	✔	✗	✗	☑	☑
JLR	✗	✗	✓	☑	✗	✔	✗	✗	✗	☑
Daimler	✗	☑	✔	✗	✗	✔	☑	☑	☑	☑
Renault-Nissan	✗	☑	✔	✔	✗	✔	☑	☑	✗	✔
Tesla	☑	☑	✔	✔	✔	✔	✓	✓	✔	✔
Cooperation	1	6	0	3	0	0	2	4	4	5

✔ ... existing activities in this area ✓ ... future activities intended in this area ☑ ... existing cooperation in this area

Table 15: Activities of OEMs in the business ecosystem of BEVs (2019; BMW AG, 2019; Daimler AG, 2019a; Debarre & Gilek, 2018, pp. 7–8; Groupe PSA, 2015; Groupe PSA, 2018a; Groupe PSA, 2018b; Groupe PSA, 2018c; Groupe Renault, 2013; Groupe Renault, 2019a; Heerwagen, 2019, p. 11; Hyundai Mobis, 2019; International Energy Agency, 2019, p. 181; Ionity GmbH, 2019a; Jaguar Landrover Automotive PLC, 2019; Jaguar Landrover Deutschland GmbH, 2019; JLR, 2019; Kasperk et al., 2018, p. 136; Mazur et al., 2013, p. 1059; Mazur et al., 2013, p. 1058; Min-hee, 2018; Musk, 2012; PSA Groupe, 2019; Rong et al., 2017, p. 237; Röth et al., 2018, p. 352; Sanderson, 2018; Sovacool et al., 2019, p. 6; Srivastava et al., 2018, p. 10; Srivastava et al., 2018, pp. 9–10; University of Warwick, 2017; Volkswagen AG, 2018b; Volkswagen AG, 2019b; Volkswagen AG, 2019c; Volkswagen AG, 2019d; Volkswagen AG, 2019f; Volkswagen AG, 2019h)

At the same time, in the face of the high technological uncertainty and associated risks, companies are forced to cooperate with other ecosystem players. The resulting cooperation landscape can also be taken from Table 15. Black checkmarks signal internal activities of the vehicle manufacturer in this area or market relationships with other companies. Grey checkmarks are meant to indicate intended future activities, whereas white checkmarks with black borders mark cooperation in this area. Close relationships between OEMs and other companies – mainly suppliers, but also electric utilities, other (competing) OEMs and chemistry enterprises can be observed that allow OEMs to bundle resources and to share knowledge, risks and costs. Not a single company is able to cover all activities just by relying on its internal resources.

The areas that show the highest number of cooperative efforts are battery cell technology, battery recycling, reuse and remanufacturing, charging infrastructure, mobility services, electric drivetrain technology and activities as fleet operators. Battery system technology will be covered internally by all OEMs in the future, which also can be observed for financial and leasing services already today. All OEMs are involved in activities for battery recycling, reuse and remanufacturing, either internally or via cooperation. This can be explained by the legal constraint for battery sellers to take back and recycle used products (see section 8.2.5.6). The similarities between activities as fleet operators and mobility service providers can be explained by the fact that car sharing providers most often operate fleets to offer their services.

The table is not intended to show the exact behavior of all included OEMs but rather serves to illustrate OEMs' general tendency to cooperate in order to cover as many parts as possible of the BEV value-added chain. In order to gain further information on this phenomenon, which can be considered the main result of chapter 8, chapter 9 will try to shed light on value creation partnerships between three OEMs and their partners.

9 Value Creation Partnerships in the BE for BEVs

In this chapter, three case studies show the activities and interorganizational relationships of OEMs in the area of BEVs and associated technologies in order to examine the development of value creation partnerships in the course of the shift towards electric mobility.

Following the results of research question R2 (see chapter 8), the areas identified as most relevant for these case studies are battery cell technology, battery system technology, electric drivetrain technology, charging infrastructure, mobility services, battery recycling, reuse and remanufacturing and raw materials. Those are supplemented by whole vehicle projects in order to get a sense for the bigger picture as well.

This way, this chapter should allow to give an answer to research question R3:

R3: How did OEM's value creation partnerships change in the course of the shift to BEVs?

9.1 Selection of Research Objects

As mentioned in section 2.1, OEM's efforts towards BEVs and their relationships with other companies were chosen as the unit of analysis. This choice is justifiable, as OEMs are the main players in the automotive business ecosystem (Dodourova & Bevis, 2014, p. 253; Rong et al., 2017, p. 234). Additionally, the results of research question R2 have revealed, that OEMs show the most extensive reactions to the shift to BEVs, mainly by getting involved in a variety of different areas within the business ecosystem for BEVs, often in close cooperation with other companies (see section 8.4).

For research question R3, the German automotive industry was identified as the most relevant in Europe, as it is leading in European automotive employment as well as in global R&D expenditures, which is a strong sign for innovativeness (European Commission, 2014, p. 2; Spieth & Meissner, 2018, p. 9). German OEMs accounted for a total amount of 16.4 million vehicles manufactured worldwide in 2017, which is equivalent to more than 19% of the international automotive industry's overall output in this year (Verband der Automobilindustrie, 2018; Verband der Automobilindustrie, 2019). Germany is also Europe's leading automotive production site, having produced more than five million vehicles in 2017 (Germany Trade and Invest, 2018, p. 2). A prove for the validity of this choice was also given by the results of research question R1 (see section 7.3).

Daimler, BMW and Volkswagen Group were identified as the major German OEMs (Mazur et al., 2015). In the passenger vehicle segment, they are the three German automotive companies that sell the highest number of vehicles and are not foreign-held (BMW AG, 2019; Daimler AG, 2019a; Ford Motor Company, 2019; PSA Groupe, 2019; Volkswagen AG, 2019d). Their exact sales numbers in the years from 2014 to 2018 are shown in Figure 29. Daimler, BMW and Volkswagen Group were chosen as research objects for the case studies in order to find an answer to research question R3. Following the argumentation outlined in section 9.1 and the results of research questions R1 and R2, the efforts of these companies and their partners in the areas of battery cell technology, battery system technology, electric drivetrain technology, charging infrastructure, mobility services, battery recycling and reuse, raw materials and whole BEVs will be examined.

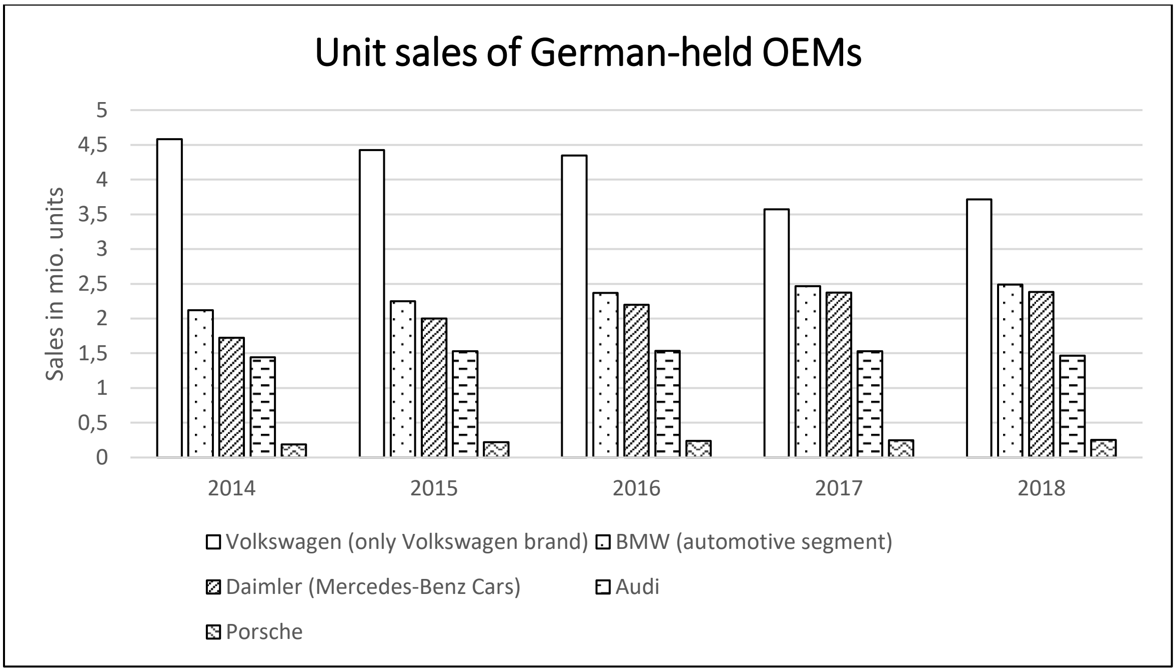


Figure 29: Unit sales of German-held OEMs (own creation, according to BMW AG, 2016; 2017; 2018; 2019; Daimler AG, 2016; 2017; 2018; 2019; Volkswagen AG, 2016; 2017; 2018; 2019)

9.2 Explanation of Approach

As already outlined in chapter 2, the case studies in this thesis consist of narratives and timelines. The narratives cover all relevant activities of the chosen OEMs and their partners in the respective areas, whilst the timelines are used to illustrate these findings and allow easier comparison and interpretation. In order to guarantee for reliability of results, the exact research procedure for collecting data is outlined in section 9.2.1. Additionally, the criteria for data collection can be taken from section 9.2.2. Finally, different coding schemes were used in the timeline representations, which are described in section 9.2.4. In order to improve retrievability and reliability, a case study database was created and complemented by a case study protocol, which can be found in Figure 59, Figure 60 and Figure 61 on pages A25, A26 and A27 in the appendix.

9.2.1 Procedure

As already mentioned in section 2, the case studies were developed using secondary data only following a procedure that includes press releases, business reports and databases. The exact procedure for data collection consisted of six different steps:

1) Using the OEM's global English press portal to find press releases to the topic of BEVs. For this purpose, the search term "electric vehicle" was used, without narrowing down the time frame. This search delivered a thorough overview over the OEM's activities in the area of BEVs. All relevant interorganizational relationships and BEV projects mentioned in the collected data were listed in the case study database.
2) Using the "M&A" category of Nexis' "Company and Financial" database to find international mergers and acquisitions involving the respective OEM by using its name as a search term. In order to get a feasible number of results, the term "electric" was used to preselect entries. Nexis is a business database service offered by LexisNexis, which collects data from over 40000 sources, including global news, industry and company profile information (LexisNexis, 2019). All relevant interorganizational relationships mentioned in the collected data were listed in the case study database.
3) Using Reuters' global news service for complementing the collected data. The search terms were "OEM's name; cooperation", "OEM's name; partnership", "OEM's name; joint venture", "OEM's

name; alliance" and "OEM's name; integration". All relevant interorganizational relationships mentioned in the collected data were listed in the case study database. Reuters is one of the world's largest global news and media services operated by Thomson Reuters Group. Covered topics include business, financial, politics and technology news. (Reuters, 2019)

4) All identified interorganizational relationships and BEV projects contained in the case study database after steps 1) to 3) had been carried out were then further assessed using internet portals related to electric mobility, newspaper articles, industry reports and additional press releases published by other companies than the OEMs themselves in order to validate findings and fill the gaps in the existing entries of the case study database. For easy access and efficiency reasons, an internet search engine was used in this step.
5) Screening of OEMs' business reports from 2018 back to the year when BEVs were first mentioned as part of an OEM's strategy to gain further insights and check the completeness and viability of identified relevant interorganizational relationships. In case of identification of additional IORs not considered before, they were assessed through an additional iteration of step 4).
6) Reading of publicly available interview transcripts with OEMs' CEOs allowed gaining an understanding of the company's motives and the connection between different events.

More than 3000 data sets were screened this way for each case study, applying criteria outlined in section 9.2.2. After data collection, all identified relationships were assessed according to scales described in section 9.2.3 in order to finally be able to classify them relative to the interorganizational relationship types for technology sourcing that were defined in section 5.3. In the end, cases were written and timelines were developed. A case study protocol of all cases can be found in Figure 59, Figure 60 and Figure 61 on pages A25, A26 and A27 in the appendix.

9.2.2 General Criteria for Data in the Case Study Database

General criteria were defined to identify interorganizational relationships and vehicle projects that were to be included in the case study database.

9.2.2.1 General Criteria for Vehicle Projects

In order to be considered for case studies, vehicle projects had to be identified as relevant. Relevance was defined by using the one key criterion that a project had to be a BEV as defined in chapter 6. Additionally, only battery electric cars that showed a technological step forward were included. This excludes concept cars that were only intended to show new designs but were based on an already existing BEV chassis that was not modified.

9.2.2.2 General Criteria for Interorganizational Relationships

In order to be considered for case studies, interorganizational relationships had to be identified as relevant. Relevance was defined by using five key criteria:

1) A close connection to BEVs as defined for the scope of this thesis.
2) Consistency of the scope of a relationship with one of the previously defined categories (battery cell technology, battery system technology, electric drivetrain technology, charging infrastructure, mobility services, battery recycling, reuse and remanufacturing, raw materials, whole vehicles).
3) Economic character of the interorganizational relationship. For this reason, no relationships with universities, public research organizations or political entities like governments alone were considered.
4) Actual operative interactions. Companies an OEM is or was only connected to through minor investments without having any operative interaction with the OEM were not considered. However,

holding a majority share in another company was considered as an operative interaction. This is justified by the influence that can potentially be exerted over the other enterprise in this case.

9.2.3 Scales Used for Further Categorization

In order to allow easier categorization of identified interorganizational relationships and vehicle projects, a number of scales were developed:

9.2.3.1 Scales for Vehicle Projects

1) Maturity:
    a. Concept study: No or only minor functionality. Focus is not technology development.
    b. Prototype: Fully functioning. Focus is technology development.
    c. Short run: Limited availability for customers. Often intended for field testing.
    d. Series production: Full availability for customers. Built on an industrial scale.
2) Vehicle type:
    a. Conversion design: Adapted conventional car initially built for an ICE drivetrain.
    b. Purpose design: Specifically developed for an electric drivetrain.

9.2.3.2 Scales for Interorganizational Relationships

1) Importance:

    Describes the importance of an interorganizational relationship for an OEM's activities in the field of BEVs from an external observer's point of view. This is assessed using three criteria:
    a. Shows change in relationship type.
    b. Allows extension of the OEM's knowledge base in BEV technology.
    c. Significantly extends OEM's product or service portfolio in European markets or enables continuation of already offered products and services. The term significantly in this context intends to exclude products or services that are or were only offered in a single city without the intention to expand to other regions.

    Only those relationships identified as being important by fulfilling one of the above mentioned conditions were subsequently included in the final case studies and timelines.
2) Relationship type

    All identified interorganizational relationships were assigned to one of the interorganizational relationship types for technology sourcing that were elaborated in section 5.3 using the outcome of an assessment based on the relationship scope, the strategic relevance of the IOR's focus, the time horizon and the legal autonomy. It has to be mentioned that relationships that spanned more than one of the examined areas were assessed for each area individually.
    a. Relationship scope:

        Describes the functions carried out cooperatively. This was assessed using the information contained in the collected data.
        i. Supplier: the other company only supplies products or services to the OEM within a predefined scope of exchange.
        ii. R&D: both companies jointly perform R&D activities.
        iii. Procurement: both companies jointly purchase products or services.

iv. Manufacturing: both companies jointly manufacture products.

v. Installation: both companies jointly provide installation services.

vi. Operation: both companies jointly operate systems.

vii. Marketing: both companies jointly perform marketing activities.

viii. All: includes all above mentioned functions (R&D, Procurement, Manufacturing, Installation, Operation and Marketing).

ix. Customer: the other company buys products or services from the OEM within a predefined scope of exchange.

b. Timeframe:

The duration of an interorganizational relationship was determined using dates specified in the collected data. The timeframes mentioned in the case studies do not only refer to the duration of activities and relationships in terms of actual operations that led to any kind of an output, but in terms of their publicly known existence. This is due to the fact that the start and end point of operations are hard to determine from secondary data only. If the beginning of an interorganizational relationship was not exactly mentioned in the collected data, publication dates of press releases or news were taken as an indicator. For internal activities, the first public presentation of prototypes served the same purpose whenever necessary. If the ending of an interorganizational relationship could not be determined, it was assumed to be lasting until today. The only exception were relationships which focused on technology or components that were substituted at a known point in time, which in this case was used as the ending date of the relationship. Additionally, joint development projects were considered as finished when the jointly developed product, service or technology entered series production.

Timeframes were only defined at the basis of whole years without considering the exact date or month of the start or end of an interorganizational relationship.

c. Strategic:

Describes the strategic dimension of an interorganizational relationship for the OEM. This was assessed using two criteria:

i. High commitment to the relationship. This could either be expressed through considerable investments in the other company or the explicit mentioning of an IOR’s strategic dimension in an interview with high-ranking company representatives, business reports or press releases.

ii. Common alignment of both partner’s corporate strategies. This might either refer to the overall strategy of a company or to the strategy of specific departments or regarding specific product or service groups.

If one of the above mentioned criteria was met, an interorganizational relationship was regarded as strategic. Although long-term supply relationships can also be considered to be strategic sometimes, this does not apply to the classification in the scope of this thesis. The strategic dimension is only used to distinguish strategic alliances from partnerships as defined in Table 8 in section 5.3.

d. Legal autonomy:

Describes the ownership structure of companies involved in an interorganizational relationship.

i. Complete: Complete legal autonomy of involved parties.

ii. Investment: OEM holds shares of the other company or both companies hold shares of each other.

iii. Joint Venture: both companies hold equal or almost equal shares of a commonly founded company.

iv. Integration: majority ownership by OEM and/or integration into OEM.

3) Ecosystem sphere:

Describes the ecosystem sphere an OEM's interorganizational relationship partner can be accounted to referring to Moore's (1996, p. 27) depiction of an exemplary business ecosystem.

a. Core contributions: other company is either direct supplier to OEM or performs distributing activities.

b. Extended enterprise: other company is standard body, indirect supplier, direct customer, indirect customer or supplier of complementary products/services.

c. Business ecosystem: other company is government agency, stakeholder or competing organization.

d. Other business ecosystem: other company is not considered a player within the business ecosystem for BEVs.

4) Position in the value-added chain

Following the argumentation in section 5.2, an interorganizational relationship can be assessed regarding the relative position of steps performed by the involved parties along the value-added chain.

a. Vertical: Partner's activities are located before or after OEM's contribution to value creation in the same value-added chain.

b. Horizontal: Partner's activities are located at the same value-added step as OEM's activities in the same or a different value-added chain. If the allocation of tasks was not further specified in the collected data, a relationship was considered horizontal if both partners intended to jointly carry out activities. Otherwise, their relative position in the supply chain was used, without regarding the exact focus of the relationship.

c. Lateral: Partner's activities are located at another value-added step as OEM's activities, and in different value-added chain.

All identified interorganizational relationships were subsequently assigned to one of the interorganizational relationship types for technology sourcing that were elaborated in section 5.3 using the outcome of the assessment based on the above mentioned scales.

9.2.4 Coding Schemes for Timelines

A number of coding schemes was used in the timeline representations in order to distinguish different categories.

Although vehicle projects and OEM's activities towards BEVs covered in the case study narratives reach back far longer, the timeframe for the narratives and timelines covering IORs was chosen to be the years from 2007 to 2020. This decision was taken based on the fact that most OEMs included BEVs in their official long-term drivetrain strategy at roughly this time (see Table 17). The timelines for BEV projects start with the first BEVs featuring ZEBRA battery cell technology to illustrate this fact. All earlier BEVs were equipped with battery systems based on lead acid cells, and therefore were not seen as a viable solution for individual mobility.

9.2.4.1 Coding Schemes for Vehicle Projects

1) Maturity level: Different colors were used to highlight the maturity of each vehicle project.
    a. Concept study: Red.
    b. Prototype: Blue.
    c. Short run: Green.
    d. Series production: Grey.
2) Vehicle type: Different framing styles were used to highlight the vehicle type of each project.
    a. Conversion design: Dashed line.
    b. Purpose design: Full line.

Additionally, proposals and actual legislation changes regarding emission limits were included in the timeline representation in order to show the chronological sequence of events.

9.2.4.2 Coding Schemes for Interorganizational Relationships

1) Business ecosystem sphere: Different colors were used to highlight the ecosystem sphere other companies belong to.
    a. Core business: Red.
    b. Extended enterprise: Blue.
    c. Business ecosystem: Green.
    d. Other business ecosystem: Grey.
    e. Internal activities: White.
2) Placement in the value-added chain: Different shapes were used to highlight the relative position of value-added steps performed by parties involved in an interorganizational relationship. The different shapes can be taken from Table 16.

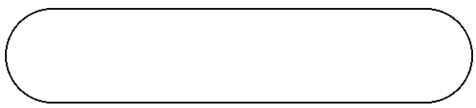
Placement in the value-added chain	**Symbol**
Vertical: Partner's activities are placed before OEM's in the value-added chain	
Vertical: Partner's activities are placed after OEM's in the value-added chain	
Horizontal	
Lateral	

Table 16: Coding scheme for placement in the value-added chain

This coding scheme of course is not applicable to OEMs' internal activities.

9.3 Case Study 1: BMW

9.3.1 BMW AG

Bayerische Motorenwerke AG (BMW) is a globally operating German automotive OEM with headquarters in Munich. The company was founded in 1916 and today is one of the leading producers of cars and motorcycles in Europe as well as one of the biggest German industrial enterprises with more than 130.000 employees in 2018. BMW's products are marketed under the three brands BMW, MINI and Rolls-Royce, which all belong to the premium segment. Besides development, production and distribution of motor vehicles, BMW also has a strong financing branch that covers financial and leasing services, fleet management and insurance services for BMW's own and other brands.

The products offered under the BMW brand are targeted at a wide group of customers reaching from small cars for environmentally conscious drivers to high-performance cars marketed under the BMW M sub-brand. MINI is used for marketing premium compact cars, whilst Rolls-Royce manufactures a small quantity of expensive luxury cars for a small circle of wealthy customers. BMW i was introduced as a sub-brand to market electric cars from 2011.

9.3.2 History of BMW's Activities Towards Alternative Drivetrains

Despite the existing basic knowledge in electric drivetrain technology through continuing research and development from the late 1960s, BMW never regarded the technology a viable solution to individual mobility. Until 2004, the official medium and long-term outlook considered hydrogen combustion engines the only future alternative drivetrain technology, with hydrogen fuel cells added to replace generators. In 2005, things changed a bit, as hybrid drivetrains were introduced as an additional strategy for high-power cars. As a short-term solution, BMW bundled a couple of measures like optimized diesel and petrol engines, active aerodynamics, intelligent energy management and lightweight materials to its "EfficientDynamics" concept, that should ensure a gradual reduction of fleet CO_2 emissions to meet the voluntary goal of 140 g/km in 2008 which had been introduced in an agreement between the European Automobile Manufacturers Association (EAMA) and the European Commission in 1998. In 2006, BMW's development portfolio was officially complemented by drivetrain electrification up to hybrid cars for the medium-term future. The resulting modular architecture for hybrid drives that was under development from 2005 first launched to markets in two vehicles in 2009. Norbert Reithofer was appointed CEO in 2006 and presented his vision of BMW's future in the strategy package "Number ONE" in 2007, which meant the shift of perspective from a producer of products to the provider of services. The proposed strategic goal was to become the globally leading provider of premium products and premium services for individual mobility in 2020 based on the four pillars growth, profitability, access to technologies and customers and the aim of shaping the future. This package included increased investment in technology and new drive concepts, and mentioned the explicit intend to engage in cooperation with other companies for the first time. Additionally, a diversification of offerings along the value-added chain and automotive lifecycle was intended to achieve organic growth beyond the core business.

Although series development of hydrogen technology had already started in 2001 and a small fleet of vehicles was produced in 2007, problems with the high-pressure hydrogen storage system and the emergence of the European Commission's intend to introduce legally binding CO_2 emission goals for 2012 led to increased interest in alternative drivetrain concepts again. For this reason, an internal venture called "project i" was set up in 2007 in order to elaborate solutions to the problem of individual mobility in highly populated areas. As a first step to examine usage patterns of electric cars, 612 compact cars were equipped with an electric drive system and leased to customers in the USA and Europe. Results of these field trials showed, that the project's goal, the future Megacity Vehicle, would have to feature an electric engine. As a consequence, BMW's official long-term R&D strategy of hydrogen combustion engines was complemented by purely electric mobility for the first time in 2009, and the series production of the electrically propelled Megacity Vehicle was announced to start before 2015. The newly developed purpose-design vehicle should not just feature a completely new drivetrain, but also a lightweight aluminium chassis and a passenger compartment made from carbon-fibre reinforced plastics and its manufacturing should be more sustainable than ever. In 2011, a second field trial was started in order to test the actual Megacity Vehicle's drivetrain technology in an early stage. A new sub-brand called BMW i was introduced in 2011 to market new electric and electrified cars; a whole family of cars was planned to be launched. In the following years, R&D expenditures were increased considerably in an attempt to reach further advancements in the new technology. As a consequence, the importance of strategic partnerships in the face of the diversity of future drivetrain concepts was stressed in order to get access to technology and customers, bundle competences and reach economies of scale. In 2012, hydrogen combustion technology was abandoned as the official long-term technological development goal, although research in fuel cells - which had already started in 2000 - continued in a partnership with Toyota and was announced as the new long-term development goal in 2014. The proposed short and medium term solution were electrified drivetrains and hybrid cars. Additionally, BMW acknowledged the persistent significance of internal combustion engines as the primary drive technology in the near future by expanding its EfficientDrive program to all produced vehicles with internal combustion engine. When the BMW i3 was launched to markets in 2013, it was accompanied by a whole new distribution concept that also included direct distribution to selected dealers, flagship stores and sales over telephone and an online portal. In 2014, the product portfolio was supplemented by BMW's first plug-in hybrid vehicle, that included technology developed in the course of project i. Additionally, BMW engaged in the build-up of charging infrastructure and additional services in order to foster growth in the newly created business ecosystem for BEVs.

With the new CEO Harald Krüger, in 2016 the strategy package for the next years until 2025 was presented under the name Number ONE > NEXT. It still focuses on individual mobility in the premium segment and individual services. However, BMW's understanding of its own role shifts from a provider of premium individual mobility solutions to a technology company for premium mobility and services. The strategy consists of development in the four core areas of design, autonomous driving, connected mobility, electric drivetrains and mobility services (D-ACES). A high number of plug-in hybrid electric and purely electric vehicles were announced and all electric and electrified vehicles were bundled under the eDrive name and will be marketed under the BMW i sub-brand in the future. The official goal is a share of 15 to 25% of sold vehicles in 2025 to be electrified. In the face of technological change, BMW again stresses the importance of partnerships in research and development. Consequently, BMW again increased its R&D investment rate from 2017 to almost match the level that was reached during development of the BMW i3. Efficient internal combustion engines, plug-in hybrid vehicles, electric cars and fuel-cell electric vehicles are all considered viable solutions for different use cases of individual mobility, which is why all solutions are intended to be present in BMW's future product portfolio. Besides, BMW does not expect a fast shift but rather a long period of transition. For this reason, flexible architectures and platforms constitute the basis of future developments that allow fitting of all different drivetrain technologies in all offered vehicles. Today, five plants produce components for electric drivetrains. Electric drivetrain technology is developed in Munich and built in Dingolfing and Landshut. Battery modules are built in Dingolfing, Spartanburg (USA) and Shenyang/Tiexi (China) with the joint venture BMW-Brilliance that was set up in 2003. Electric vehicles currently are built in Leipzig and will be built in Oxford (UK) from 2019, in Shenyang (China) from 2020 and in Munich from 2021. In the future, all European plants will be equipped to allow flexible manufacturing of a variety of different drivetrain technologies in accordance with the overall development strategy. The next fifth generation of the eDrive drivetrain technology will be launched in 2020 and is announced to be completely free from rare earths.

Today, BMW's market share is three times higher in electrified vehicles than for normal cars. As a result, more than 80% of buyers of BMW i3s are first-time customers of BMW's products. BMW i3 production was extended from an initial number of 100 pieces a day to over 200 units in 2018.

As a consequence of its endeavours to improve engine efficiency and develop alternative drivetrain technologies, BMW was able to reduce the fleet CO_2 emissions of its offered vehicles in Europe below the legal limit of around 130 g/km in 2015. However, in spite of growing sales figures of its fully electric and plug-in electric vehicles, which reached 140000 units in 2018, BMW was not able to further reduce the average

CO_2 fleet emissions from 2017 to 2018, which stayed constant at 128 g/km (WLTP). In order to reach the legal goal of around 95 g/km to be phased in from 2020, additional measures will be necessary. BMW plans to meet the new CO_2 emission goals from 2021.

9.3.3 BMW's BEV Projects

First prototypes of electric cars were already built and tested by BMW's engineers before the first oil crisis raised the consciousness for the limitedness of oil supplies. At the 1972 summer Olympic Games in Munich, two electrically propelled BMW 1602 were used as support vehicles at the running events. The cars had already been under development from 1969 and featured an electric DC engine in shunt-connection specifically designed by Bosch and conventional 12 volt lead-acid batteries supplied by Varta. Research and development on electric vehicle technology was continued from 1975 with a BMW LS that served as a test carrier for a newly developed Bosch DC engine in series connection layout and advanced lead-acid battery technology from Varta. After ABB had invented the sodium-sulfur battery technology in 1981, BMW started the research project "Elektroauto mit Hochvoltbatterie" that in 1987 culminated in eight BMW 325iX that were equipped with a shunt-connected DC engine from ABB. For the first time, these vehicles were deployed in field testing by the German postal service and as staff car for local government authorities. In 1991 and 1993, BMW presented its first purpose-built electric vehicles with the E1 concept cars, this time using a sodium-metal chloride or ZEBRA battery and a permanently excited synchronous AC engine. These concept cars were especially aimed at the US market, since first zero-emission vehicle legislation was introduced in California in 1990, but never brought to markets. From 1992, BMW built 25 test carriers for new electric components based on the BMW 3 series (E30) in order to further develop electric drivetrain technology. Some of these cars were involved in a huge research project that promoted electric mobility on the German island of Rügen in the 1990s. Those cars were first equipped with sodium-sulfur batteries which were later changed to the sodium-metal chloride type due to handling difficulties. One example was even used for first tests with the then-new nickel-cadmium battery technology. A variety of different permanently-excited synchronous engine types were deployed in these cars, with a maximum power of 45 kW. Testing continued with ten prototypes of the next generation BMW 3 series (E36) from 1995 through 1997. Despite the high number of early initiatives towards development of electric drivetrain technology, the following chapters will only cover BEVs built after 2007.

After BMW had taken up development of its Megacity Vehicle, which was later presented as the BMW i3, field tests were started with 612 adapted MINI E in 2008. The cars were equipped with li-ion battery technology and an asynchronous AC motor with 150 kW and were only leased to selected customers. From 2011 to 2012, a series of 1100 modified BMW 1 series cars was built for a second field testing project that already featured a prototype of the electric drivetrain technology developed for the BMW i3 and was called BMW ActiveE. Again, these cars could only be leased by selected customers; some of them were later deployed in the DriveNow car sharing service. The car had already been presented as BMW Concept ActiveE in 2009.

In 2011, BMW showed a first concept study of the later BMW i3's design. The car itself was launched to markets in 2013 and was the first purpose design electric vehicle sold by the company, featuring an aluminium chassis and a passenger compartment made from carbon-fibre reinforced plastics. The first generation had a 60 Ah battery and a hybrid synchronous electric engine with 125 kW and could also be ordered with an additional internal combustion engine to extend its range. In 2016, the second generation of the BMW i3 was introduced with a larger battery of 120 Ah, but still the same engine. As a consequence of BMW's D-ACES strategy introduced in 2016, a number of new electric vehicles was presented in the following years. This included the BMW i Vision Dynamics, which will be built as BMW i4 in Munich from 2021 and the third generation of the BMW i3, which is equipped with a battery of 120 Ah. Additionally, a sportier version called BMW i3s was introduced with a slightly stronger engine of 135 kW. Like the previous generations, the model is manufactured in BMW's Leipzig plant. In 2018, a MINI Electric Concept was presented that will be built with the BMW i3s' engine as the MINI Cooper SE from the end of 2019 in BMW's Oxford (UK) factory. The BMW iX3 will be the first vehicle to be produced exclusively in BMW-Brilliance's Shenyang plant in China from 2020 and exported to all other countries. From 2021, BMW's new flagship model called iNEXT will be manufactured in Dingolfing. This is planned to be the first vehicle to feature BMW's highly automated driving technology currently under development in Munich. Until 2025, seven other electric models are scheduled for production but have not yet been presented to the public. In this year, BMW plans to offer a variety of 25 different electrified models, which will all be manufactured using 100 % renewable energy.

Additionally, several prototypes and concept cars have been presented by BMW and its sub-brands in the past, but did not have any economic relevance. Those can be taken from Figure 30 together with all other BEV projects.

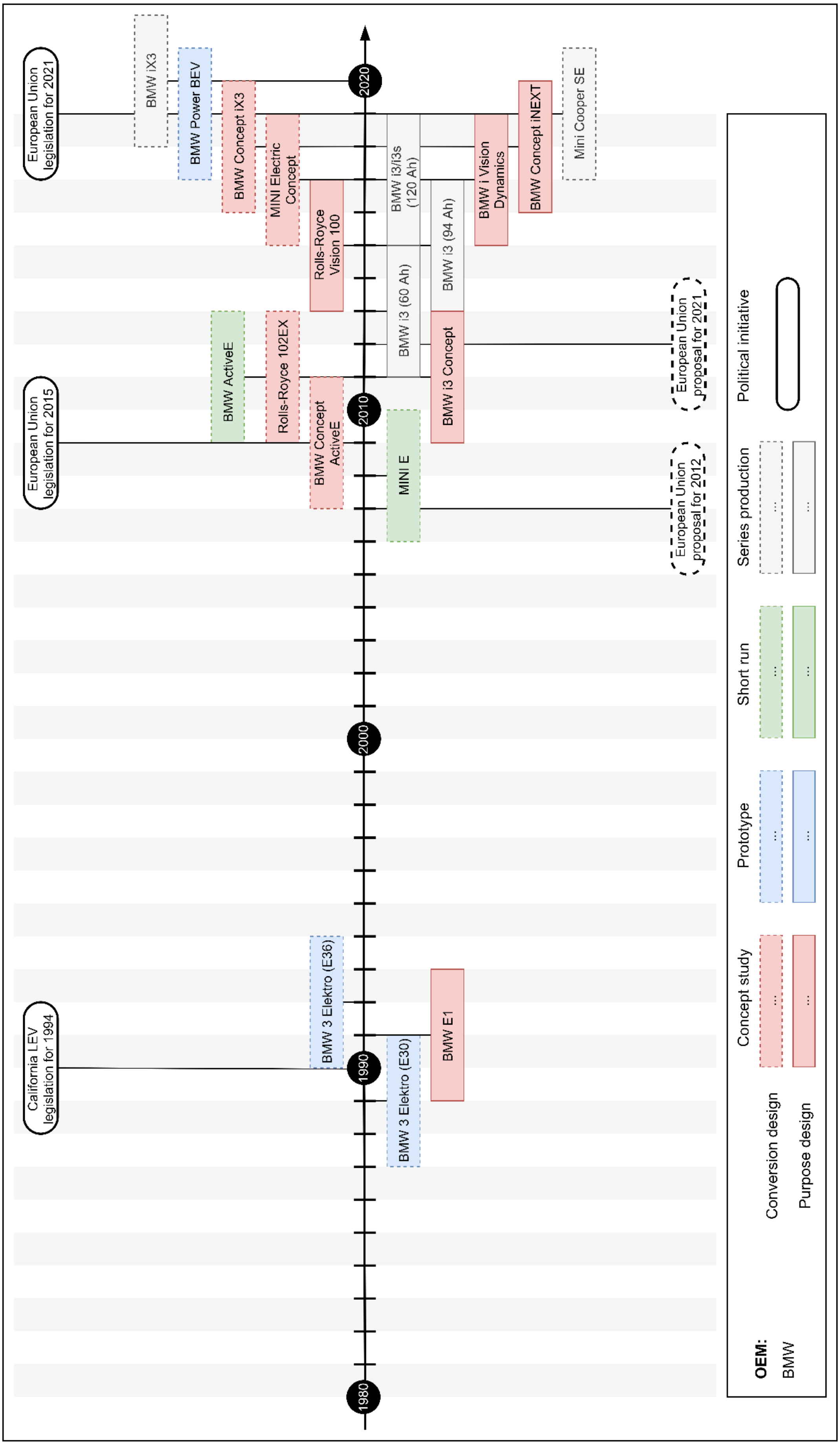


Figure 30: Timeline of BMW's BEV projects (own creation)

9.3.4 BMW's IORs in Complete Vehicles

Most of BMW's electric models were developed in-house and assembled at BMW's and MINI's plants in Leipzig, Oxford (UK) and in the future also in Munich. However, BMW also develops and manufactures whole vehicles together with other companies.

In 2003, BMW set up its first Chinese joint venture BMW-Brilliance with Brilliance that was extended until 2040 in 2018. In 2020, the BMW iX3 is scheduled for production in BMW-Brilliance's Tiexi/Shenyang plant. For the first time, the company will be the exclusive producer of a car that is sold globally. For this reason, BMW announced its interest to increase its stake in the joint venture from 50 to 75% following a relaxation of government regulations for foreign companies in China. However, this deal will not be performed before 2022. A timeline of BMW's interorganizational relationships for research, development and manufacturing of complete vehicles can be found in Figure 31.

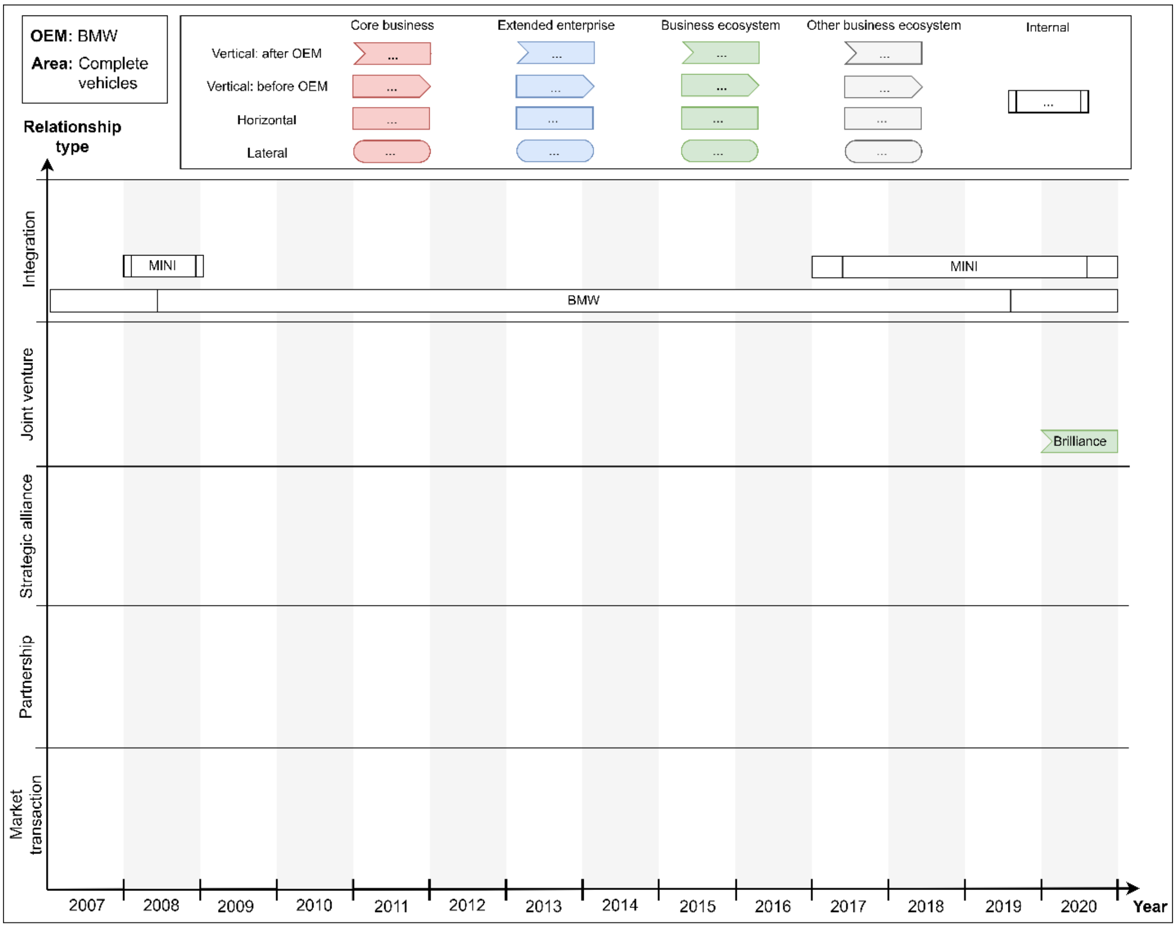


Figure 31: Timeline of BMW's IORs in complete vehicles (own creation)

9.3.5 BMW's IORs in Raw Materials

After first experiences with carbon-fibre reinforced plastics for the roof panels of BMW M sports cars, BMW decided to make extensive use of the material in the passenger compartment of the BMW i3 for the first time in a series-produced compact car. For this reason, a joint venture with the German carbon fibre specialist SGL Group was set up in 2009 that consisted of a plant in Moses Lake (USA) and a second manufacturing facility in Wackersdorf. The raw material is supplied by a joint venture between SGL Group and Mitsubishi Rayon in Japan, processed to carbon fibres in the world's largest fibre production site in Moses Lake, and sent to Wackersdorf, where textile carbon fibre layers are produced. Subsequently, body parts are manufactured in BMW's plants in Leipzig and Landshut. The joint venture was further intensified by BMW's acquisition of 15 percent of SGL Group's stakes and further high investments into the expansion of facilities. Although carbon components were later implemented in other models as well, BMW in 2017 decided to limit the use of expensive carbon fibre materials in an attempt to keep profit margins high and consequently sold its 49% share of the joint venture to SGL Group. Nevertheless, SGL Group still supplies the needed components for BMW models.

In 2012, BMW signed an agreement with aeroplane OEM Boeing for a partnership including carbon fibre recycling and manufacturing automation. The agreement reached with Toyota in 2012 also initially was aimed at research and development in lightweight materials. It is unclear, whether this aim was fulfilled or not. Additionally, BMW has been engaged in a partnership since 2018 with Umicore and Northvolt to develop a closed lifecycle loop of raw materials for EV battery cells. The alliance includes the supply of battery anode and cathode materials from Umicore.

BMW has always followed the strategy to source critical raw materials for electric engine and battery cell production themselves and hand it over to its suppliers if needed. For this reason, long-term supply contracts were signed. Ganfeng Lithium in 2018 was appointed as BMW's supplier of lithium for the next five years. BMW plans to source cobalt directly from Australia and Morocco in the future, with contracts with Glencore already signed in 2019 for the post-2020 period.

A timeline of BMW's interorganizational relationships for sourcing of raw materials can be found in Figure 32.

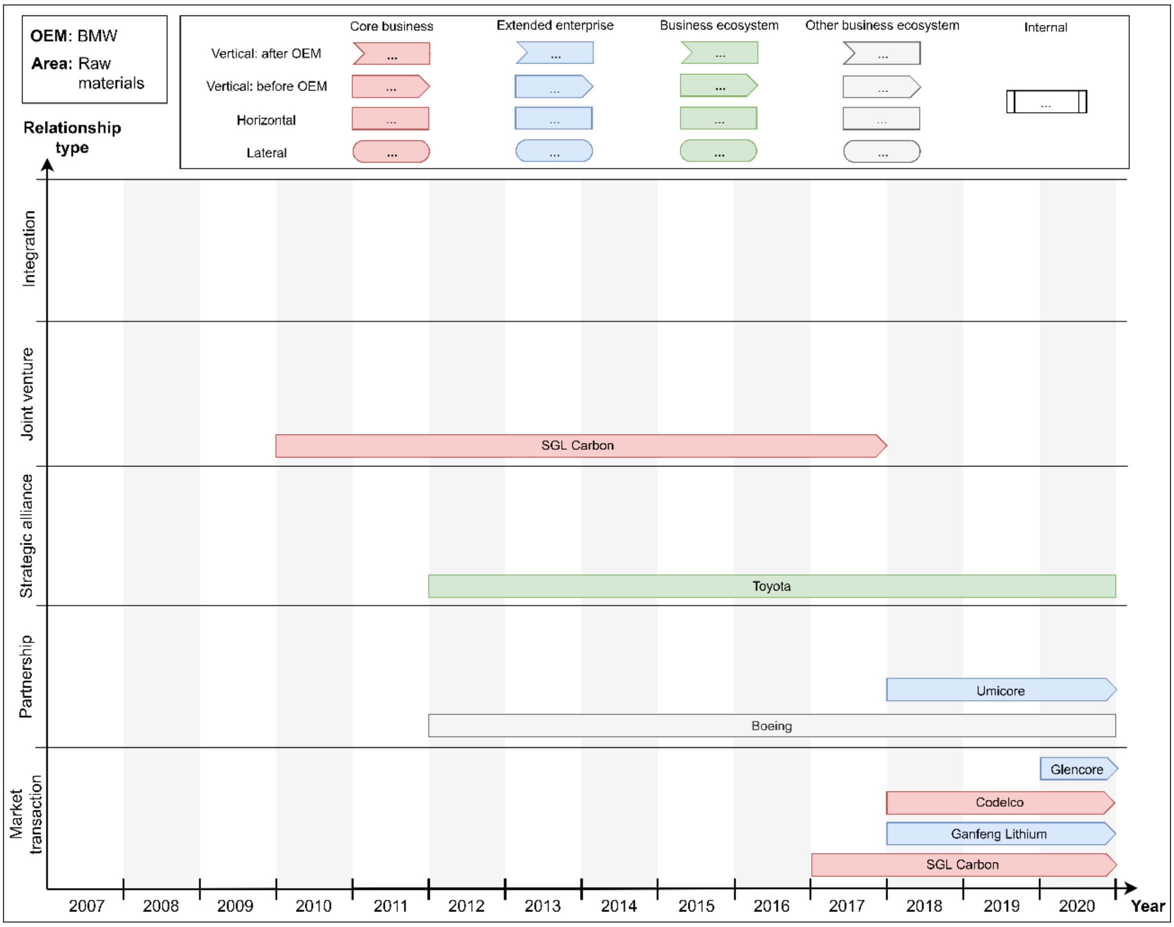


Figure 32: Timeline of BMW's IORs in raw materials (own creation)

9.3.6 BMW's IORs in Battery Cell Technology

The MINI E presented in 2008 for field testing purposes did not feature a drivetrain developed by BMW, therefore also the lithium-ion battery technology was supplied by a US company called AC Propulsion; the exact supplier of battery cells was E-One Moli Energy from Taiwan. Lithium-ion (NMC) batteries for the Megacity Vehicle project, later to be published as the BMW i3, came from SB LiMotive, which was a joint venture between Samsung SDI and Bosch. However, as Samsung SDI's contribution to this enterprise was cell technology and Bosch was only responsible for system development, it can be concluded, that the actual battery cell manufacturing plant stayed more or less the same after termination of the joint venture was announced in 2012. An early version of the Megacity Vehicle's drivetrain was implemented in the BMW ActiveE, which means that the battery technology in this car also was supplied by SB LiMotive. When SB LiMotive ceased operations in 2012, Samsung SDI took over its battery cell business and has since then been the supplier of battery cells for BMW's i3 and i3s.

In 2012, BMW announced to take up research and development in lithium-ion technology in a strategic alliance with Toyota. The actual binding agreement that was signed in 2013 however, concentrated on lithium-air cell technology instead.

In 2017, BMW partnered with Solid Power in an attempt to develop solid state battery cells. Additionally, BMW has been cooperating with Sila nanotech on silicon anode material for the automotive market since 2018. In 2018, BMW announced to be engaged in a partnership with Umicore and Swedish battery cell company Northvolt, in which Northvolt is responsible for research and development in battery technology, which will be supplied to BMW in the future.

BMW has never seen an own battery cell production as a competitive advantage, which is why BMW will not take up battery production in the future. However, in 2018, the company announced to open its own battery cell competence centre in Munich in 2019. There, BMW will do research and development in lithium-ion cell technology and also build its own built-to-print prototypes. The final products will then be built and supplied according to BMW's exact specifications by Northvolt and the Chinese battery cell specialist CATL. For this reason, BMW in 2019 signed a long-term supply agreement with CATL worth €4 billion. Additionally, CATL will build a cell production plant in Erfurt as part of the deal. Consequently, CATL will supply lithium-ion (NMC) battery cells for the future MINI Cooper SE, BMW iX3 and BMW iNEXT. The battery cell supplier for the BMW i4 is still unclear, but will be an external company.

A timeline of BMW's interorganizational relationships in battery cell technology can be found in Figure 33.

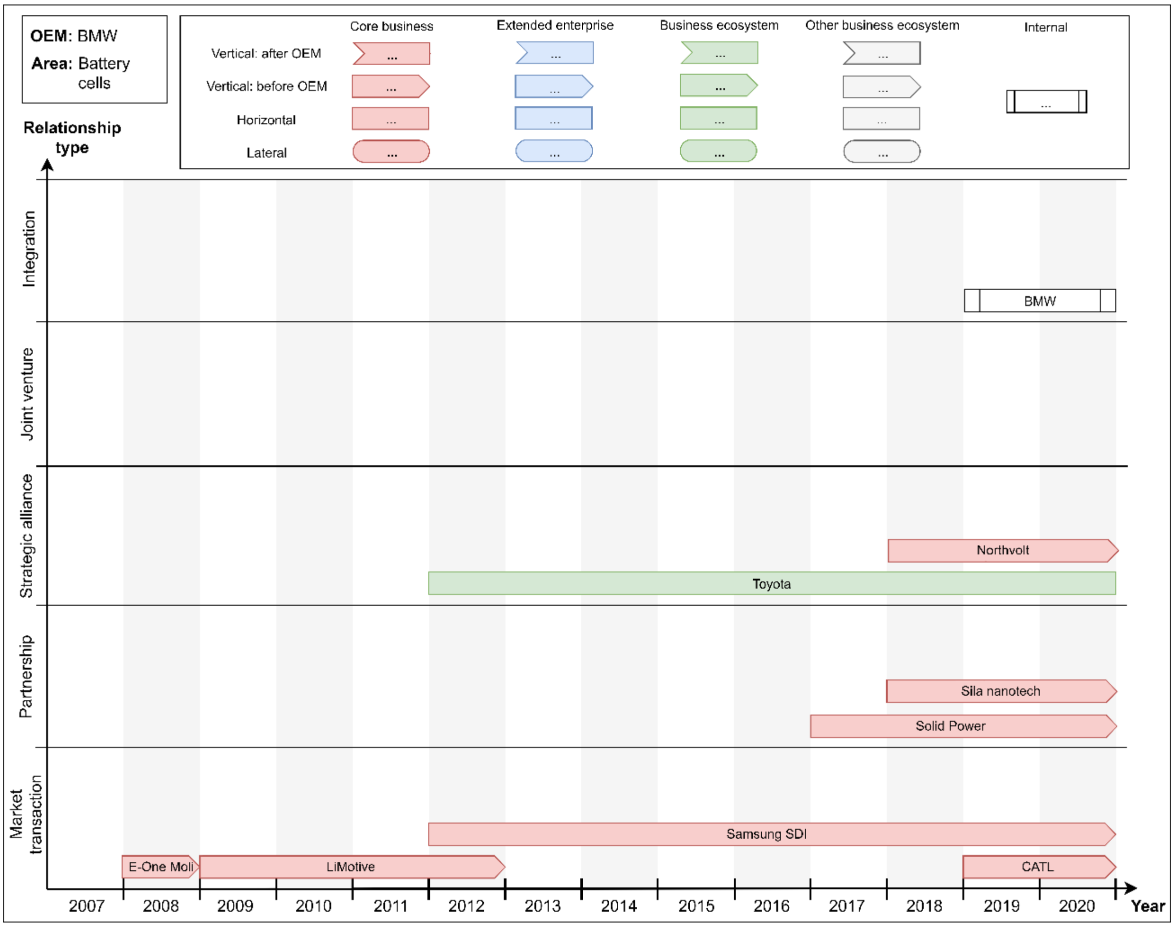


Figure 33: Timeline of BMW's IORs in battery cell technology (own creation)

9.3.7 BMW's IORs in Battery System Technology

Battery systems were included in the scope of a joint venture with PSA that started in 2011 but ended shortly after in 2013.

The MINI E presented in 2008 for field testing purposes did not feature a drivetrain developed by BMW, therefore also battery technology was supplied by a US company called AC Propulsion. The battery system for the BMW ActiveE Concept car was developed together with SB LiMotive in 2009. However, battery systems have always been considered by BMW as a source of competitive advantage, which is why the BMW ActiveE's and BMW i3's battery system was developed in-house from 2009 and has been built from supplied cells in BMW's own battery system production line in Dingolfing since 2013. From then, all battery systems in BMW's battery electric and plug-in electric vehicles have been developed in Munich.

Additional battery system manufacturing facilities are located in Spartanburg (USA) since 2015 and Shenyang (China) since 2018 which is operated by the BMW-Brilliance joint venture. However, Spartanburg has only been building batteries for PHEVs so far.

In 2018 it was announced, that the Chinese joint venture with Brilliance will manufacture the fifth generation eDrive system to be featured in the BMW iX3 from 2020, which will be exclusively built in China for all markets. For this reason, the battery plant that was opened in 2017 will be extended for accommodating the production facilities for the new model's batteries.

A timeline of BMW's interorganizational relationships in battery system technology can be found in Figure 34.

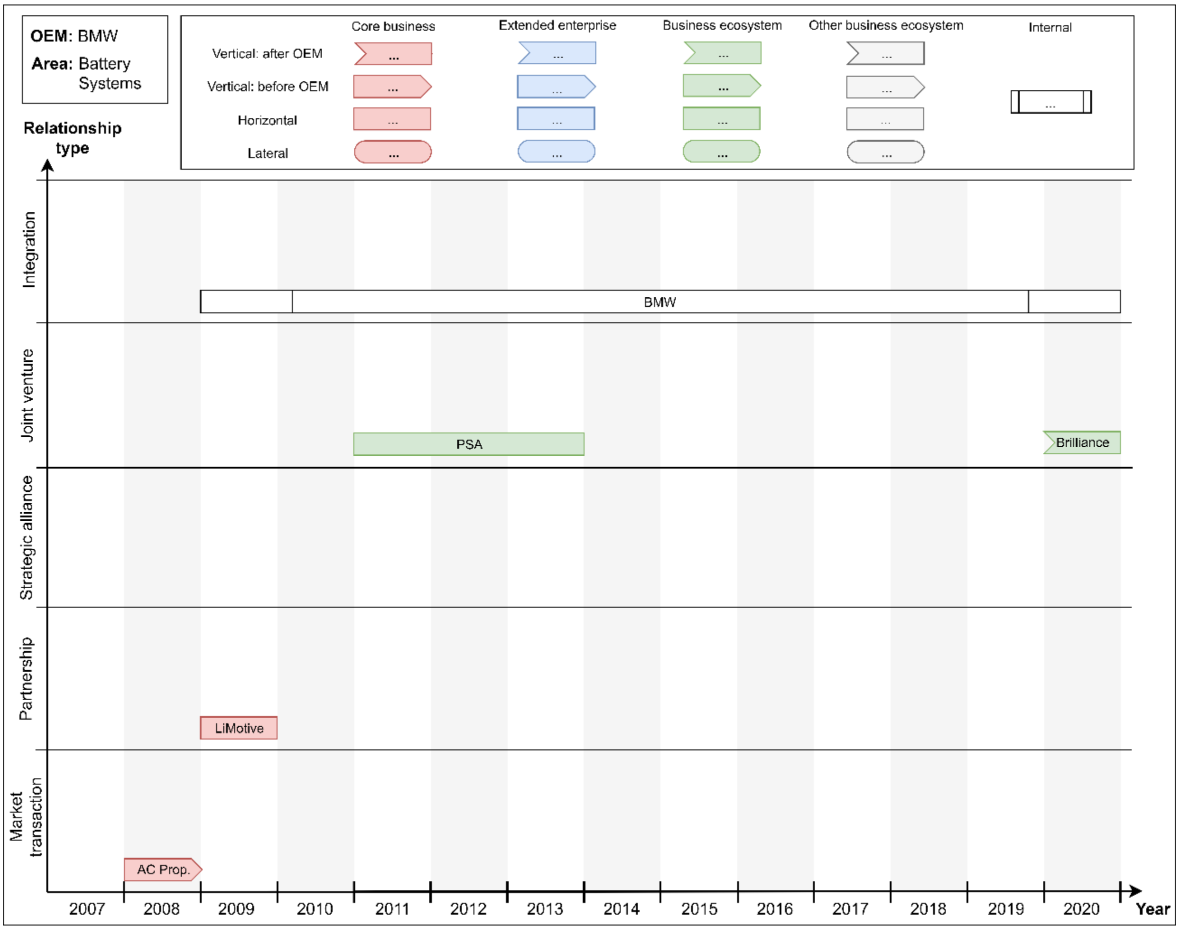


Figure 34: Timeline of BMW's IORs in battery system technology (own creation)

9.3.8 BMW's IORs in Electric Drivetrain Technology

The small series of MINI E featured an electric drivetrain that was specially developed for this purpose by US company AC Propulsion based on its tzero technology, which was also licenced for the early Tesla Roadster.

Like in cars propelled by an internal combustion engine, BMW has always considered the engine as the core of a vehicle and thus highly relevant for product differentiation. For this reason, since the BMW ActiveE was launched in 2011, all electric vehicles marketed by the company have featured an electric motor that was developed in-house in Munich and built in the company's own facilities in Landshut.

From 2011, BMW was engaged in a joint venture with PSA called "BMW Peugeot Citroën Electrification" that was aimed at development of hybrid drivetrain components like electric machines, battery packs, generators, power electronics, chargers and software. Research and development was located in Munich, whilst production was intended to start in Mulhouse from 2014. The employees were recruited from both companies, only 100 external engineers were intended to be involved. Also external companies should be included in development tasks and allowed as customers. However, after PSA had developed closer ties with GM in 2012, which preferred range extenders over plug-in hybrid vehicles, the joint venture was ended in 2013 and BMW took over its research and development department.

In 2018 it was announced, that the Chinese joint venture with Brilliance will manufacture the fifth generation eDrive system to be featured in the BMW iX3 from 2020, which will be exclusively built in China for all markets. In 2019, BMW announced a strategic alliance with Jaguar Land Rover for development and joint purchase of next-generation drivetrain electrification technology. The research and development department will be based in Munich, whilst both partners will be responsible for manufacturing individually.

A timeline of BMW's interorganizational relationships in electric drivetrain technology can be found in Figure 35.

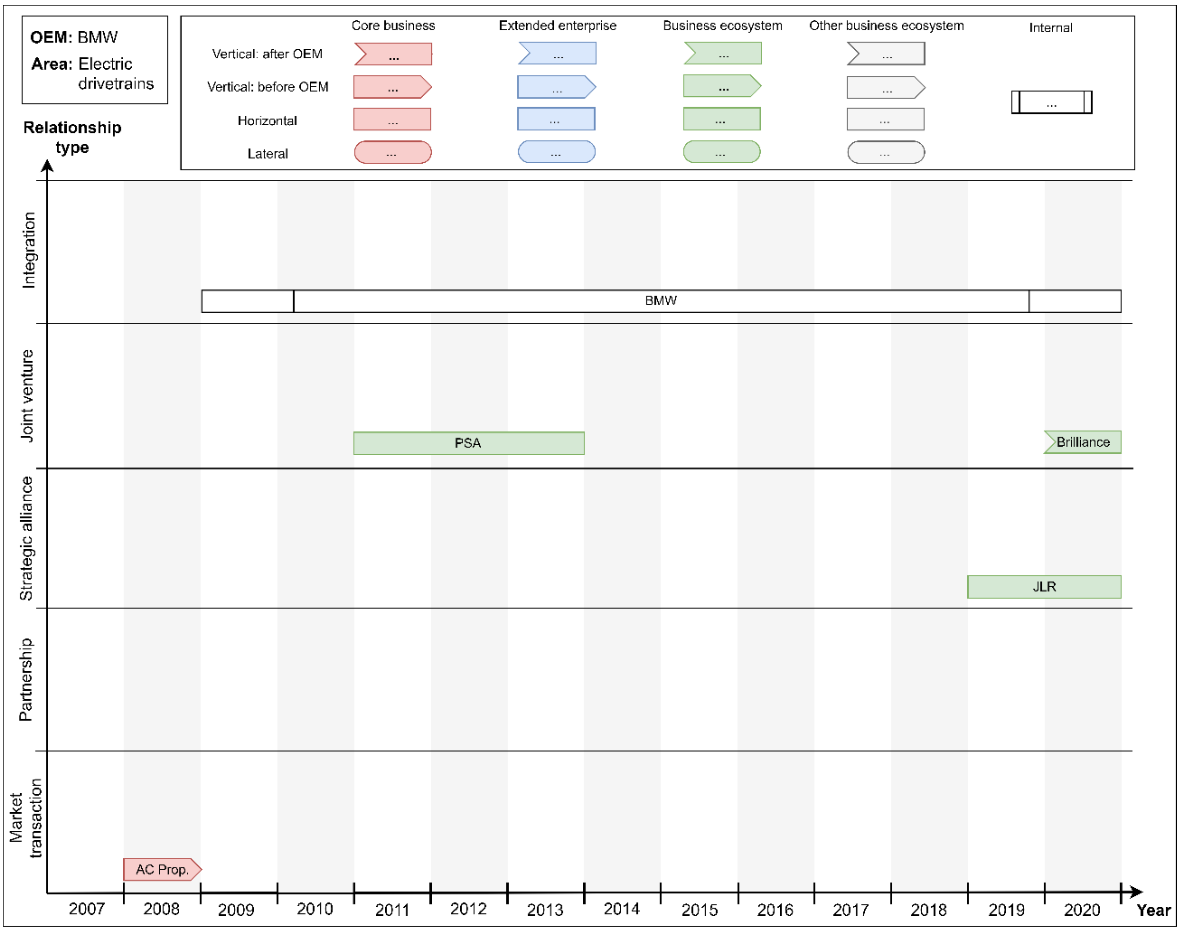


Figure 35: Timeline of BMW's IORs in electric drivetrain technology (own creation)

9.3.9 BMW's IORs in Charging Infrastructure

With the market launch of the BMW i3 in 2013, a bundle of additional services was offered under the BMW 360° ELECTRIC program, which includes charging at home, public charging stations, flexible mobility for long-distance drives and maintenance and repair assistance. As part of this program, the ChargeNow charging platform was introduced in 2014, which unites many individual owners and operators of charging infrastructure. For development and installation of the necessary equipment, BMW had started a strategic alliance with the British charging infrastructure experts from Chargemaster in 2013. Additionally, both companies were engaged in the common installation of fast charging stations. However, BMW's close connection with the company ended in 2018, when British Petrol acquired Chargemaster.

Schneider Electric and The Mobility House have been engaged in a partnership with BMW since 2013 for developing and manufacturing of the BMW i Wallbox that can be ordered as an additional option for faster charging at home.

Already in 2012, BMW had set up a joint venture with Daimler, Bosch, Siemens, EnBW and RWE for development and operation of an eRoaming system for electric charging networks called Hubject. Together with Daimler, Ford and Volkswagen, another joint venture was founded in 2017 to build a whole network of fast charging stations along highways in Europe in order to facilitate long-distance travelling with electric vehicles. In 2019, Hyundai joined this joint venture.

In 2017, BMW launched a new subsidiary called Digital Charging Solutions, which offers access to ChargeNow and other charging solutions to other OEMs, with first customers being Peugeot and Audi. However, Digital Charging Solutions and ChargeNow together with some mobility services offered by BMW were included in a joint venture with Daimler formed in 2019.

A timeline of BMW's interorganizational relationships in charging infrastructure can be taken from Figure 36.

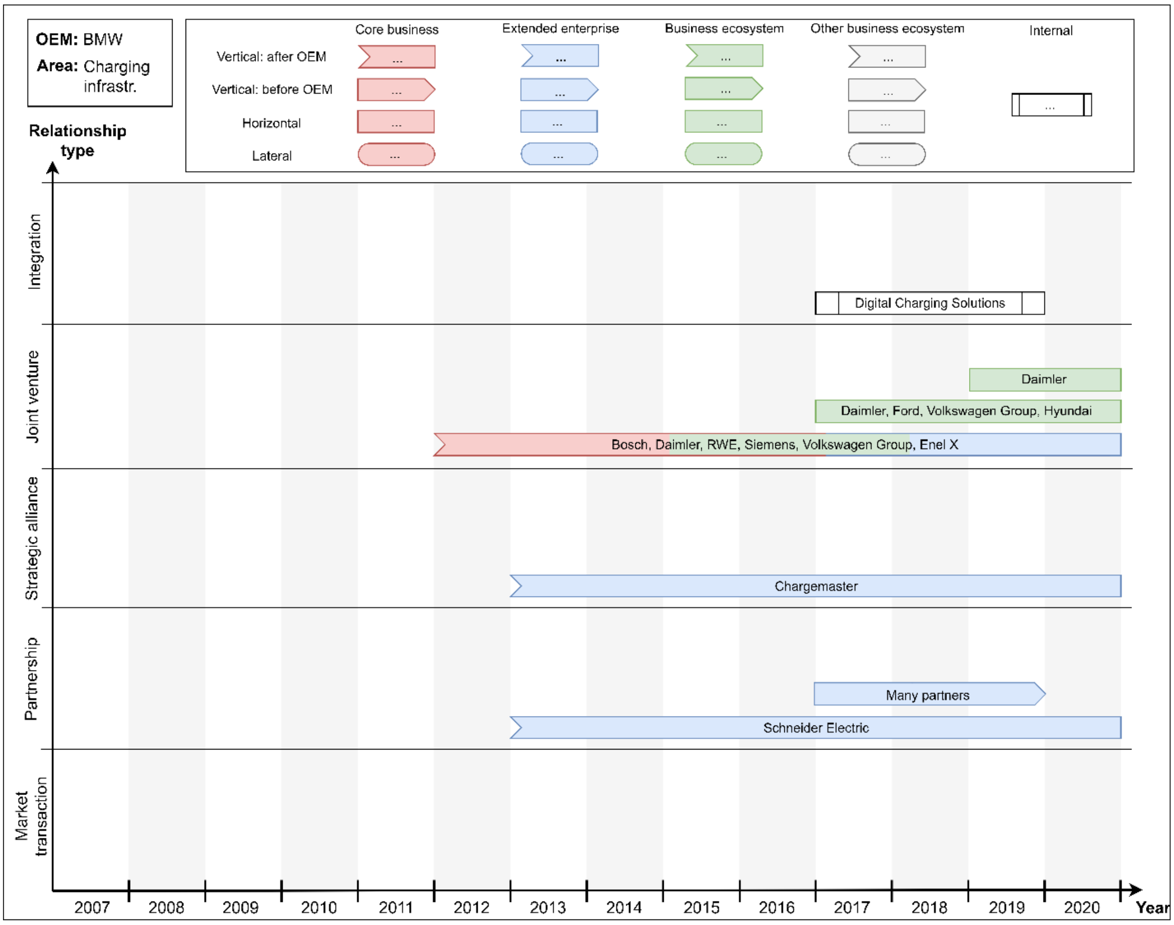


Figure 36: Timeline of BMW's IORs in charging infrastructure (own creation)

9.3.10 BMW's IORs in Mobility Services

Mobility services were first mentioned in BMW's corporate strategy in 2007 with the introduction of the Number ONE strategy package. The first actual service that was introduced accordingly was the DriveNow car-sharing service that started in Germany in 2011 as a joint venture with car rental company SIXT and was later rolled out in additional countries. BMW provided vehicles, whilst an IT platform and car-sharing know-how was contributed by SIXT. Since 2012, the offered fleet has also been consisting of electric vehicles. DriveNow was fully acquired by BMW in 2018.

BMW was involved in a number of partnerships that included the enlargement of its DriveNow fleets in cities such as Munich, Hamburg and Copenhagen. From 2013, BMW's own fleet management company Alphabet offered an own program for electric vehicles to companies called AlphaElectric.

From 2016, BMW has been offering ParkNow, which is operated by its full subsidiary Parkmobile Group Europe in Europe. The operation of all mobility services was taken over by a joint venture set up with Daimler in 2019.

A timeline of BMW's interorganizational relationships in mobility services can be found in Figure 37.

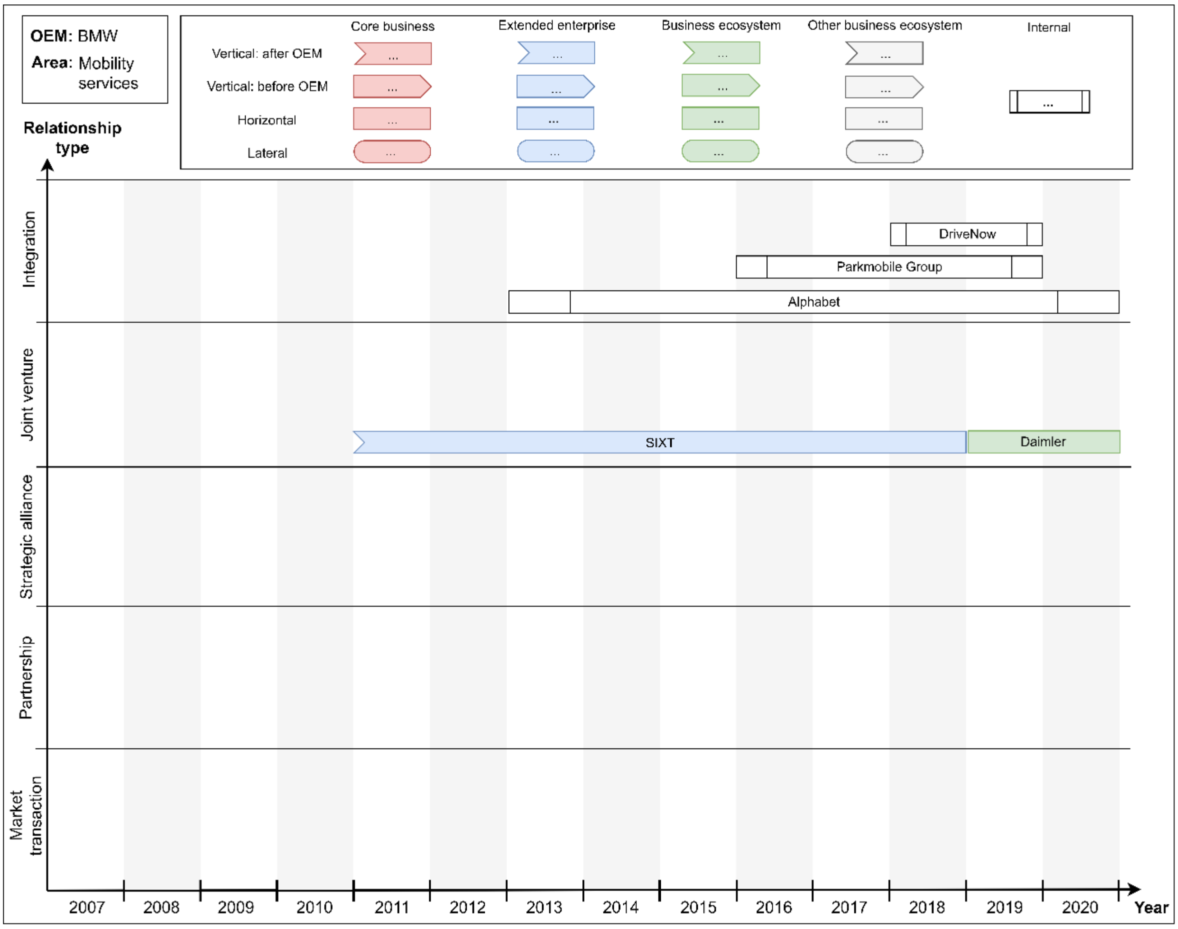


Figure 37: Timeline of BMW's IORs in mobility services (own creation)

9.3.11 BMW's IORs in Battery Reuse and Recycling

BMW's battery systems first employed in the BMW i3 and Active E are constructed in a way that allows replacement of single modules and therefore facilitates second use. For the long time until recycling of materials can be realized in economically feasible ways, BMW considers the extension of battery lifetime as the major goal. For this reason, BMW gives an 8 year or 100.000 kilometres guarantee for its battery systems. Already from 2013 to 2018, used batteries were implemented in stationary energy storage systems in a partnership with Vattenfall and Bosch. Subsequently, Vattenfall ordered 1000 old BMW i3 batteries in 2017 for similar additional projects. Already in 2015, NextEra Energy had placed the largest-ever order for second-life EV batteries when signing contracts to order 20 MWh of old batteries from the BMW ActiveE and early BMW i3 over the next years. NextEra Energy will operate them in various industrial sized stationary electricity storage systems.

In 2016, a joint venture with Viessmann Group was announced called Digital Energy Solutions that offers energy management solutions, which also involves application of used EV batteries as stationary energy storage devices. From 2018, BMW has been engaged in a partnership with Northvolt and Umicore to develop a sustainable value-added chain for industrialized EV battery cells in Europe. This also covers recycling of materials together with Umicore.

A timeline of BMW's interorganizational relationships in battery reuse and recycling can be found in Figure 38.

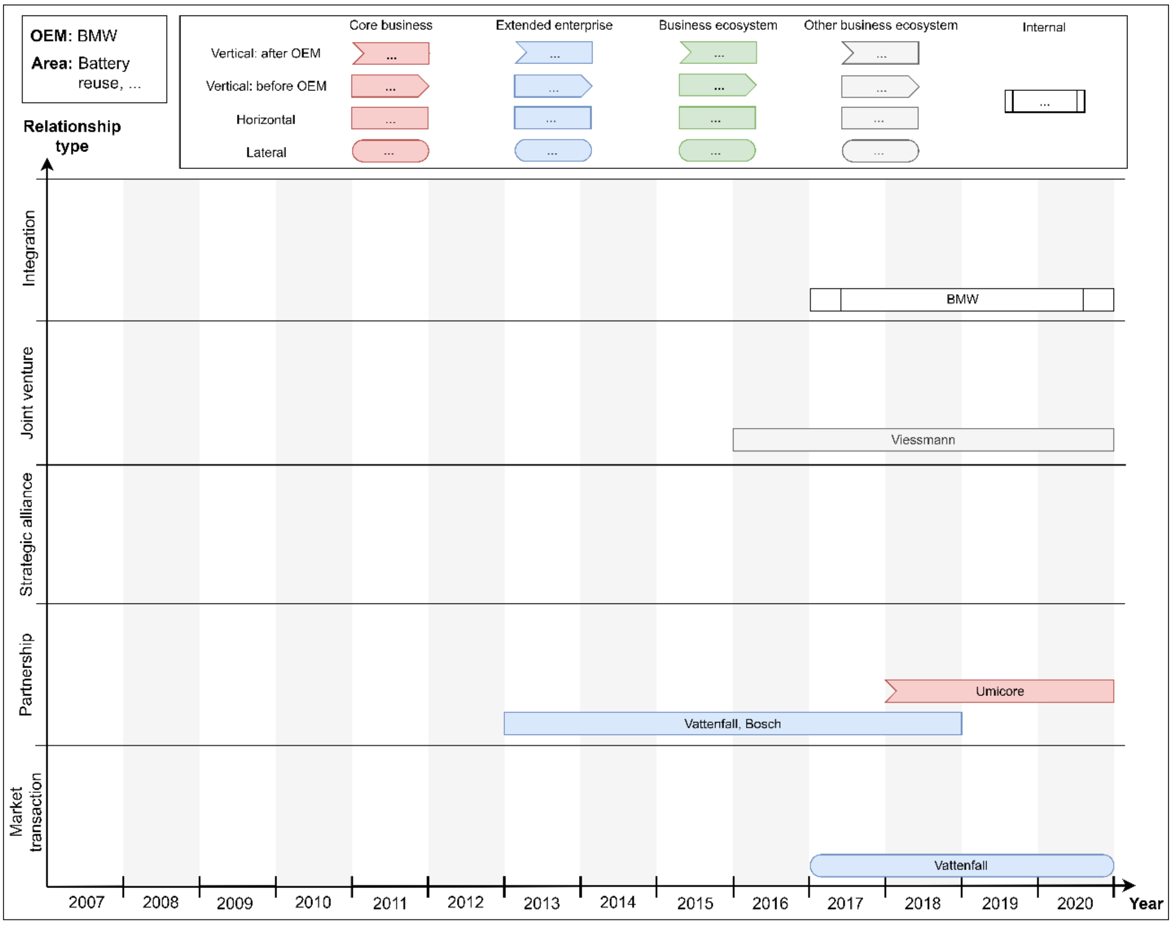


Figure 38: Timeline of BMW's IORs in battery reuse and recycling (own creation)

9.4 Case Study 2: Daimler

9.4.1 Daimler AG

Daimler AG is a globally operating German automotive OEM with headquarters in Stuttgart. The roots of the company reach back to the end of the 19th century, when automotive pioneers Carl Benz and Gottlieb Daimler founded their then-independent enterprises, which were merged to Daimler-Benz AG in 1926 and later renamed to Daimler AG. In the course of its long history, the company was not just involved in the automotive industry, but also operated in several other industries like aerospace, railways, telecommunication, electronics and electric devices. In 1998, Daimler merged with American automotive company Chrysler to form DaimlerChrysler. The close ties were cut in 2007, when Daimler sold the majority of its shares in Chrysler and was renamed to Daimler AG again. Today, Daimler is focusing on its core business as one of the leading producers of cars, buses, trucks and vans in Europe with a total workforce of almost 300.000 in 2018. Daimler AG consists of the five divisions Mercedes-Benz Cars, Daimler Trucks, Mercedes-Benz Vans, Daimler Buses and Daimler Financial Services. An ongoing reorganization process will lead to the formation of three legally independent companies named Mercedes-Benz AG, Daimler Truck AG and Daimler Mobility AG in the next years that will be bundled under the roof of Daimler AG holding. Passenger cars are developed and manufactured by Mercedes-Benz Cars and Mercedes-Benz Vans, which are to be combined to Mercedes-Benz AG. Daimler AG markets its passenger cars under the Mercedes-Benz, AMG, Maybach and Smart brand names, which are all accounted to the premium segment. Besides development, production and distribution of motor vehicles, Daimler also covers other areas along the automotive value-added chain such as financing, leasing, insurance and fleet management services with its Daimler Financial Services division, which was renamed to Daimler Mobility AG in 2019.

The products offered under the Mercedes-Benz brand comprise a variety of premium products from compact cars to high-performance sports vehicles marketed under the AMG sub-brand. Smart is used for marketing very small premium compact cars for use in urban areas, whilst Maybach manufactures luxury vehicles. EQ was introduced as a sub-brand to market electric vehicles in 2016.

9.4.2 History of Daimler's Activities towards Alternative Drivetrains

Daimler historically never regarded BEVs as a viable solution for the individual mobility of the future mass-market. Although commercial vehicles and buses with electric drivetrains were already tested by Daimler from the early 1970s, the low range offered by lead acid batteries and the high costs associated with purely electric drivetrains led to a concentration of efforts on hybrid drivetrains that combined electric motors with internal combustion engines. Not many chances were seen for the application of these technologies in passenger cars at the time. Besides hybrid drivetrains, Daimler also conducted tests with hydrogen combustion engines.

The 1980s and early 1990s saw first tests with battery electric drivetrains in passenger cars as well, but after commencing research in fuel cell technology with the NECAR project in 1994, Daimler should favour this technology for the following years. Nevertheless, advancements in battery technology were achieved at the time by a joint venture between AEG and Anglo American Corporation. The company had improved ZEBRA battery technology in the early 1980s and ended up belonging to Daimler after its acquisition of German electric devices company AEG in 1988. In the early 1990s, prototypes of what should later be brought to series production as the Mercedes-Benz A-Class and Smart City-Coupé were presented, that were intended to be flexibly equipped with internal combustion engines or electric motors powered by batteries or fuel cells. However, Daimler did not believe in the future of battery technology, which together with a relaxation of emission regulation in California was the reason why both cars were only launched to markets with conventional internal combustion engines. When Daimler teamed up with Chrysler to form DaimlerChrysler at the end of the last millennium, most efforts in BEV technology were abandoned in favour of fuel cell drivetrains. Daimler started a cooperation with Canadian fuel cell expert company Ballard for the development of fuel cell-powered electric cars that were expected to reach maturity within the following few years. At the beginning of the new millennium, Daimler envisioned a five-step action plan to reduce CO_2 emissions, which included optimization of internal combustion engines, improvement of conventional fuels and CO_2-neutral biogenic fuels, hybrid drives as an intermediary step and emission free mobility with fuel cell electric vehicles as the long-term solution.

Even after Dieter Zetsche was appointed CEO of Daimler in 2006, the five-step action plan stayed the same; market maturity of fuel cell cars was expected to be reached between 2012 and 2015. This changed in 2007, when first field tests with a small fleet of electric Smart cars were conducted and BEVs were officially acknowledged as viable option for future individual mobility besides fuel cell electric cars, which were developed in a joint venture with Ford and Ballard at the time. This alliance was later enlarged through Nissan's participation.

Research and development expenditures were constantly raised in order to allow further development of alternative drivetrain technologies. The official roadmap to an emission-free individual mobility was called the "Road to the Future" and consisted of a three-lane approach that included parallel development of optimized internal combustion engines and hybrid variants, electric cars using batteries or fuel cells as energy storage technology and support of research in high-quality conventional and alternative fuels. In the long run, fuel cell cars were considered to hold the highest potential for larger cars, whereas battery electric drivetrains were seen most appropriate for small city vehicles.

From 2009, first hybrid, fuel cell and battery electric cars were manufactured in a small-scale series production and rented or sold to selected customers. Additionally, Daimler announced the development of additional business models close to the existing core business, which resulted in the creation of a business innovation team that introduced Daimler's first mobility services concentrating on car sharing and ride hailing. These offerings have been continually extended until today.

For the first time, the importance of strategic partnerships and joint ventures was stressed by Daimler from 2010 for bundling of technological know-how and to achieve cost advantages in the face of the variety of different alternative drive systems that were developed simultaneously. Suppliers should be integrated into research and development activities in order to achieve market maturity of new technologies as fast as possible.

In 2012, the first freely available series production BEV manufactured by Daimler was launched to the market under the Smart brand, followed by the first respective model of the Mercedes-Benz brand in 2014. The same year, Daimler also introduced its first plug-in hybrid electric vehicle. All were based on existing high-volume models initially constructed for being powered by an internal combustion engine. For the following years until 2017, ten new plug-in hybrid cars were planned to be introduced.

In 2016, Daimler launched its "CASE" strategy to illustrate its four strategic key areas of research and development, which are connectivity, autonomous driving, shared & service offerings and electric driving. The whole CASE strategy is embedded into the "5C" overall corporate strategy consisting of growth in the core business, a change in corporate culture towards start-up mentality and adaptations in the company's organizational structure; all while focusing on customer needs. Daimler should transform from a producer of cars to a provider of individual mobility. As part of this strategy package, the EQ brand was presented for bundling all of the company's efforts in the area of battery electric passenger cars and additional services to create a whole electric mobility ecosystem. More than ten purely electric cars were announced to be brought to series production until 2025, the first of them was already launched to markets in 2019. By 2025, 15 to 25% of all sold vehicles are expected to be battery electric cars. The high number of new BEV models in the coming years is complemented by a number of battery electric bus and truck models offered by Daimler from 2018.

All electric models of the EQ brand are based on a flexibly designed scalable common architecture that allows manufacturing within the existing global production network, on the same production lines as conventionally powered vehicles. Additionally, electrification of internal combustion engines will be implemented to achieve further improvements in efficiency through 48-volt primary electrical systems and integrated starter-generator units. Together with electrified models of all existing product series, more than 130 electrified variants will be offered by Daimler until 2022. This electrification offensive includes the investment of €10 billion in new electric models and the adaptation of existing production facilities in Bremen for electric SUV models, Sindelfingen for luxury and executive EQ models, Rastatt for compact EQ models, Tuscaloosa (USA) for SUV EQ models, Vitoria (Spain) for EQ vans and Hambach (France) for compact EQ models. Further plants will be adapted to accommodate the production of electric vehicles according to local demand. An additional €1 billion will be invested in the creation of a global battery production network with two factories in Kamenz and Untertürkheim, and additional factories in Sindelfingen, Tuscaloosa (USA) and Jawor (Poland). In 2020, Smart is planned to become the first car manufacturer to transform from a manufacturer of conventional cars to an exclusive producer of BEVs.

Fuel cell cars are considered an integral component of Daimler's current electrification offensive. However, top management admitted to not see a chance for fuel cell cars to contribute significantly to lowering average fleet CO_2 emissions below the stringent limits dictated by government regulations for 2020 due to the lack of appropriate hydrogen infrastructure. Additionally, the increased range and cost reductions achieved through advances in battery technology further limit the appeal of fuel cell technology for future wide-scale application in passenger cars. For this reason, the joint venture with Ford and Nissan for pre-series development of fuel cell technology was ended in 2018. However, Daimler still does internal research in the area, is involved in a joint venture for the roll-out of hydrogen infrastructure and has taken up series production of a plug-in hybrid model with fuel cell system in 2017.

As a consequence of its endeavours to improve engine efficiency and develop alternative drivetrain technologies, Daimler was able to reduce the fleet CO_2 emissions of its offered vehicles in Europe below the legal limit of around 130 g/km in 2015. However, in spite of constantly growing sales figures of its fully electric and plug-in hybrid electric vehicles, Daimler was not able to further reduce the average CO_2 fleet emissions from 123 g/km (NEDC) in 2015. Instead, the value increased to 132 g/km (NEDC) in 2018 as a consequence of a shift in demand towards larger and heavier and from diesel towards gasoline powered cars. In order to reach the legal goal of around 95 g/km which will be phased in from 2020, additional measures will be necessary.

9.4.3 Daimler's BEV Projects

As a consequence of the company's long history, Daimler had already been involved in development and production of BEVs before internal combustion engines emerged as the dominant technology at the end of the 19th and beginning of the 20th century. However, it was not before 1972 that research in the technology was taken up again, when a Mercedes-Benz LE 306 van was equipped with a battery electric drivetrain consisting of lead-acid batteries from Varta and a DC shunt motor of 35 to 56 kW supplied by Kiepe. The car was equipped with a special battery changing mechanism and was deployed during the 1972 Olympic Games and in a fleet trial with German electric utility RWE. After further prototypes were developed based on transportation vehicles, 1990 saw the first passenger test car, the so-called Mercedes-Benz 190-Elektro featuring an asynchronous electric engine manufactured by then-subsidiary AEG and a ZEBRA battery supplied by the joint venture between AEG and Anglo American Corporation. Some of these cars participated in a field testing project on the German island of Rügen from 1992 to 1996.

As a consequence to the announced Clean Air Act und Zero Emission Mandate in California in the 1990s, Daimler presented two concept studies called “Vision A 93” and “Studie A” to the public in 1993 and 1994 which were compact cars that could be equipped with either a conventional petrol or diesel engine or an electric induction motor with 40 kW powered by batteries or fuel cells. The underlying initial concept of a small city car had already been developed by Daimler engineers with the NAFA concept car in 1982. Although the “Vision A 93”/“Studie A” car was brought to series production as the Mercedes-Benz A-Class in 1998 and was designed to accommodate an alternative drivetrain right from the beginning, the car was only made publicly available with conventional internal combustion engines. However, a battery electric version had been developed to market maturity in 1997 with a ZEBRA battery developed in close cooperation with AEG Anglo Batteries. A relaxation in Californian zero-emission policy brought an end to the project.

Already in 1994, a joint venture with Swiss company SMH, producer of the Swatch wristwatch series, was set up to build a small city car, which was initially intended to be equipped with a battery electric drivetrain by Swatch's founder and CEO, industry visionary Nicolas G. Hayek. The first concept study of the resulting Micro Compact Car Concept was presented the same year in two versions with either a small ICE or a 40 kW electric engine. The car was launched to markets in 1998 as the Smart City-Coupé with a conventional drivetrain only as a consequence of Daimler's refusal to fit the car with a purely electric drivetrain due to economic and technological concerns. Consequently, SMH sold its shares in the joint venture to Daimler in 1998.

In 2007, a small series of 100 Smart fortwo (450) was equipped with a brushless DC motor and a sodium-nickel chloride battery and deployed in field testing in London until 2009 for gaining real-world experience with electric drivetrains. These cars were called Smart fortwo electric drive and based on a concept study that had been presented the previous year. A second similar project took place from 2009 to 2011 with more than 2000 Smart fortwo (451) that featured a lithium-ion battery system and the same motor as the first short run. The cars were rented to selected customers in a full-service business model with the key objective to evaluate customer behaviour.

In 2009, a concept study was presented that was called Concept BlueZERO E-Cell and was propelled by an electric motor. The car could be equipped with different energy storage systems like batteries, fuel cells or a range extender thanks to its flexible architecture that was based on the same sandwich-floor construction implemented in the Smart fortwo, Mercedes-Benz A-Class and Mercedes-Benz B-Class.

Already in 2010, the first Mercedes-Benz BEV was presented with the A-Class E-CELL featuring a permanent-field synchronous electric motor with peak power of 70 kW and a lithium-ion battery. The car made use of the fact that the basic layout of the A-Class had initially been designed to accommodate a variety of different drivetrains. Five hundred units were manufactured and rented to selected customers in Europe.

The same year, a full electric version of the Mercedes-Benz SLS AMG was presented that had a drive concept consisting of four synchronous electric motors of 98 kW each which were powered by a high-performance lithium-ion battery. Initially, the car was named SLS AMG E-CELL but was later renamed to SLS AMG Coupé electric drive and manufactured in a limited run from 2013 with improved engines of 138 kW each.

In 2012, series production of the third generation of the Smart fortwo electric drive started at the Smart plant in Hambach (France). For the first time, the car was freely available to customers in more than 30 countries and assembled on the same production line as the conventionally-powered Smart fortwo. The lithium-ion battery could either be rented or bought; the permanent-field synchronous electric motor had 50 kW.

From 2014 to 2017, a Mercedes-Benz B-Class electric drive was available that was based on a concept study that had been presented in 2012 and featured lithium-ion battery technology and an induction motor with 132 kW. The car was later renamed to Mercedes-Benz B 250 e.

After the introduction of the new Smart 453 series in 2014, the fourth generation of the Smart electric drive products was launched in 2017 with a lithium-ion battery and a separately excited three-phase synchronous motor with 60 kW. For the first time, the whole product portfolio of the brand consisting of the fortwo, forfour and cabrio models is also offered as electric drive version. In 2018, the cars were renamed to Smart EQ fortwo, Smart EQ forfour and Smart EQ fortwo cabrio respectively.

In 2019, the first car of a whole new family of Mercedes-Benz BEVs was introduced with the Mercedes-Benz EQC, which is based on a concept study presented in 2016. The car is the first product featuring the newly developed EVA (Electric Vehicle Architecture) platform, which in turn was designed upon Daimler’s existing MRA (Mercedes Rearwheel Architecture) platform for conventionally-powered Mercedes-Benz cars. Under the new EQ brand, more than ten electric cars will be introduced until 2025, which will all be designed upon the scalable EVA architecture that can be flexibly adapted to different vehicle classes. First concept studies of a Mercedes-Benz EQC, Mercedes-Benz EQV, Mercedes-Benz EQA and Mercedes-Benz EQB have already been shown. The series production version of the Mercedes-Benz EQV will be manufactured from 2020. The flexible drivetrain architecture consists of lithium-ion batteries and inductive machines with 150 kW.

Besides these cars, a high number of concept cars were shown by Smart, Mercedes-Benz and Maybach in the last years. Those can be taken from Figure 39 together with all other BEVs.

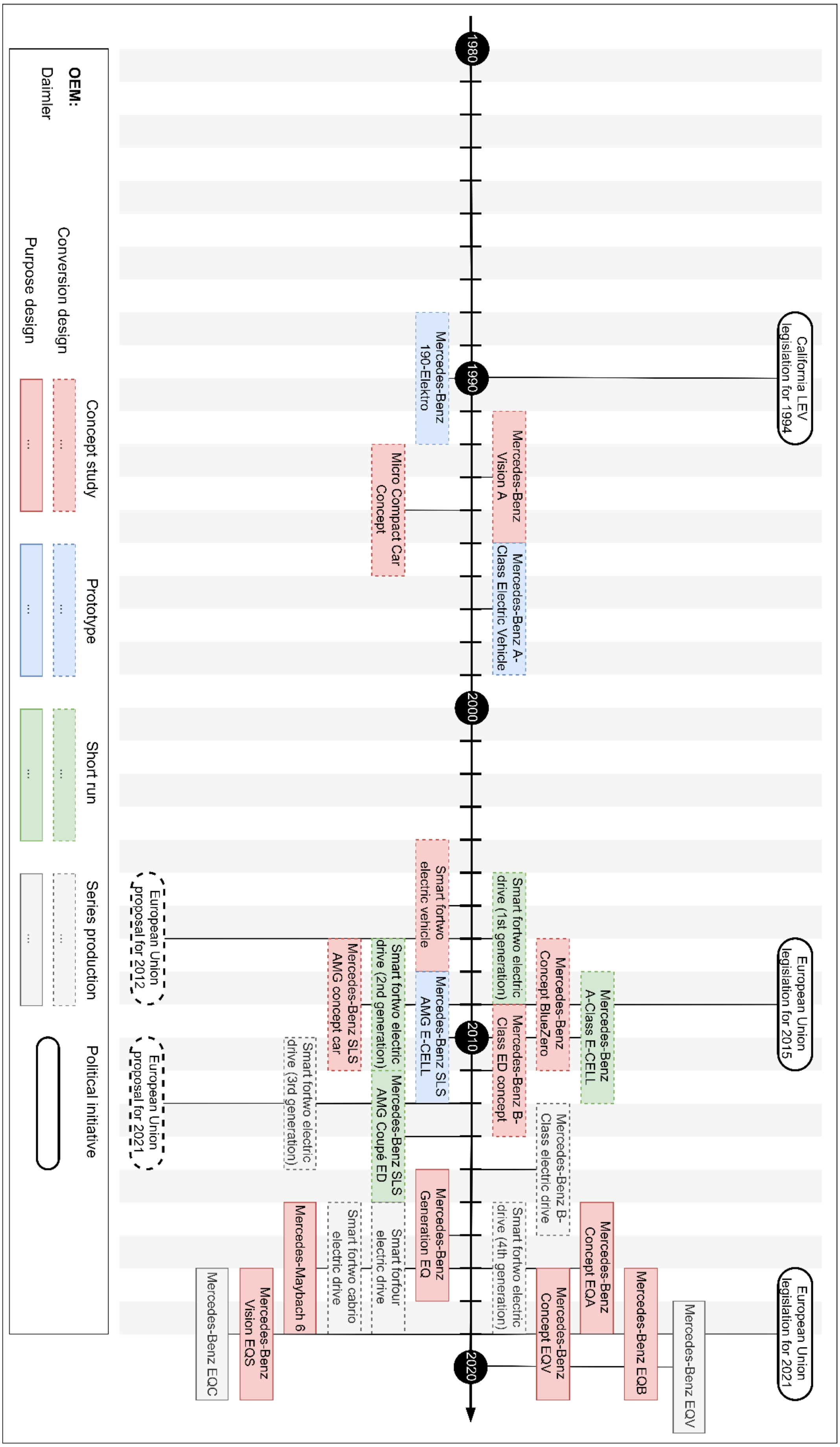


Figure 39: Timeline of Daimler's BEV projects (own creation)

9.4.4 Daimler's IORs in Complete Vehicles

The first generation of Smart's fortwo electric drive model did not only feature a drivetrain developed and manufactured by Zytek, but was also assembled at Zytek's headquarters in the UK in 2007 based on Smart chassis. For the production of the second generation, Zytek received a dedicated assembling facility at the Smart fortwo assembly plant in Hambach (France) from 2009 to 2011. Due to this reason, the relationship is considered a partnership for the second generation Smart electric drive. The third and fourth generation of the car were developed in-house and assembled at the Smart plant in Hambach (France).

The strategic alliance existing between Tesla and Daimler from 2009 to 2014 also contained aspects concerning general automotive engineering like knowledge sharing in engineering excellence and production technology.

From 2010, specialist engineers at Daimler's subsidiary Mercedes-AMG developed the electric sports car SLS AMG E-CELL, later to be marketed as SLS AMG Coupé electric drive. The car was also assembled at AMG's facilities in Affalterbach from 2013.

The Smart fortwo has been offered in a special edition tuned by Brabus and distributed in a joint venture with Daimler's Smart. The first electric vehicle covered by this agreement was the Smart fortwo BRABUS electric drive, a vehicle based on the third generation Smart fortwo electric drive in 2012.

Already in 2010, Daimler and Renault-Nissan started a strategic alliance that was extended to include electric cars in 2012. Platforms for all Smart 453 electric cars were jointly developed as a result. Since 2017, the Smart forfour electric drive has been produced at Renault's plant in Novo Mesto (Slovenia).

After first attempts to cooperate in electric drivetrain technology had been turned down by Daimler, Li Shufu, chairman of Zhejiang Geely Holding Group acquired a stake of 9.7% in Daimler via a shell company called Tenaciou3 Prospect Investment Limited, becoming the company's largest shareholder in 2018. Although Daimler initially had concerns to cooperate with Geely due to existing joint ventures with other Chinese vehicle manufacturers, they finally agreed on a joint venture in 2019. The joint venture is expected to be finalized in 2019 and will focus on global operation of the Smart brand, which includes exclusive development and manufacturing of the all-electric third generation of Smart cars from 2022.

Mercedes-Benz A-Class electric drive, Mercedes-Benz B-Class electric drive and the Mercedes-Benz EQC as well as other models that will be marketed under the EQ brand in the future are results of Daimler's in-house development and manufacturing units in Rastatt, Untertürkheim, Sindelfingen, Bremen, Tuscaloosa (USA), Hambach (France) and Vitoria (Spain). The only exception are models manufactured for the Chinese market.

A timeline of Daimler's interorganizational relationships for research, development and manufacturing of complete BEVs can be taken from Figure 40.

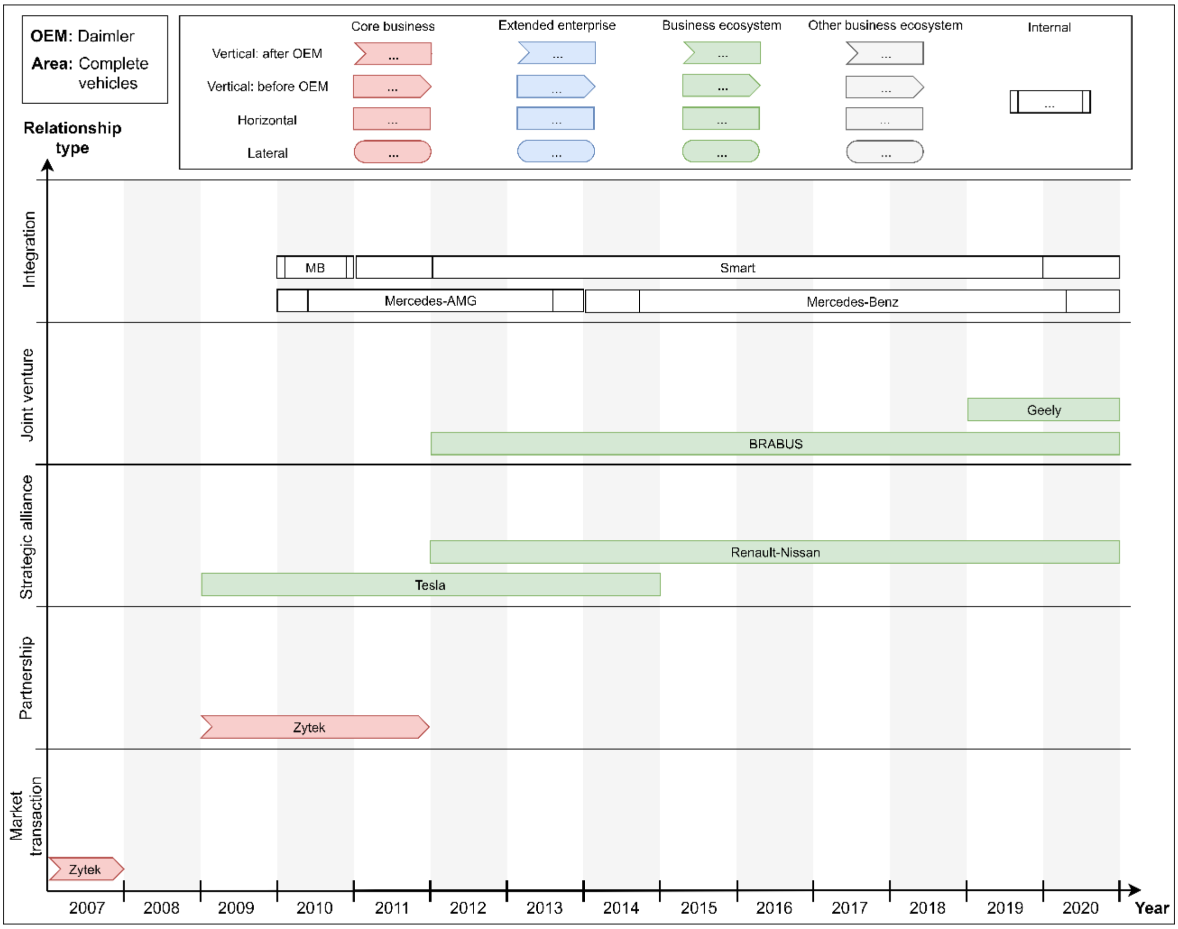


Figure 40: Timeline of Daimler's IORs in complete vehicles (own creation)

9.4.5 Daimler's IORs in Raw Materials

Although Daimler reacts to the high volatility of market prices of certain materials needed for the production of electric vehicles by negotiating long-term supply agreements and participates in sustainability initiatives for improving the transparency of the supply chain, nothing is known about actual supply contracts between Daimler and its raw material suppliers of lithium, nickel, cobalt or rare earths.

In 2010, Daimler started to cooperate with Toray Industries for the joint development of components made from carbon fibre reinforced plastics. First parts were planned to be introduced to series production until 2013 and were intended to be implemented to reduce fuel consumption and CO_2 emissions of Daimler's vehicles. In 2011, both companies formed a joint venture for the manufacturing and marketing of components that resulted from the joint development initiative. However, Daimler is not known to have implemented the manufactured parts into its electric cars, the only exception probably being the SLS AMG electric sports car. In 2014, Daimler decided to reduce its shares in the company from 45 to 5% without having any known operative cooperation. Today, the former joint venture is a fully owned subsidiary of Toray Industries.

The partnership with REMONDIS for stationary energy storage systems made from secondary use automotive batteries also includes the recycling and feeding back of raw materials into production.

A timeline of Daimler's interorganizational relationships for sourcing of raw materials can be taken from Figure 41.

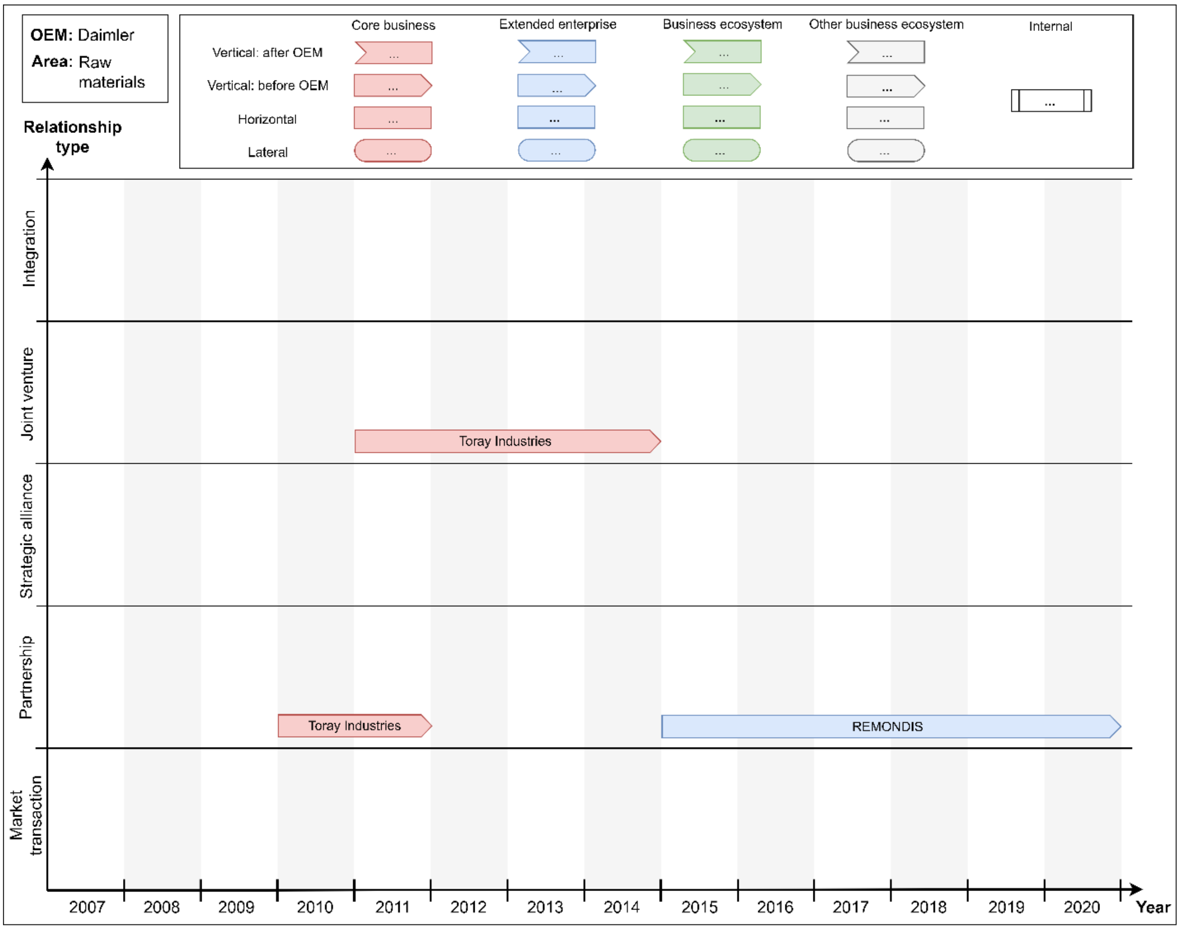


Figure 41: Timeline of Daimler's IORs in raw materials (own creation)

9.4.6 Daimler's IORs in Battery Cell Technology

The Smart fortwo electric drive manufactured in 2007 in a short run of approximately 100 units was equipped with a sodium-metal chloride or ZEBRA battery supplied by MES-DEA. The company had acquired the technology from Daimler's subsidiary joint venture AEG Anglo Batteries in 1999. Although the second generation Smart fortwo electric drive built from 2009 featured the same electric drivetrain, it had a lithium-ion battery (LCO) supplied by Tesla consisting of cells most probably manufactured by Panasonic. The same holds true for the battery cells implemented in the Mercedes-Benz A-Class E-CELL manufactured in 2010 and the Mercedes-Benz B-Class electric drive sold between 2014 and 2017.

Already in 2008, Daimler had set up a joint venture with German chemical industry enterprise Evonik Industries for joint development and manufacturing of lithium-ion battery cells for automotive applications in Kamenz called Li-Tec. Daimler considered battery cell technology a strategically important good at the time, expecting a very low number of automotive lithium-ion battery cell producers in the future. First cells (NMC) were manufactured in 2011 and implemented in the third generation Smart fortwo electric drive from 2012 to 2015. Originally, Daimler and Evonik had intended to supply their technologically superior CERIO battery cells to other companies as well. However, lithium-ion battery cells turned out to become an interchangeable commodity product due to cheap large-scale industrialized production in Asia and overcapacities in the market. In combination with the low production volumes at Li-Tec, the business was not economically justifiable and Evonik Industries sold its 50.1 % share to Daimler in 2014. Manufacturing was continued until the end of production of the second generation Smart fortwo electric drive and finally ended in 2015. Since then, the company has been focusing on research in battery cell technology as a fully-owned subsidiary of Daimler.

The strategic partnership entered with Tesla in 2009 also included sharing of Daimler's know-how in battery cell technology. It ended in 2014 when Daimler sold its shares in Tesla, which they had acquired when entering the alliance.

From 2011 to 2013, SK Innovation supplied battery cells for the SLS AMG E-CELL and electric drive. The company again earned a large scale supply contract with Daimler in 2016. In 2018 Daimler announced to have signed long-term supply contracts for battery cells from external suppliers amounting to €20 billion until 2030. The exact suppler companies were not named. However, SK Innovation, LG Chem and Farasis Energy are known to serve as suppliers for Daimler. LG Chem's batteries are included in the fourth generation of Smart fortwo electric drive, Smart forfour electric drive and Smart cabrio electric drive sold from 2017 and the Mercedes-Benz EQC which is manufactured from 2019. Farasis Energy was announced as battery cell supplier by Daimler in 2019. Daimler does not intend to take up in-house manufacturing of battery cells anytime in the future again, but announced to increase its research and development efforts in cell technology in the coming years. This includes further development and assessment of battery cells bought on the world market and research in the next generation of post-lithium-ion cell chemistry. In the course of these activities, Daimler teamed up with Sila Nanotechnologies in a strategic alliance in 2019 for conducting research in silicon electrode materials. The agreement includes a high investment by Daimler.

A timeline of Daimler's interorganizational relationships in battery cell technology can be found in Figure 42.

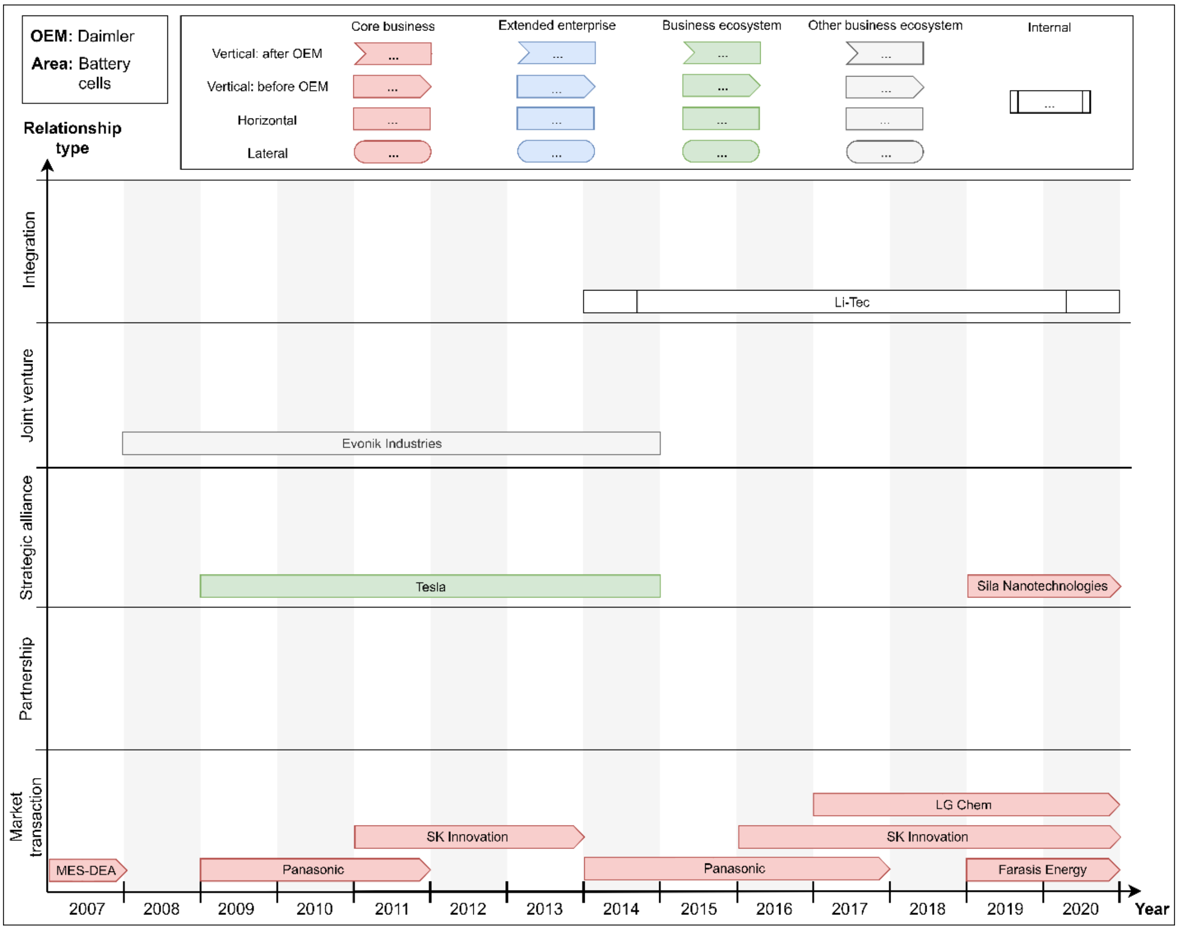


Figure 42: Timeline of Daimler's IORs in battery cell technology (own creation)

9.4.7 Daimler's IORs in Battery System Technology

The first generation of Smart's fortwo electric drive manufactured in 2007 was equipped with a sodium-metal chloride or ZEBRA battery supplied by Swiss company MES-DEA, whilst the second generation featured a battery system jointly developed with Tesla.

Daimler had bought a 10 percent stake in the start-up already in 2009. The resulting strategic alliance did not just lead to the manufacturing of battery systems for the Smart fortwo electric drive, but also for the Mercedes-Benz A-Class electric drive manufactured in 2010 and the Mercedes-Benz B-Class electric drive built and distributed from 2014 to 2017. However, Daimler had already sold its then-4% share in Tesla in 2014, which is why the supply relationship to Daimler for the battery system of the Mercedes-Benz B-Class electric drive from 2014 to 2017 can rather be considered a market transaction.

In addition to Li-Tec, Daimler founded another joint venture together with Evonik Industries in 2009 that was called Deutsche ACCUmotive and focused on development and manufacturing of battery systems. The first product of the newly created company was the battery system for the third generation Smart electric drive from 2012 to 2015. In 2014, Evonik Industries sold its 10% share of the joint venture to Daimler. Battery systems for all Mercedes-Benz PHEV and electric models of the EQ brand will be developed and manufactured in-house by Deutsche ACCUmotive, as this technology is considered the core technology of BEVs by Daimler. For this reason, €500 million were invested in the construction of a second factory in Kamenz in 2016. In the future, battery systems will also be manufactured by Daimler in additional facilities in Untertürkheim, Sindelfingen, Tuscaloosa (USA) and Jawor (Poland).

The high-performance battery implemented in the SLS AMG E-CELL and later SLS AMG Coupé electric drive from 2010 to 2013 was developed in close cooperation with Daimler's subsidiary Mercedes AMG High Performance Powertrains in Brackley (UK) which also develops drivetrains for the Mercedes AMG Petronas Formula One team.

A timeline of Daimler's interorganizational relationships in battery system technology can be taken from Figure 43.

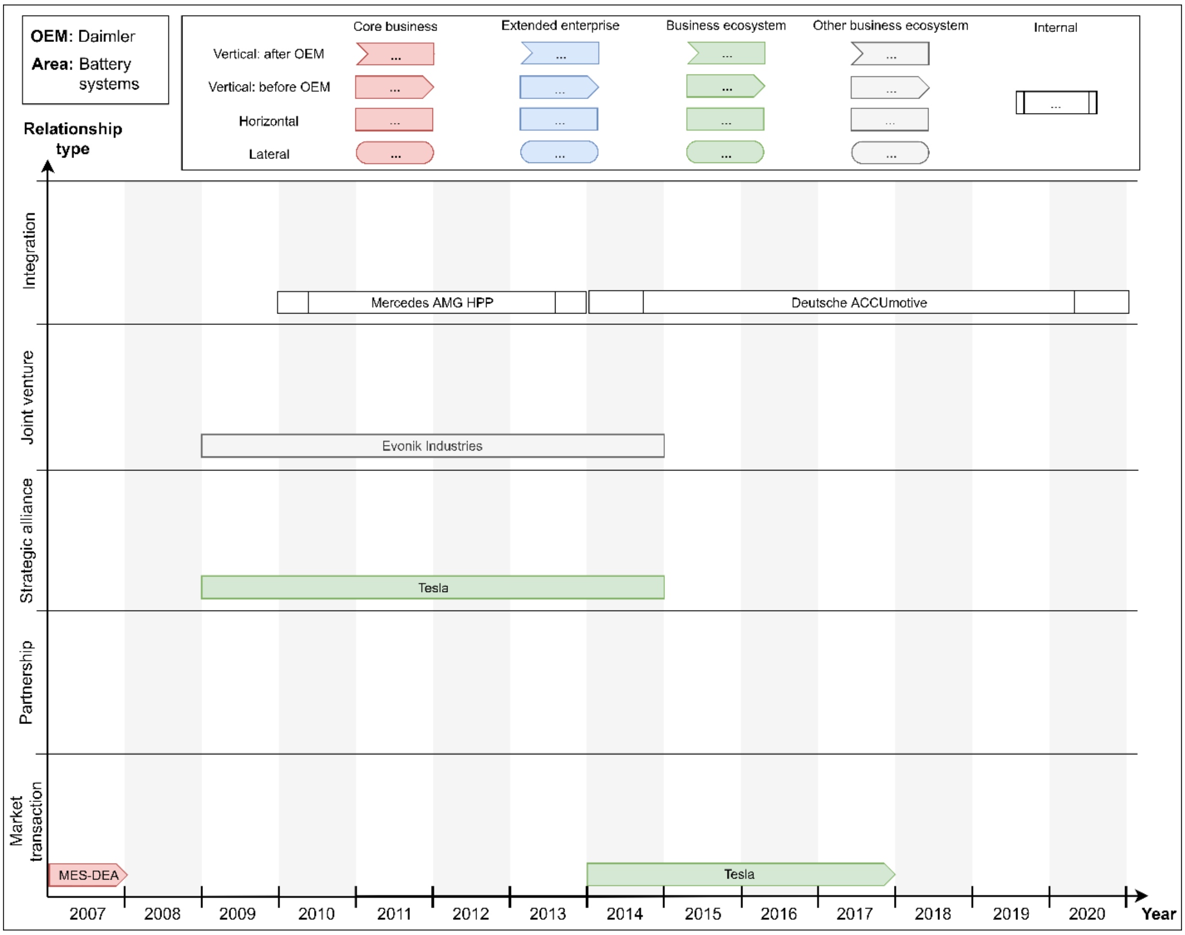


Figure 43: Timeline of Daimler's IORs in battery system technology (own creation)

9.4.8 Daimler's IORs in Electric Drivetrain Technology

The drivetrain of the first short run of Smart fortwo electric drive cars in 2007 was developed and manufactured by British powertrain specialist company Zytek. The same drivetrain was also used in the second generation Smart fortwo electric drive from 2009 to 2012.

When Daimler manufactured a small series of Mercedes-Benz A-Class E-Cell cars in 2010, electric motors were supplied by Nidec from Japan.

The strategic alliance formed with Tesla through acquisition of a 10% share in the company in 2009 also included knowledge sharing and joint development of powertrains. In 2014, Daimler sold its shares, effectively ending the strategic alliance.

In 2011, Daimler entered in a joint venture with Bosch for the development of electric motors to be used in hybrid and electric cars. The resulting company EM-motive's R&D department is located in Schwieberdingen close to Stuttgart, whilst production facilities were constructed in Hildesheim. The first product of the young company that entered series production was the electric engine featured in the third generation Smart fortwo electric drive from 2012, followed by electric motors developed and manufactured for the SLS AMG Coupé electric drive. Products were also distributed to other companies by Bosch. In 2019, Daimler announced to have sold its share of 50% to Bosch and would source electric motors from the world market in the future. Daimler reasoned the termination of the joint venture with the fact that the goal of economic production of electric motors had been reached. The joint venture was announced to have only served the goal of sharing the initial costs of building up know-how.

However, already the drivetrain of the Mercedes-Benz B-Class electric drive manufactured between 2014 and 2017 had been supplied by Tesla in a relationship that is considered a market relationship due to the fact that the strategic alliance between both companies had ended in 2014 after Daimler sold its Tesla shares. In 2012 the strategic alliance between Daimler and Renault-Nissan that had already been established in 2010, was extended to electric cars as well. Daimler bought 3.1% of shares in Renault-Nissan, whilst both Renault and Nissan each acquired 1.55 % of Daimler's shares. As a result of this strategic alliance, Renault has been supplying electric engines for the fourth generation of smart electric drive cars from 2017. The engines are manufactured in Renault's Cleon (France) plant and also featured in Renault's ZOE BEV. Due to the focus of the strategic alliance to other areas and the fact that the engine had already been developed previously by Renault, the supply relationship for electric motors is only considered to be like a market relationship.

In 2019, ZF announced to be the supplier of the drivetrain modules for the newly introduced Mercedes-Benz EQC. These modules – called eATS by Daimler – are part of a flexible scalable electric vehicle architecture that will also be used as a basis for all other BEVs marketed under the EQ brand. For this reason, it can be concluded that ZF will also be the supplier of drivetrain technology for the Mercedes-Benz EQV which will be produced from 2020.

A timeline of Daimler's interorganizational relationships for electric drivetrain technology sourcing can be found in Figure 44.

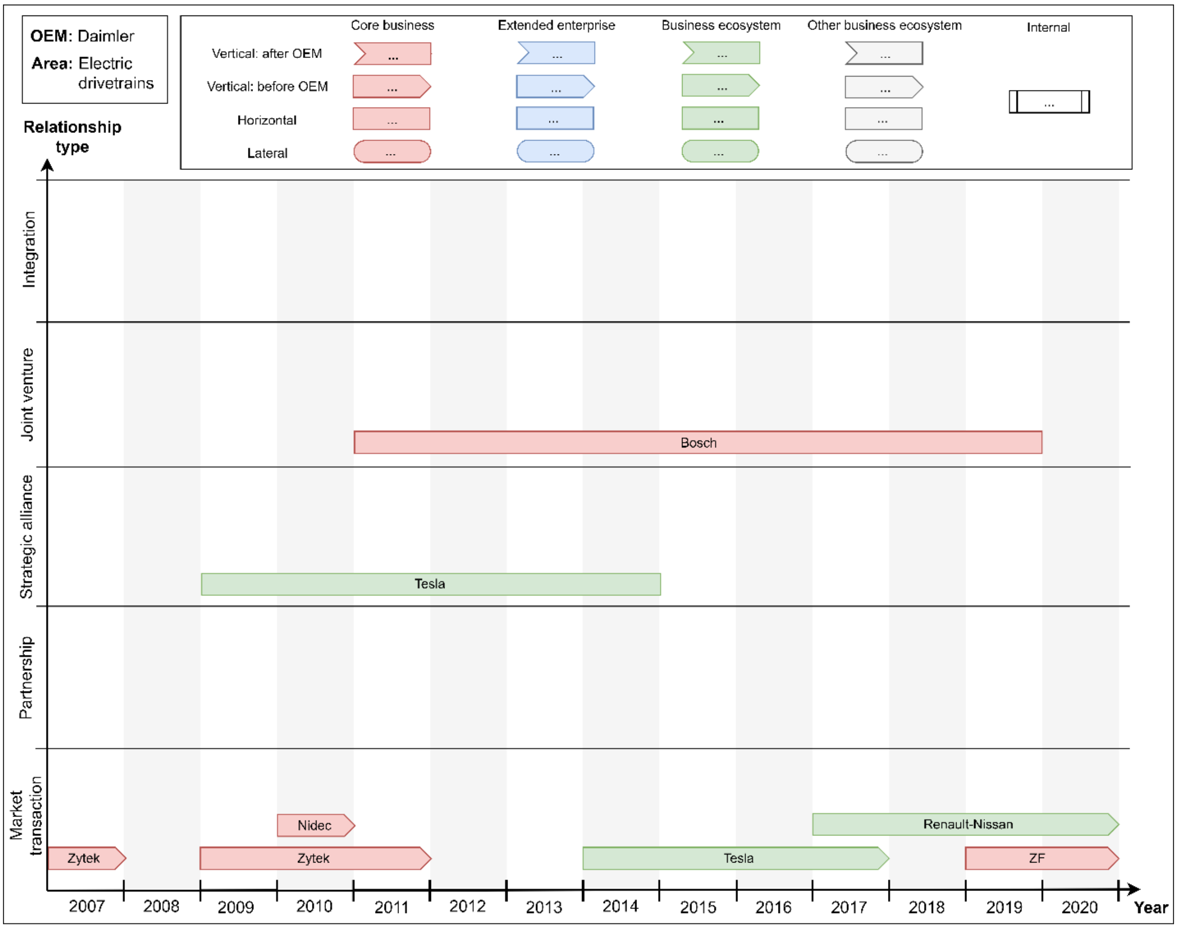


Figure 44: Timeline of Daimler's IORs in electric drivetrain technology (own creation)

9.4.9 Daimler's IORs in Charging Infrastructure

Relationships were started with enel in Italy and with EnBW in Baden-Württemberg in 2008 and 2010 for establishing e-mobility pioneering regions.

From 2012, Daimler has been participating in the joint venture Hubject with EnBW, Bosch, BMW, RWE and Siemens for the creation of an IT business platform to connect charging infrastructure providers. Already in the same year, Daimler started a strategic alliance with electric mobility specialist company The Mobility House for installation of charging infrastructure for Mercedes-Benz fleet owners and V2G technology. The alliance was intensified by Daimler's acquisition of a minority share in the enterprise.

From 2013 to 2015, wallboxes for the Smart fortwo electric drive and SLS AMG Coupé electric drive were supplied by SPX and KEBA, who also provided installation services for Mercedes-Benz customers. The current generation of Mercedes-Benz wallboxes available since 2018 are a product of ABL; additional services are provided through a cooperation with has.to.be.

Since 2017, Daimler has been involved in a joint venture with Ford, Volkswagen, Audi, Porsche and Hyundai for the creation of a fast-charging network along highways in Europe called IONITY.

Daimler acquired a minority share of the North American charging infrastructure company ChargePoint in 2017, which led to a strategic alliance for expanding the product portfolio within the electric mobility ecosystem marketed by Daimler under the EQ brand.

Since 2019, Daimler has been offering intelligent charging solutions for fleet customers in a partnership with NewMotion. The same year, Daimler introduced its "Mercedes me charge" service that allows access to and payment for a high number of charging points via a single platform. A joint venture set up with BMW in 2019 includes charging services with the ChargeNow platform that grants access to a large international network of charging points.

A timeline of Daimler's interorganizational relationships in charging infrastructure can be found in Figure 45.

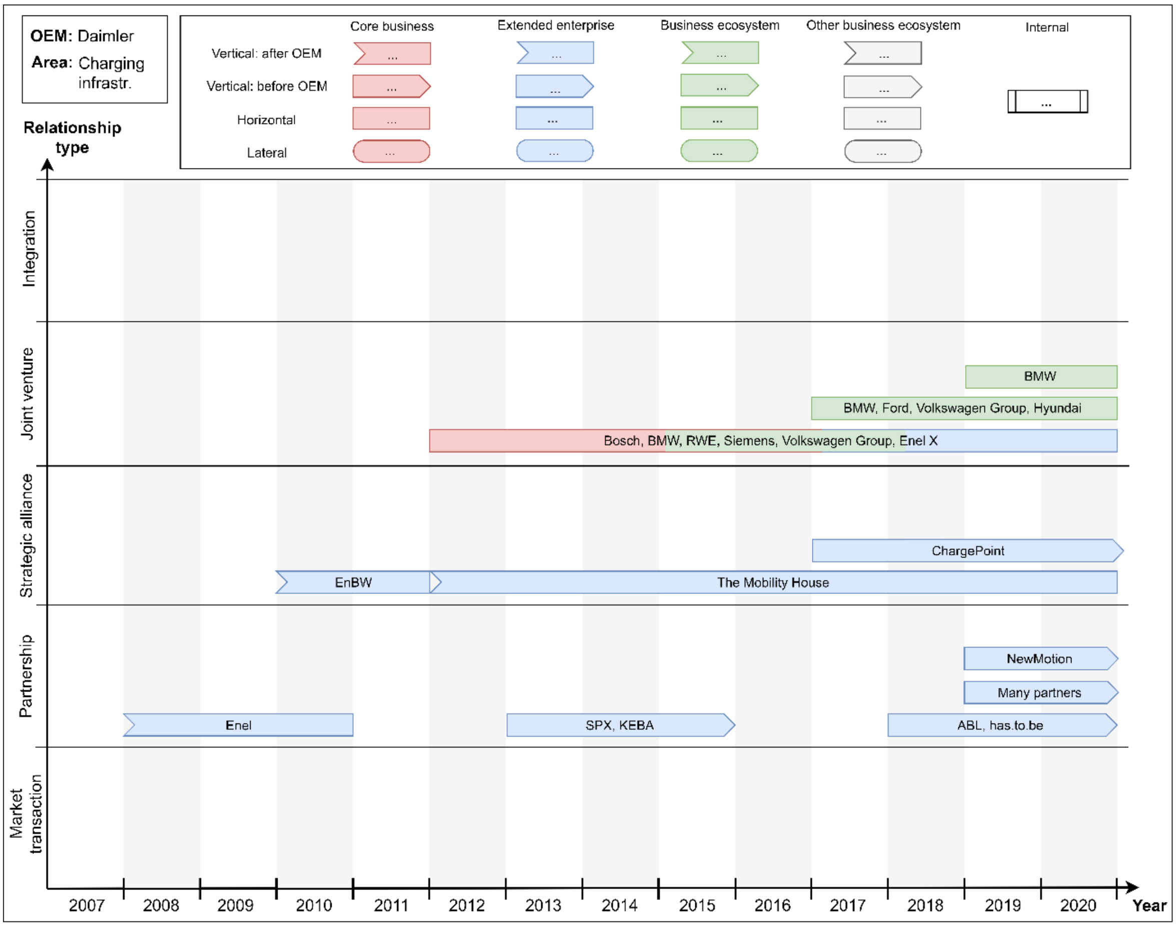


Figure 45: Timeline of Daimler's IORs in charging infrastructure (own creation)

9.4.10 Daimler's IORs in Mobility Services

With the creation of a business innovation team in 2007, which was later renamed to Lab1886, first work started at Daimler for developing new business areas close to the existing core competences. The first result in 2008 were internal trials with the free floating car sharing service car2go in Ulm in cooperation with Daimler's internal IT provider Daimler TSS. The first real-world pilot was started in Ulm. As a consequence of the concept's great success, Daimler set up a joint venture with car rental company Europcar in 2011 to roll out the concept to a number of European cities. Both companies brought their respective know-how in car sharing into the relationship. Since 2011, BEVs are part of car2go's fleet; the share has been gradually increased to 15% or 2100 cars in 2018. The same year, Daimler bought Europcar's 10% stake of car2go Europe in order to merge the service with BMW's DriveNow as part of a joint venture set up in 2019 that includes car sharing, ride hailing, parking services, charging infrastructure and other mobility services.

In 2012, a second project followed with the moovel app that was created by Daimler's internal IT, financial services and strategy departments. Already in 2011 first field tests had been conducted with a similar mobile platform called car2gether with IT company Scientific Computers that combined peer-to-peer car sharing and public transportation in Ulm and Aachen. The first two pilots for moovel were started in Berlin and Stuttgart in cooperation with ridesharing provider carpooling.com and local public transportation providers in 2012. In the following years, the platform was introduced in additional cities. Since 2017, moovel has also been offered as a white-label solution for other companies under the name of moovel transit and was rolled out in Karlsruhe and Stuttgart.

Also in 2012, Daimler bought a stake in Intelligent Apps whose ride hailing service mytaxi was integrated into the moovel platform. Daimler fully acquired mytaxi in 2014 and subsequently expanded its activities in the area over the course of the following years. The same year, mytaxi absorbed UK-based ride hailing provider Hailo in exchange for a share in mytaxi. In 2017, Clever Taxi from Romania and Taxibeat, operating in Greece and Peru, were acquired by Daimler and integrated into mytaxi. Daimler additionally is the owner of German ride hailing provider flinc, which operates independently from Daimler's other activities in this business segment. Partnerships have been existing with Deutsche Bahn and its flinkster car sharing program from 2016.

In 2016, Daimler launched its own peer-to-peer car sharing solution called Croove in Munich. The company was taken over by American provider Turo in 2017 in exchange for a stake in Turo. Additionally, Daimler acquired the majority in French private ride hailing platform provider Chauffeur Privé (renamed to Kapten in 2019) with the aim to buy the remaining shares until 2019.

All above mentioned mobility services offered by Daimler were part of the newly created company Daimler Mobility Services, a subsidiary of Daimler Financial Services AG from 2013. In 2019, Daimler Financial Services was renamed to Daimler Mobility Services AG as a consequence of the significance of these offerings for its business. Additionally, the operation of all mobility services was taken over by a joint venture set up with BMW in 2019.

In 2017, Mercedes-Benz Vans acquired a stake in US transport network operator Via and set up a joint venture called ViaVan to offer on-demand shuttle services with Mercedes-Benz vans in Europe from 2018.

In addition to the mentioned activities, Daimler also holds shares of bus platform operator FlixMobility, chauffeur service platform Blacklane and Estonian ride hailing company Taxify. However, those companies do not have any operative ties to Daimler, and Daimler's shares do not amount to a majority which is why they are not considered in the timelines.

A timeline of Daimler's interorganizational relationships in mobility services can be found in Figure 46.

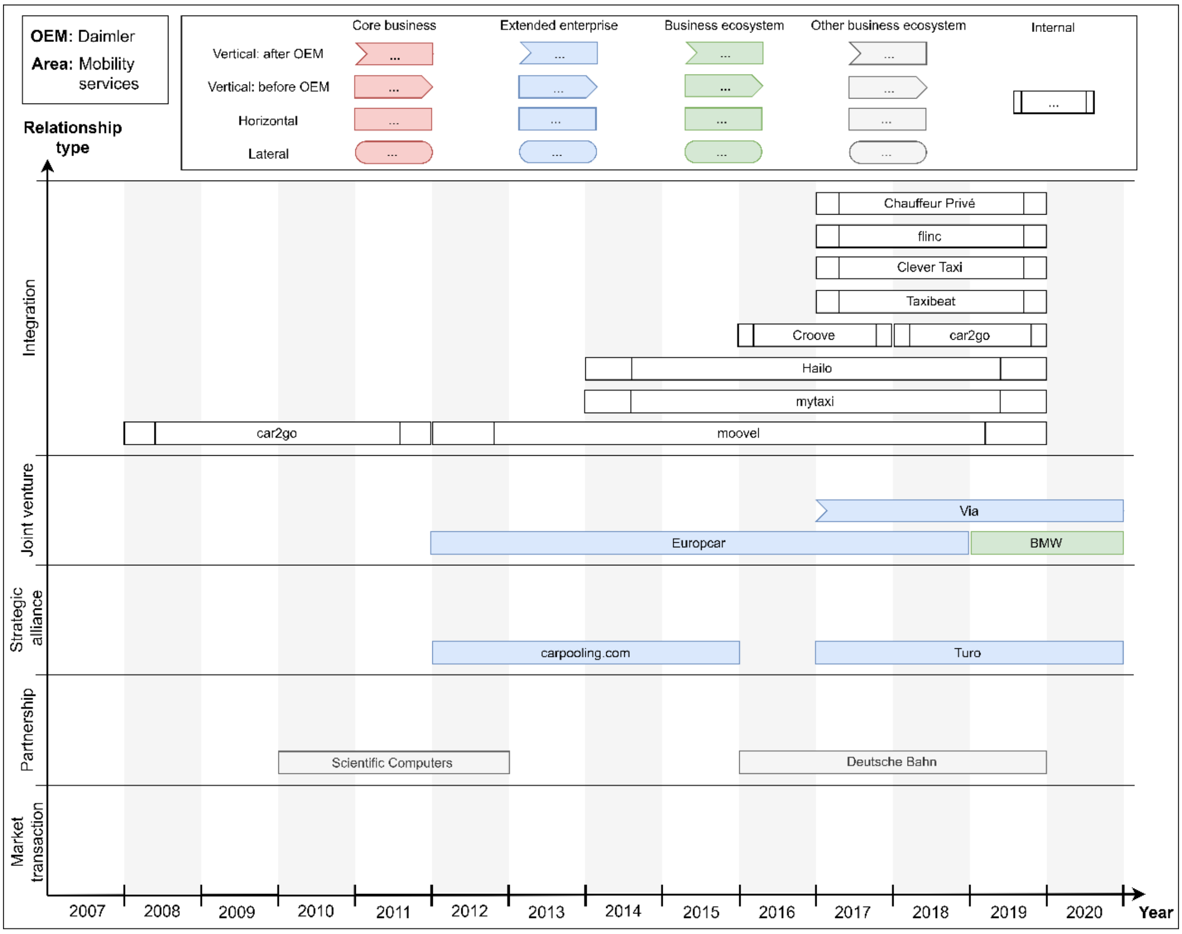


Figure 46: Timeline of Daimler's IORs in mobility services (own creation)

9.4.11 Daimler's IORs in Battery Reuse and Recycling

Daimler considers second use applications of old automotive traction batteries a viable solution to extend the battery's lifetime by at least ten years. For this reason, a joint venture with GETEC and The Mobility House was set up in 2015 to construct the largest existing second use battery storage unit at REMONDIS' Lünen site. As a part of the project, REMONDIS agreed to recycle the involved batteries at the end of their lifecycle and feed valuable raw materials back into the production loop. Additional energy storage plants were opened in Elverslingen by the same joint venture in 2018 and in Herrenhausen in a partnership together with enercity in 2017.

From 2016, Daimler decided to market its automotive battery system technology as stationary storage systems for private and industrial purposes through a newly created company called Mercedes-Benz Energy. The aim is to increase production volumes of battery systems at Deutsche ACCUmotive, who serves as a technology supplier for the new enterprise and use secondary use batteries. The products were to be distributed to private customers through partnerships with EnBW and SMA Solar Technology. However, 2018 saw the end of Daimler's home energy storage system business due to competitive disadvantages caused by the expensive technology that was only necessary for automotive applications but not for stationary storage systems. Products are still marketed for industrial applications, where products also comprise of secondary use battery modules.

From 2019, Daimler and Dutch transmission system operator TenneT cooperated in a development partnership to test the capability of automobile battery storage systems to stabilise large-scale electricity transmission systems and power plants as part of a programme funded by the German Federal Government. Additionally, Daimler announced to have started a sustainability partnership with its battery cell supplier Farasis Energy that also includes recycling of battery cells.

A timeline of Daimler's interorganizational relationships in battery reuse and recycling can be found in Figure 47.

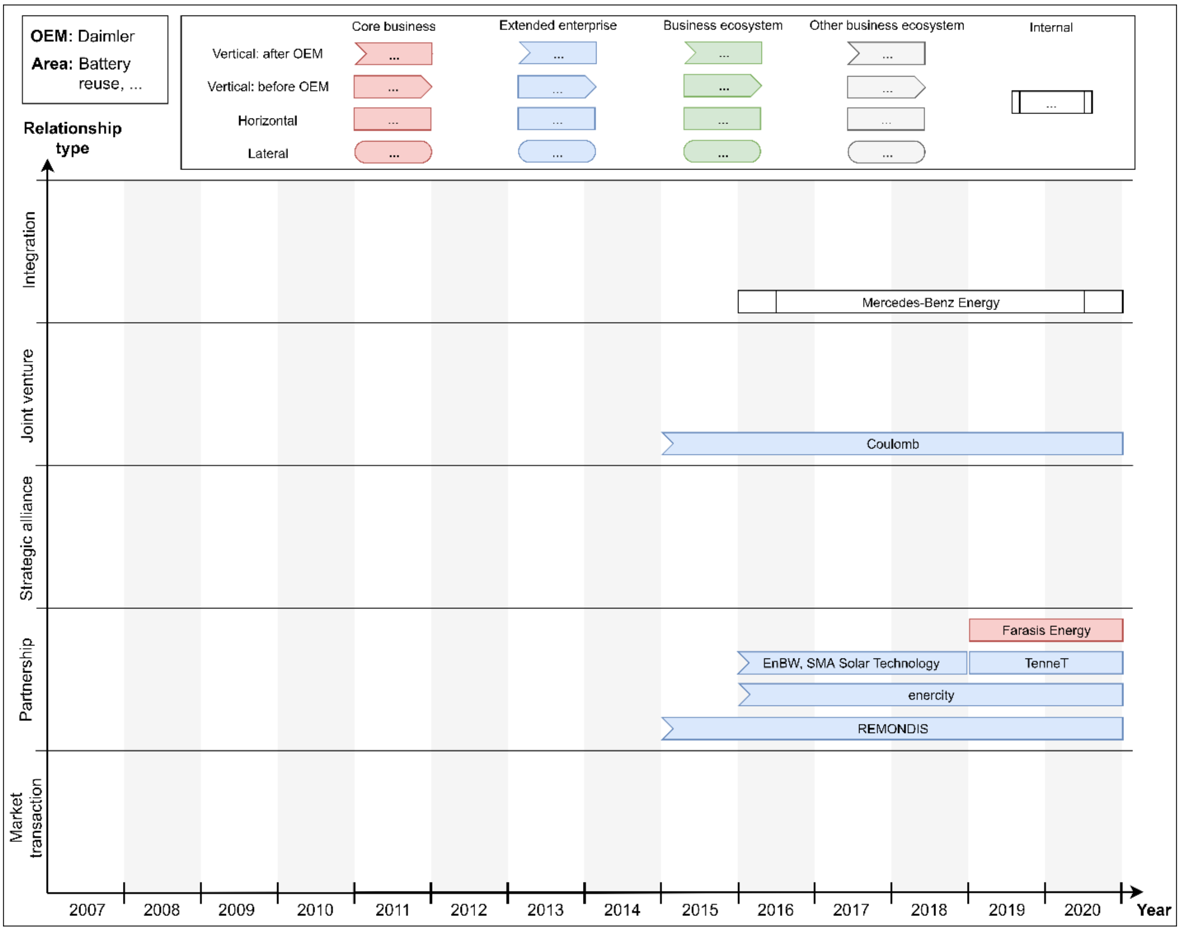


Figure 47: Timeline of Daimler's IORs in battery reuse and recycling (own creation)

9.5 Case Study 3: Volkswagen Group

9.5.1 Volkswagen Group

The Volkswagen Group is a globally operating German automotive OEM with headquarters in Wolfsburg. The company has its roots in the creation of the Volkswagen Beetle before World War II and today is one of the leading producers of cars, buses, trucks, vans and motorcycles in Europe with a total workforce of more than 660.000 employees in 2018. Volkswagen Group consists of the three automotive divisions Passenger Cars, Commercial Vehicles and Power Engineering, and the Financial Services division that provides financial and leasing services, fleet management and insurance services. The Volkswagen Group markets its passenger cars under the Volkswagen, Audi, ŠKODA, SEAT, Bentley, Bugatti and Lamborghini brands, which all are legally independent enterprises after a restructuration process in 2007. In 2012, Volkswagen Group was merged with Porsche Holding SE, after a long transaction process that had already started in 2009. As a result, the Porsche brand was added to the Group's portfolio.

Products offered under the Volkswagen, Seat and ŠKODA brand can be accounted to the volume segment and include a broad range from small city cars to sedans. Audi manufactures premium cars targeted at a wide group of customers reaching from small cars for environmentally conscious drivers to high-performance cars marketed under the Audi Sport sub-brand. The Porsche and Lamborghini brands are used to market sports cars, whilst Bentley is a producer of luxury vehicles. Bugatti manufactures short runs of luxury sports cars.

9.5.2 History of Volkswagen Group's Activities Towards Alternative Drivetrains

Although fleet trials with alternative drivetrain concepts had already taken place before, Volkswagen started strategic initiatives in the area for the first time in 2003 with the introduction of its official fuel strategy. This included activities in three distinct areas, which were improved efficiency of internal combustion engines, the search for alternative energy sources in fuel production and the development of a CO_2-neutral drivetrain. However, the vision of an alternative drivetrain concept was still somewhat vague, as only fuel cell-powered electric cars were mentioned as a possible solution that could stand at the end of development, with an expected market breakthrough in about 20 years' time in 2004.

In the following years, Volkswagen concentrated on the support of research in biogenic fuels, hoping for continuing relevance of its existing knowledge in internal combustion engine technology. In 2005, this approach was complemented with hybrid drive concepts. The long-term goal was the development of fuel-cell powered cars, and from 2007 also of battery electric cars. Market maturity of electric drivetrains featuring either fuel cells or batteries was expected to be reached twenty years later.

A focus of Volkswagen's R&D activities was laid on the development of modular architectures in order to allow synergies between all of the Group's brands. These efforts resulted in the creation of the MLB matrix system for longitudinally installed engines in 2007 and a second architecture called MQB for vertically installed engines in 2012. As a consequence of the company's focus on parallel development of improved ICEs, hybrid drivetrains and electric cars featuring batteries or fuel cells, this latter platform already was developed in a way that allowed installation of the whole variety of different drivetrains. However, due to the poor range of BEVs at the time, Volkswagen stressed the importance of further advancements in battery technology before market maturity of these cars could be reached. In the meantime, BEVs were only considered a viable solution for short distance travels, whereas ICEs and hybrid drivetrains were expected to allow coverage of longer distances in the medium term. FCEVs were seen as the most viable solution for individual mobility in the long term.

In 2008, Volkswagen expected a market share of 13% for electric cars by 2020. Alternative drivetrain technologies were bundled under the BlueMotion Technologies label for the Volkswagen brand from 2009, with similar labels introduced for all other brands at roughly the same time.

In 2010, first fleet trials with battery electric cars were started, which lasted until 2012. Market maturity of fuel cell cars was not expected before 2025 at the time, whilst improvements in battery technology already increased the technology's attractiveness for application in niche markets. However, ICEs were still expected to dominate for the next twenty years. At the same time, hybrid drive development was advanced with the market introduction of Volkswagen's first series production HEVs from 2010. Those were considered as combining the advantages of both technologies. The increased relevance of the topic led to the creation of a general department for electric mobility in 2011 in order to orchestrate all brand's respective activities within the whole Group. The aim was to reach a share of BEVs of 3% of all sold cars in 2018.

In 2013, Volkswagen introduced its first series production BEVs and PHEVs. In 2014, a dedicated e-mobility campus was opened in Wolfsburg with workplaces for more than 1000 engineers. Research and development expenditures had already reached twice the level of 2010 by the time as a consequence of ongoing investments into alternative drivetrain technologies. After Volkswagen had already stressed the importance of close cooperation with suppliers in previous years for reaching fast market maturity of new technologies, 2015 saw the creation of its Future Automotive Supply Tracks initiative. Selected suppliers have since then been integrated in development projects at an even earlier stage through this program in order to leverage their existing technological competences.

Following the Diesel Scandal, in which Volkswagen was accused of manipulation for reducing CO_2 fleet emissions of its vehicles, Matthias Müller was appointed CEO in 2015. Subsequently, he introduced a new strategy program called "TOGETHER – Strategy 2025" that consists of four pillars: transformation of the core business towards electric mobility and autonomous driving, the creation of a new business field for sustainable mobility services, increased innovative efforts regarding digitalization and industry 4.0, and an optimization of portfolios and processes in order to be able to finance needed investments. Altogether, these measures should safeguard Volkswagen's transformation from a producer of cars to a provider of sustainable mobility.

More than 20 additional PHEVs and BEVs were announced until 2020, a goal that was even increased in following years to 80 new electrified models by 2025, 50 of which BEVs. At this point in time, Volkswagen plans to offer electrified variants of all of its more than 300 different models. The basis for this electrification offensive is a newly developed modular electric drive matrix called MEB that will be complemented by a number of additional vehicle platforms designed for purely electric drivetrains in the future. Cooperation with engineering service providers and external partners is considered a key factor of success by Volkswagen for achieving this goal. As a result, Volkswagen intends to achieve a BEV share of 20 to 25 percent of its sold cars by 2025; investments of €20 billion are planned until 2030. Due to the lack of appropriate infrastructure, hydrogen fuel cell cars are not considered a medium term solution for individual mobility any more, whilst a range of 300 to 600 kilometres allows usage of BEVs for medium and long distance drives. Nevertheless, Group research activities in the area of fuel cell technology are continued under coordination by Audi.

BEVs and their components have been built within Volkswagen Group's production network since 2013 alongside conventional models at facilities in Bratislava, Dresden and Wolfsburg. The current electrification strategy called Roadmap E led to the start of production for the first next generation BEV with a range of almost 500 kilometres in 2018 at the company's Brussels plant together with its battery system, whilst electric engines are manufactured at a dedicated facility in Györ (Hungary). Porsche's first BEV model has been assembled in a dedicated production line at its headquarters in Zuffenhausen since 2019. Production of the first cars belonging to the Volkswagen ID family based on the new MEB platform is scheduled to start at the end of 2019. For this purpose, Volkswagen adapted its production facilities in Zwickau to only produce cars designed upon MEB, making the plant its European e-mobility centre of competence. From 2021, more than 300000 BEVs are to be assembled there annually. Battery systems are manufactured in Brunswick, whilst electric motors come from Volkswagen Group Components' plant in Kassel. In the future, additional BEVs will be built in Hanover, Emden, Böllinger Höfe, Mlada Boleslav (Czech Republic) and Chattanooga (USA).

As a consequence of its endeavours to improve engine efficiency and develop alternative drivetrain technologies, the Volkswagen Group was able to reduce the fleet CO_2 emissions of its offered vehicles in Europe below the legal limit of around 130 g/km in 2015. However, in spite of constantly growing sales figures of its fully electric and plug-in electric vehicles, Volkswagen Group's was not able to further reduce the average CO_2 fleet emissions from 120 g/km (NEDC) in 2016. Instead, the value increased to 123 g/km (WLTP) in 2018 as a consequence of a shift in demand from diesel towards gasoline powered cars and new measurement methods. In order to reach the legal goal of around 95 g/km which will be phased in from 2020, additional measures will be necessary.

9.5.3 Volkswagen Group's BEV Projects

First tests with battery electric cars were conducted at Volkswagen as early as in 1976 with converted Volkswagen Golf models that featured a DC engine of 50 kW and a lead-acid battery that allowed a range of 50 kilometres. The same year, Audi engineers fitted an Audi 100 with the first battery electric drivetrain in a prototype called Audi 100 C1. Research was continued with a short run of Volkswagen Golf I CitySTROMer in 1981 that again relied on lead-acid battery technology and were trialled in field testing in conjunction with electric utility RWE. The next generation car was called Volkswagen Golf II CitySTROMer, featured similar technology as the previous model and was built in a short run of 70 units in 1985. The cars were first deployed in fleet testing with energy companies to gain practical insights in everyday use and later sold to private individuals. In 1992, a SEAT Toledo was equipped with an electric drivetrain and used as an escort vehicle at the 1992 summer Olympic Games in Barcelona. The next short run of 120 vehicles was manufactured from 1993 to 1996. In spite of the advantages of already existing sodium metal chloride batteries, Volkswagen again implemented lead-acid battery technology in the cars called Volkswagen Golf III CitySTROMer. Nevertheless, the range of the cars had been increased to 90 kilometres.

It should take another thirteen years, until Volkswagen presented its next all-electric car with the e-up! concept car in 2009 based on the newly developed "New small family" with an electric engine of up to 60 kW and 210 Nm. This was Volkswagen's first BEV powered by lithium-ion battery technology. The same year, Audi presented two versions of its e-tron concept study with two asynchronous electric motors that allowed for a system output of 150 kW and 2650 Nm and the Audi R8 e-tron Concept with a futuristic drivetrain consisting of three electric motors and a solid state battery. The car was intended to be hand-crafted in a small series production at Audi Sport from 2012 with lithium-ion battery technology. However, the project was abandoned due to problems related to battery costs after only ten units had been finished. A second short run was manufactured and distributed to customers from 2015 to 2016, this time with two electric engines of 170 kW each and a lithium-ion battery with 92 kWh.

First fleet trials of the new technology were conducted with a fleet of eighty Volkswagen Golf VI Blue-e-motion from 2010. The same 85 kW electric engine and 26.5 kWh lithium-ion battery were also implemented in Volkswagen Lavida blue-e-motion prototypes in 2010 and SKODA Octavia Combi Green E-Line and Audi A3 e-tron prototypes in 2012. The goal was to test components intended to be used in a series of electric versions of several models. However, the only car that finally entered series production was the e-Golf that was manufactured in Wolfsburg from 2014. The first generation featured an 85 kW synchronous motor and a lithium-ion battery with 24.2 kWh which was updated to a 100 kW engine and a 35.8 kWh battery for the second generation in 2017.

Already in 2013, Volkswagen had celebrated the market launch of its first series production BEV: the e-up! with a 60 kW engine and a 18.7 kWh lithium-ion battery. A second generation was announced for 2019 with an increased battery now featuring 32.3 kWh and a slightly improved electric engine with 61 kW. Additionally, the car has been marketed as SEAT Mii electric and SKODA CITIGO iV from 2019.

2015 saw presentations of the first concepts of two new electric cars. Audi showed the e-tron quattro concept, an all-electric SUV that is based on the MQB platform architecture with an all-wheel drive consisting of three electric motors with up to 370 kW and a new battery technology that allowed a range of 500 kilometres. The car entered series production at the end of 2018. An additional Audi e-tron Sportsback was announced to be launched in 2019 based on the same platform.

Also in 2015, Porsche gave a glimpse of its vision of an all-electric sports car with the Mission E. The car was launched to the market in 2019 as Porsche Taycan with permanently excited synchronous machines and a 93.4 kWh lithium-ion battery. This model not only is Porsche's first fully electric car, but also the first BEV with an 800-volt power network.

In 2016, Volkswagen showed the first concept car designed upon the newly developed MEB platform for electric mobility with the BUDD-e. After additional concept studies, a study called ID was announced to be the first series production car of the new family from 2019. Accordingly, the whole family of cars based on the modular electric drive matrix was named ID; the model to enter series production in 2019 will be called the ID.3. Series production versions of the Volkswagen ID.Buzz, ID.Buggy, ID.Roomz, ID.Crozz and ID.Vizzion are to be manufactured from 2022 at latest together with models of other brands that are based on the same architecture, like the Audi Q4 e-tron, SEAT el-Born, CUPRA Tavascan and ŠKODA Vision iV.

For 2020, Audi announced the series production of an all-electric sports car called Audi e-tron GT based on the same architecture as Porsche's Taycan.

A number of additional all-electric prototypes and concept studies were presented by Volkswagen Group's brands in the course of the last years. However, a full list would exceed the scope of this thesis. Those can be found in the timeline in Figure 48 together with all other BEVs.

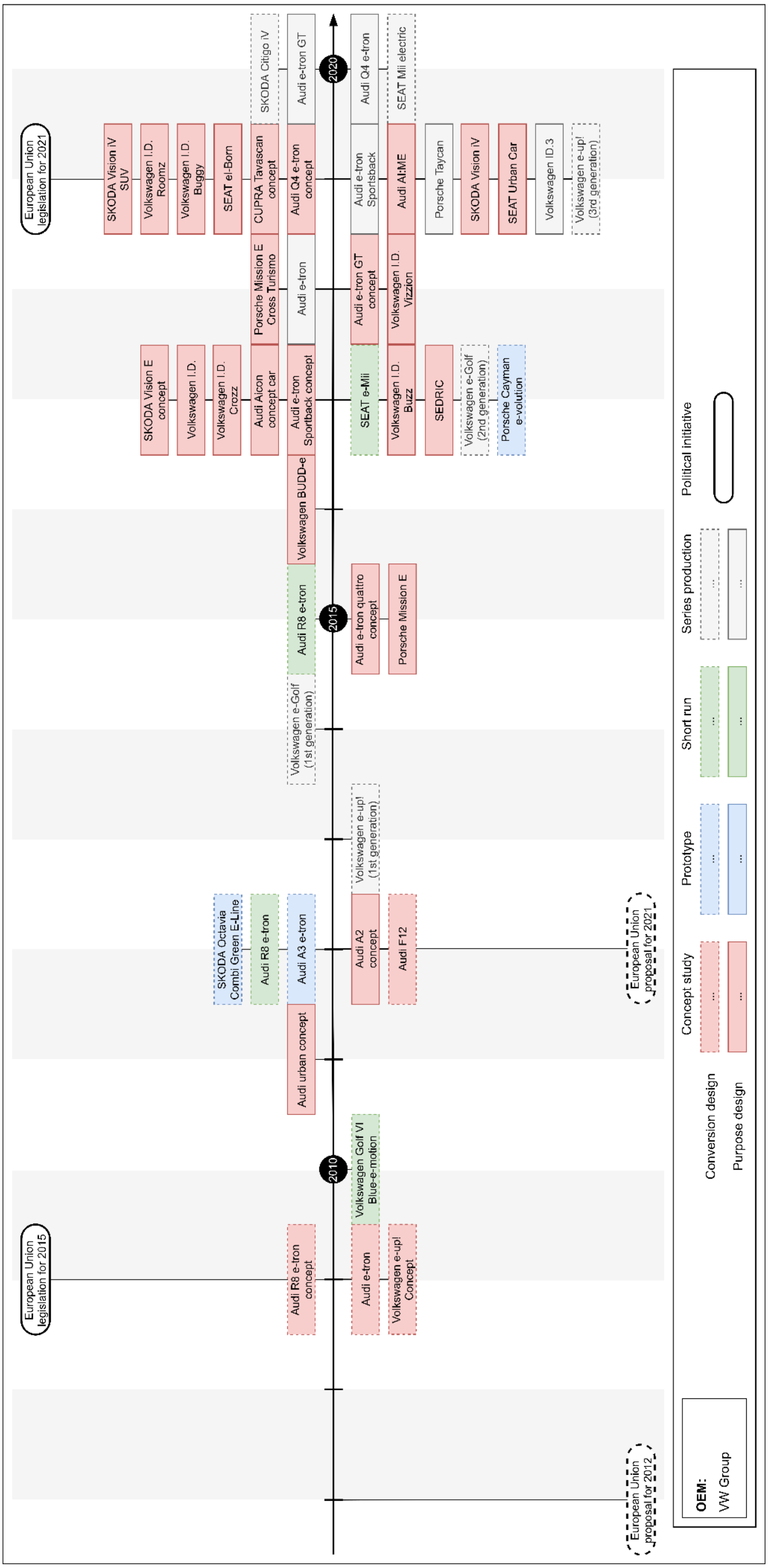


Figure 48: Timeline of Volkswagen Group's BEV projects (own creation)

9.5.4 Volkswagen Group's IORs in Complete Vehicles

Development work for battery electric cars started at Audi with the presentation of two show cars in 2009. Since then, a number of concept studies has been presented. Additionally, Audi produced a short run of Audi R8 e-tron sports cars in a cooperation with Audi Sport. From 2015, Audi's engineers were working on a new electric car architecture based on the Volkswagen Group's MQB platform which has been produced at Audi's Brussels plant as the Audi e-tron since 2018. In 2017, Audi announced to have started work on three new joint platforms with Porsche, one of which will be called PPE and enter series production in 2021. Another one has already been publicly presented with Porsche's Taycan and will also be produced as the Audi e-tron GT at Audi Sport in Böllinger Höfe from 2020. Series development of the car started in 2018 at Audi Sport.

Also in 2009, the Volkswagen brand presented its first BEV with a concept study of the e-up!. Since then, numerous concept studies have been presented. In 2013, series production of electric cars started at Volkswagen with the e-up! and later also the e-Golf at facilities in Dresden, Wolfsburg and Bratislava. In 2019, series production of the new ID.3 started at Zwickau, further BEV models will also be manufactured by Volkswagen at Hanover, Chattanooga and Emden. The ID.3 is based on a new modular electric drive matrix that has been developed at Volkswagen since 2015 and will also serve as a basis for cars marketed under the Audi, ŠKODA and SEAT brands.

In 2015, Porsche took up development work for the Porsche Mission E project, which was presented as the Porsche Taycan in 2019. The car is manufactured at Porsche's own plant in Zuffenhausen. Additionally, future electric car architectures are developed in close cooperation with the sister brand Audi. In 2018, Porsche entered a strategic alliance with Croatian electric sports car manufacturer Rimac for joint development of electric car technology. The deal also includes the acquisition of a 10% share in the start-up.

SEAT's and ŠKODA's first electric cars will be introduced in 2020 based on Volkswagen's e-up! and manufactured at Volkswagen Group's plant in Bratislava. Volkswagen Group announced to increase the number of plants in the future that produce cars for more than one of its Group brand.

In 2019, Volkswagen announced that its MEB architecture will also be offered to other companies in an attempt to reach economies of scale. In the course of this project, a small-series BEV based on the modular electric matrix will be developed and manufactured in a partnership with e.GO.

Volkswagen's plans for the MEB architecture also include relationships that can be considered pure customer relationships. This way, Volkswagen intends to be able to market the car at prices that are competitive to conventionally powered cars. The first customer was announced to be Ford as part of a partnership that focuses on joint development of artificial intelligence and commercial car. As Ford will pay a fee to Volkswagen for each unit delivered to them, the MEB architecture had already been developed by Volkswagen beforehand and the focus of the existing partnership lies in other areas, the relationship is considered to be a market transaction in this area according to the criteria applied in this thesis.

A timeline of Volkswagen Group's timeline of interorganizational relationships for research, development and manufacturing of complete BEVs can be found in Figure 49.

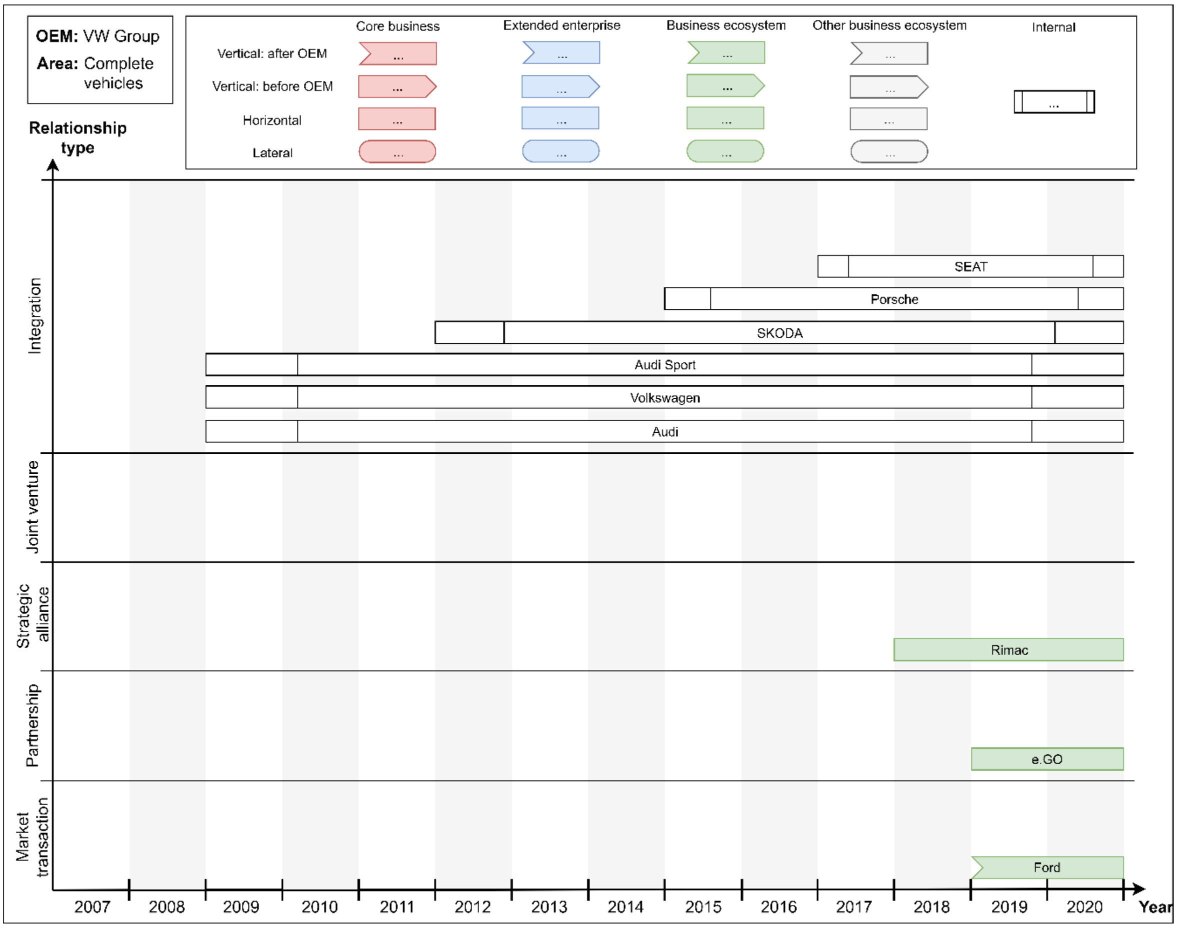


Figure 49: Timeline of Volkswagen Group's IORs in complete vehicles (own creation)

9.5.5 Volkswagen Group's IORs in Raw Materials

Although Volkswagen Group secures its supply of rare raw materials like cobalt, nickel and lithium over long-term contracts, not much is known about actual partners.

In 2019, Volkswagen announced to have signed a ten-year contract for lithium supply with Ganfeng Lithium. The deal also includes a partnership for research in battery recycling and solid-state battery technology.

A timeline of Volkswagen Group's interorganizational relationships for sourcing of raw materials can be found in Figure 50.

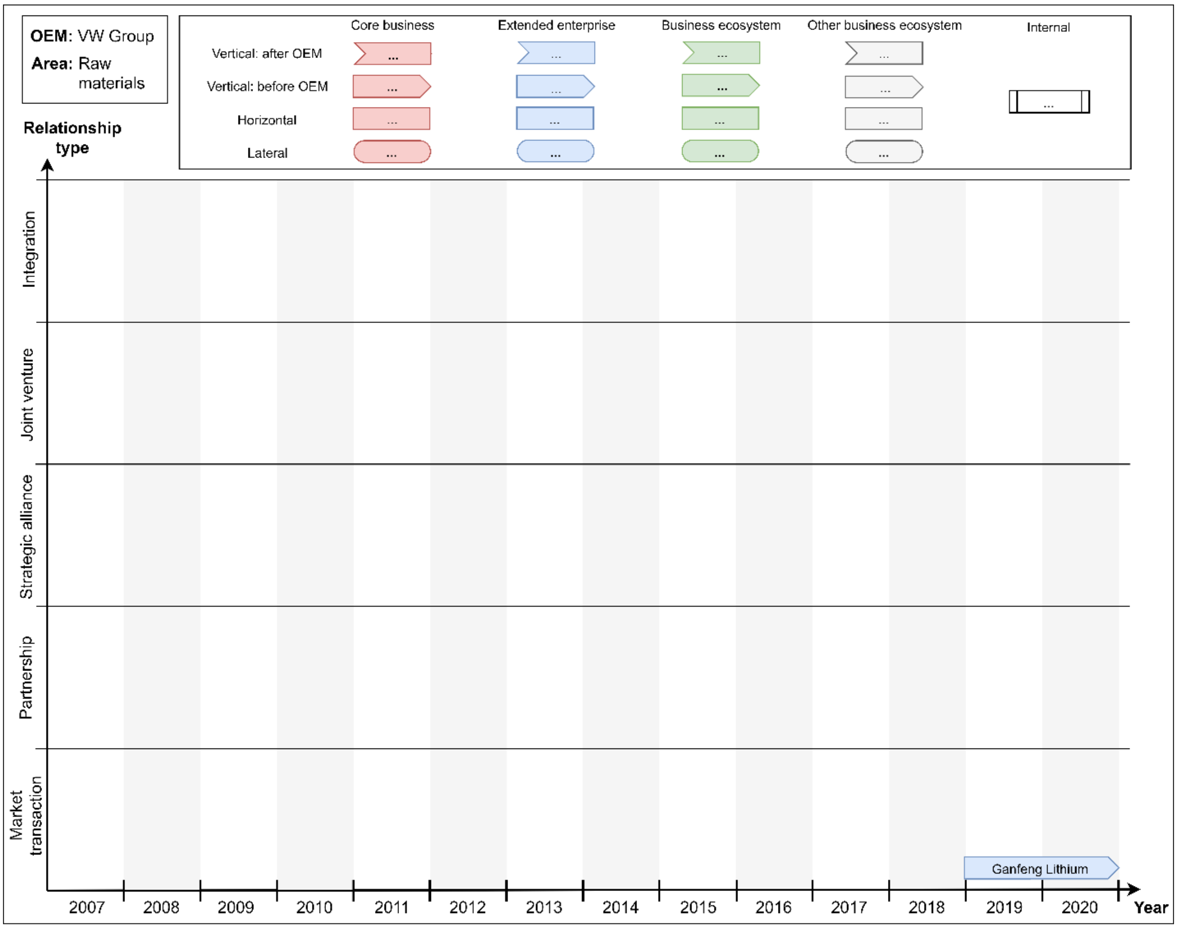


Figure 50: Timeline of Volkswagen Group's IORs in raw materials (own creation)

9.5.6 Volkswagen Group's IORs in Battery Cell Technology

Already in 2008, Volkswagen entered a first partnership with Sanyo for the development of lithium-ion batteries that should be suitable for automotive purposes in battery electric and hybrid cars. The company should stay Volkswagen's and Audi's supplier of battery cells until 2016 even after it was acquired by Panasonic in 2012.

In 2010, a joint venture was founded with German battery expert company Varta for research in automotive lithium-ion battery cell technology. The aim was to develop an improved cell chemistry and find technologically and economically superior production procedures. Varta intended to contribute to the project with its knowledge regarding battery cell technology and manufacturing procedures. The project was supported by public funding and prolonged in 2014. In 2018, the joint venture ended its operative activities after contracts had ended and Varta did not see any chance for a profitable business case in the future.

In 2012, Volkswagen Group's teamed up with QuantumScape for research in solid state battery technology. In the long term, production of respective cells is planned as well. The relationship was intensified in 2018, when a joint venture was founded that should safeguard Volkswagen Group's access to the technology. A long-term supply contract for lithium with Gangfeng Lithium signed in 2019 also includes a cooperation in solid-state batteries.

From 2014, Volkswagen Group has been engaged in a partnership with Forge Nano to explore new material coating technologies in an attempt to improve lithium-ion battery performance.

From 2015, Audi was developing a traction battery system for its e-tron electric cars based on cells supplied by LG Chem and Samsung SDI. Both companies also served as suppliers for a new generation of battery cells to be used in the Volkswagen e-up! and e-Golf models from 2017 and were named key suppliers of battery cell technology for BEVs based on the newly developed modular electric drive matrix from 2019 alongside SK Innovation.

Batteries are considered the main differentiation instrument of BEVs by Volkswagen Group. For this reason, the Group bundled its battery cell research activities in a centre of excellence in Salzgitter in 2017, where also a pilot production line for battery cells is located.

In 2019, Volkswagen Group announced the creation of a joint venture with Northvolt that is intended to take up lithium-ion battery cell production at Volkswagen Group's Salzgitter site at the end of 2023 or beginning of 2024. Volkswagen Group invested €900 million and expects an annual output of 16 GWh of batteries in the future.

A timeline of Volkswagen Group's interorganizational relationships in battery cell technology can be taken from Figure 51.

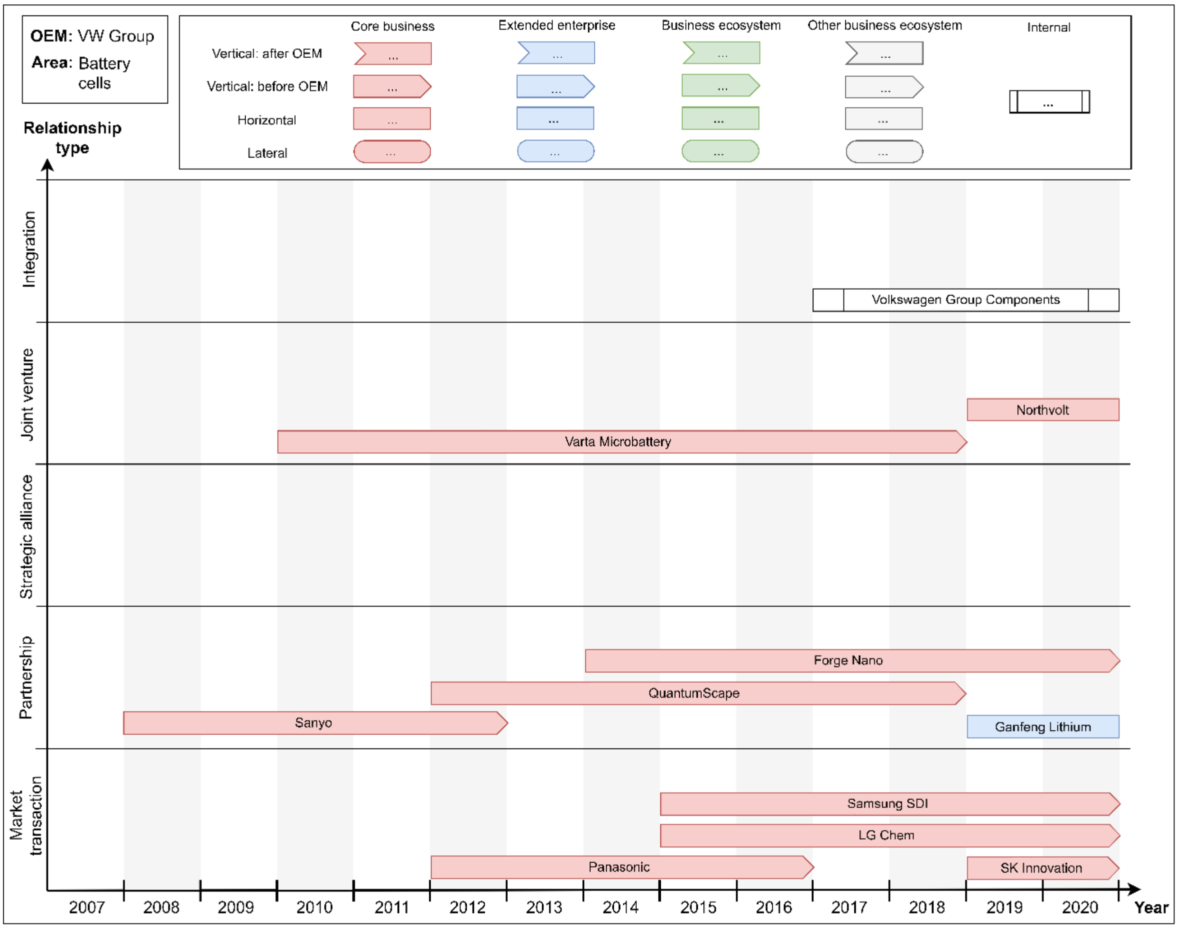


Figure 51: Timeline of Volkswagen Group's IORs in battery cell technology (own creation)

9.5.7 Volkswagen Group's IORs in Battery System Technology

From 2008 to 2012, the Volkswagen Group was involved in a partnership with Sanyo for the joint development of lithium-ion battery systems that could be used for automotive applications. At roughly the same time, from 2009 to 2010, another partnership with Toshiba existed, which aimed at the joint development of next-generation battery systems.

Volkswagen Group regards battery systems as the core competence for developing BEVs. For this reason, Volkswagen's battery system development was fully internalized for the following years, starting with battery systems for the Volkswagen Golf Blue-e-motion in 2010 that were manufactured by the company itself. In 2013, a battery system production plant was opened in Brunswick that has since then been the exclusive supplier of battery systems for Volkswagen's e-up! and e-Golf models. Production was extended in 2018 to also manufacture battery systems for all cars based on the new MEB platform. An additional battery system factory is expected to open in Chattanooga (USA) in the coming years.

Already in 2012, Audi took up development of battery systems at a dedicated competence centre in Gaimersheim, which also includes a pilot production line for prototypes. Battery systems for Audi's R8 e-tron and e-tron have been developed there. The battery system of Audi's current e-tron BEV is built at a production facility in Brussels.

Porsche's Taycan sports car presented in 2019 features a battery system that is supplied by Dräxlmaier Group.

A timeline of Volkswagen Group's interorganizational relationships in battery system technology can be found in Figure 52.

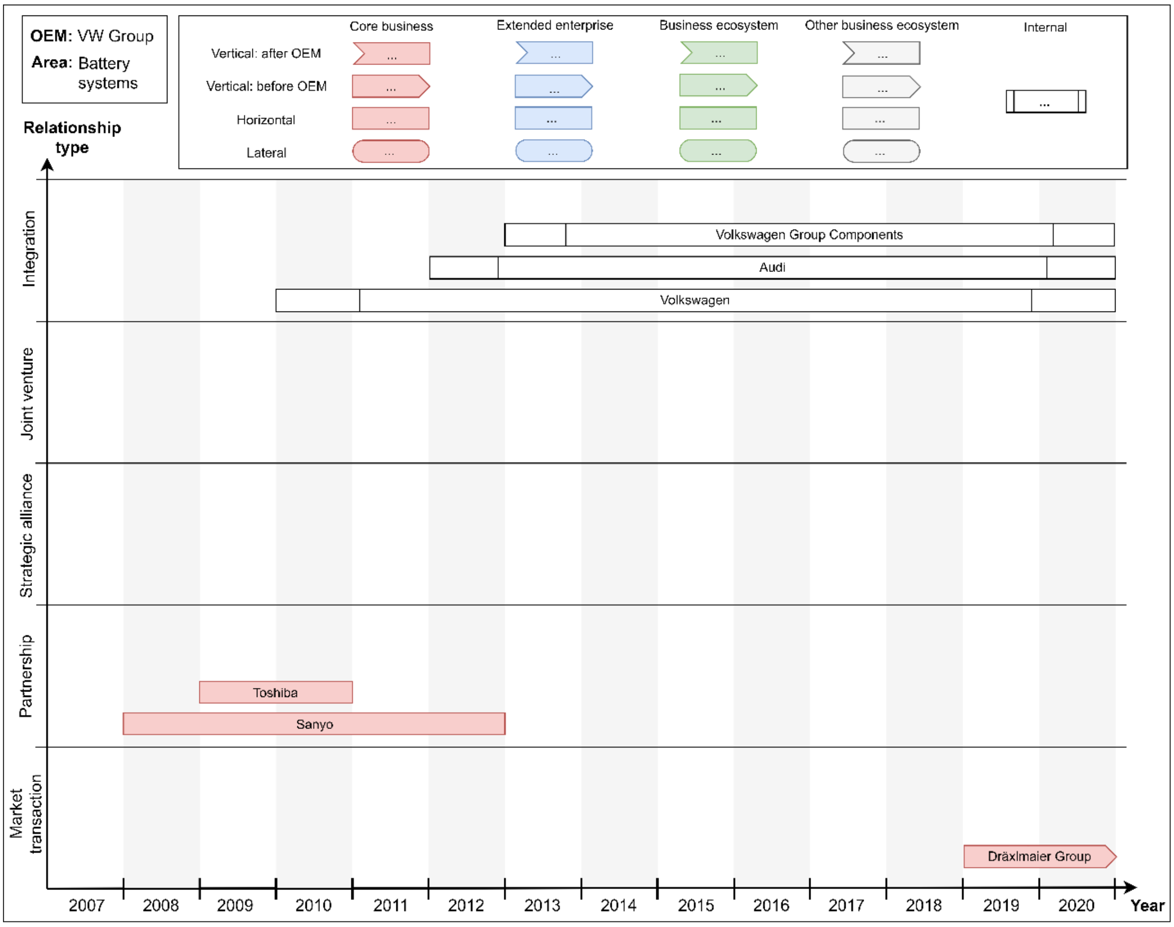


Figure 52: Timeline of Volkswagen Group's IORs in battery system technology (own creation)

9.5.8 Volkswagen Group's IORs in Electric Drivetrain Technology

After a strategic alliance with Toshiba for the development of an electric drivetrain for Volkswagen's "New Small Family" that lasted from 2009 to 2010, Volkswagen manufactured drivetrains for the series production version of the resulting e-up! at its plant in Kassel from 2013. Electric motors for all of Volkswagen's prototypes and publicly available BEVs have been manufactured there since 2010, making it Volkswagen Group's competence centre for electric drivetrains.

Audi considers the production of electric motors a strategically important area in its transformation process towards electric mobility. For this reason, series production of electric engines for its e-tron models started at Audi's engine plant in Györ (Hungary) in 2018, where development work had also been carried out beforehand.

Electric motors for Porsche's Taycan model have been developed by Porsche since 2015 and are manufactured by Porsche at its headquarters in Zuffenhausen.

A timeline of Volkswagen Group's interorganizational relationships in electric drivetrain technology can be taken from Figure 53.

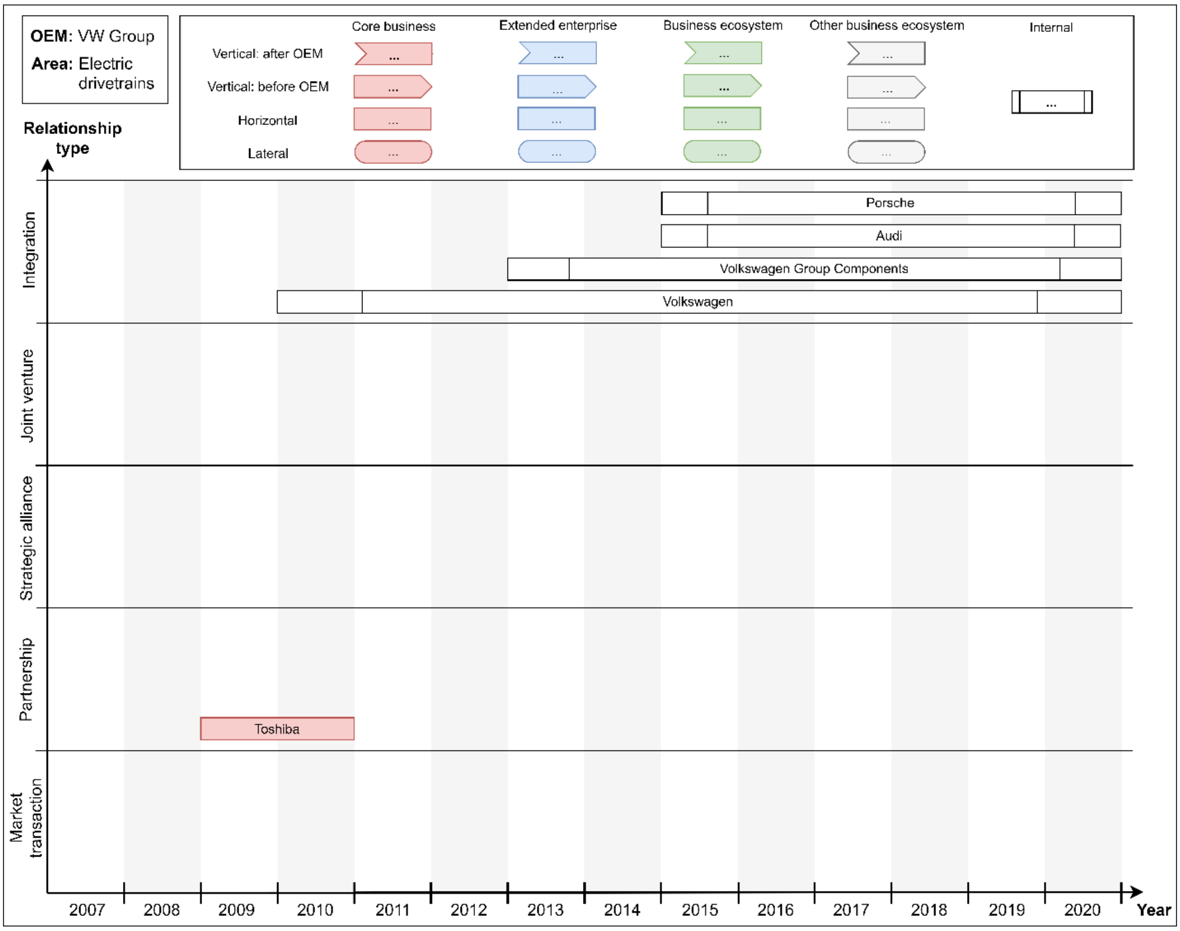


Figure 53: Timeline of Volkswagen Group's IORs in electric drivetrain technology (own creation)

9.5.9 Volkswagen Group's IORs in Charging Infrastructure

Volkswagen Group's activities in charging infrastructure did not start before 2016, when the Volkswagen Group entered the already existing joint venture Hubject between BMW, Bosch, Daimler, EnBW, innogy and Siemens. The aim of the company is to offer a platform for charging infrastructure users that allows access to a number of different charging networks over a single software interface. In 2019, enel X was welcomed as an additional partner in the joint venture.

Since 2017, the Volkswagen Group has been involved in a joint venture with Ford, Daimler and Hyundai with the Porsche, Volkswagen and Audi brands for the creation of a fast-charging network along highways in Europe called IONITY.

From 2018 to 2019, Porsche Engineering erected charging parks that feature Porsche's fast charging technology at Porsche dealerships. The goal is to promote fast charging with high-voltage power networks; additional fast charging parks might be installed at other dealerships in the future. Since the Taycan is the first series production car featuring 800-volt power network technology, appropriate charging infrastructure is considered a strategic necessity by Porsche.

In 2018 Volkswagen Group started development work on a mobile charging station for BEVs that can be deployed in regions with an insufficient power infrastructure. First stations of the type will be set up from 2019; the start of series production is expected for 2020.

The same year, Volkswagen announced a strategic partnership with supermarket chain TESCO for the installation of charging stations at TESCO's parking lots. Necessary equipment will be supplied by Pod Point, who will also operate the system in cooperation with Volkswagen. Altogether, more than 2400 stations at 600 supermarkets all over the United Kingdom are planned.

In 2019, Volkswagen Group founded Elli Group to provide full-service solutions for electric mobility, consisting of charging infrastructure, fleet management and the supply of CO_2-neutrally produced electricity in Germany.

Together with its electrification initiative, Volkswagen Group in 2019 announced the creation of a European charging network consisting of 36000 charging points at Volkswagen Group plants and dealerships throughout Europe. In total, more than €250 million will be invested in the project, which is part of Volkswagen's strategy to promote electric mobility as a viable solution for individual mobility on a daily basis. Additionally, Volkswagen Group partnered with charging infrastructure software provider has.to.be in order to achieve a simple, standardized and convenient charging experience at its stations.

In 2019, Volkswagen's WeCharge service was started which allows access to a high number of different partner charging networks for its customers. The service is part of an extensive "Volkswagen We" mobility ecosystem created by Volkswagen together with the launch of its first mainstream BEV model based on the MEB platform.

A timeline of Volkswagen Group's interorganizational relationships in charging infrastructure can be taken from Figure 54.

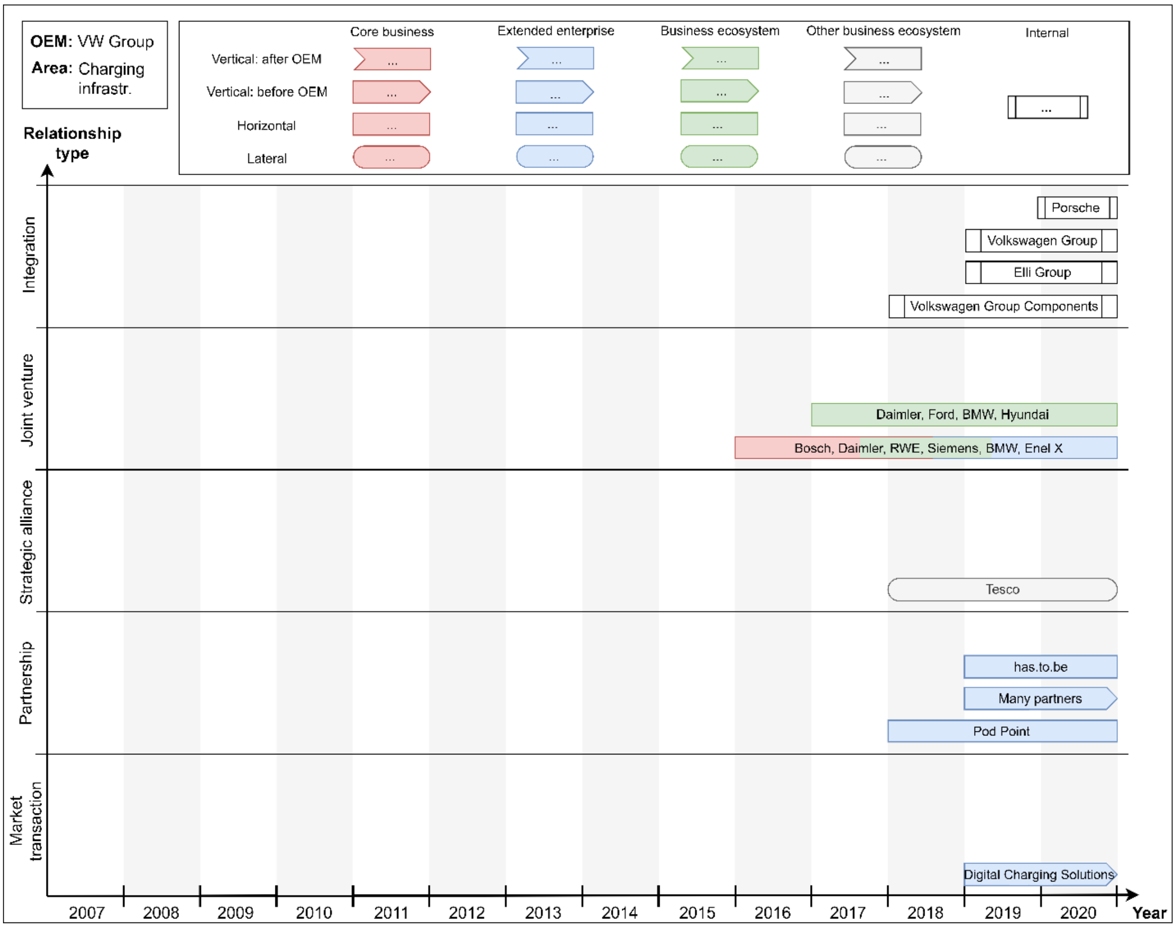


Figure 54: Timeline of Volkswagen Group's IORs in charging infrastructure (own creation)

9.5.10 Volkswagen Group's IORs in Mobility Services

In 2011, Volkswagen Group started its first car sharing project with 200 Volkswagen Golf in Hannover. As a consequence of the bad utilization rate and the resulting lack of economic viability, the project called Quicar was downsized in 2016 and operation was taken over by Greenwheels. Greenwheels is a Dutch car sharing provider which also operates in Germany and was said to be one of the few profitable car sharing companies at the time. In a joint venture with Pon Holdings, Volkswagen Group had already secured a share of the company in 2013.

Following the presentation of its new strategy in 2016, which includes mobility services as one of its four main pillars, Volkswagen Group intensified its efforts in this area. To reach the goal of becoming one of the leading providers of sustainable mobility, Volkswagen Group changed the focus from internal development towards partnerships, acquisitions and venture capital investments.

From 2016, Audi has been offering a short-time car rental model called “Audi on demand” at certain locations in Germany. Through a partnership between Audi and car rental company SIXT, customers of Audi on demand also have access to SIXT’s car park since 2019. Audi plans to expand its mobility services in the future under the Audi on demand brand.

In 2016, Volkswagen Group acquired a share of the ride hailing company Gett for $300 million. In the course of the resulting strategic alliance, Volkswagen Group offered discounts for Gett drivers for selected car models. Although the deal was announced as being a central part of Volkswagen’s strategy, it became common currency in 2018 that Volkswagen Group had to write off its investment following other companies’ market dominance.

The mobility start up MOIA was founded by Volkswagen Group in 2016. The company subsequently developed a purpose-designed car for ride hailing and ride pooling based on Volkswagen Group’s existing knowledge in electric car technology. The service was first launched in Hamburg at the end of 2018 after extensive testing had taken place in Hanover from 2017.

From 2017 to 2018, Volkswagen Group’s ŠKODA brand provided a car sharing service called HoppyGO in the Czech Republic. In 2018, the company was merged with Leo Express to form a joint venture that offers peer-to-peer car sharing and other products related to mobility as a service.

In 2018, Volkswagen Group founded UMI Urban Mobility International to offer a car sharing service called WeShare as part of its Volkswagen We mobility ecosystem. The service was scheduled to start in Germany in 2019; an international rollout is planned from 2020 with an all-electric fleet. Additionally, a parking service has been offered by the newly founded enterprise since 2018.

As the last of the four volume brands under the roof of the Volkswagen Group, SEAT introduced test operations of a car sharing service in Barcelona with a small fleet of five e-Mii electric car prototypes in 2018. The same year, the brand acquired the car sharing company Respiro to offer car sharing services in Madrid for the first time.

A timeline of Volkswagen Group’s interorganizational relationships for mobility services can be found in Figure 55.

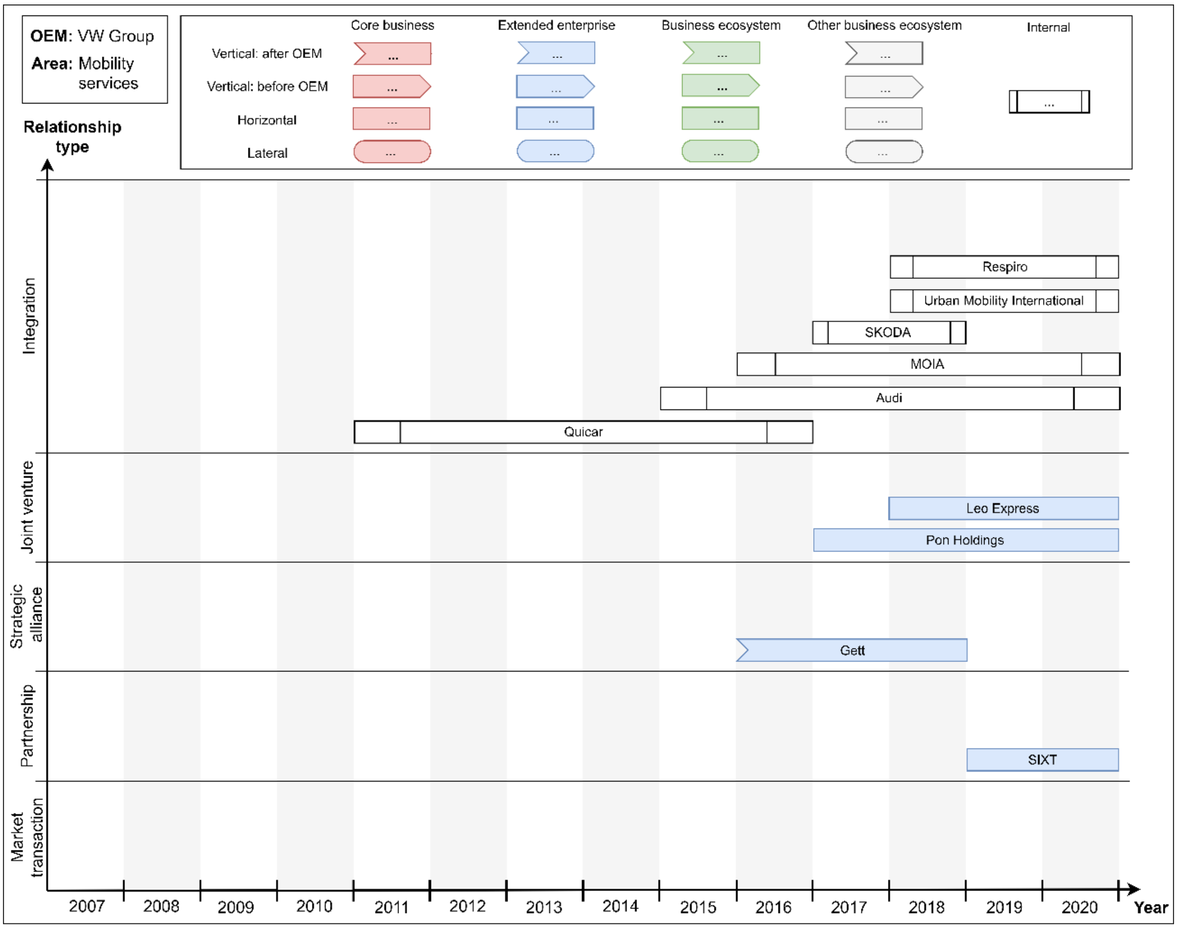


Figure 55: Timeline of Volkswagen Group's IORs in mobility services (own creation)

9.5.11 Volkswagen Group's IORs in Battery Reuse and Recycling

Due to the small scale of BEV production before 2016, no actions towards battery reuse and recycling by Volkswagen Group are known before the introduction of its new strategy in 2016. From 2017, Audi started tests with old EV traction batteries to power its fleet of electric cars used in its production plants. The vehicles had previously been powered by lead acid batteries. In 2019 Audi opened a test facility in Berlin that uses second use automotive lithium-ion batteries for power grid balancing. At the same laboratory, concepts for battery recycling will be developed.

Volkswagen Group Components' mobile charging solution for BEVs features second use batteries that are used for storing electric energy in regions where the power grid is too weak to allow fast charging of battery electric cars. The concept currently has been tested since 2018 and is scheduled to enter series production in 2020.

A long-term supply contract with Ganfeng Lithium signed in 2019 also includes joint research in battery recycling. Additionally, Volkswagen Group's battery competence centre in Salzgitter will house an additional pilot plant for battery recycling from 2020.

A timeline of Volkswagen Group's interorganizational relationships in battery reuse and recycling can be taken from Figure 56.

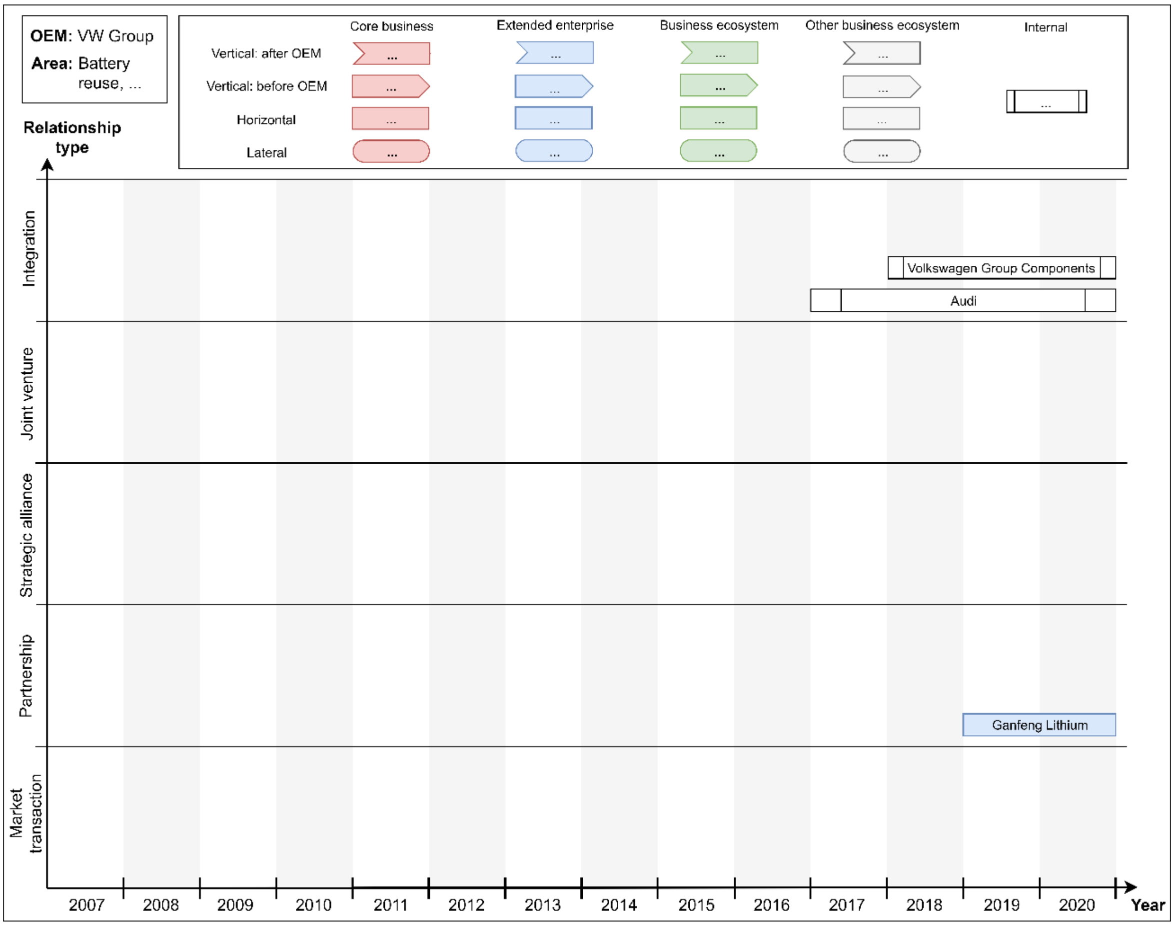


Figure 56: Timeline of Volkswagen Group's IORs in battery reuse and recycling (own creation)

9.6 Results

A comparison of all three case studies allows gaining insights into general trends caused by the shift towards BEVs.

9.6.1 Activities Towards Alternative Drivetrains

BMW, Daimler and Volkswagen Group all incorporated different alternative drivetrain technologies at roughly the same time, according to their business reports. Although fuel cell technology seemed to be the most promising technology before 2005, already in 2007 all three OEMs considered BEVs an equally valid solution (see Table 17). Nevertheless, neither of both technologies was yet mature enough, which is why the importance of HEVs was stressed as an intermediate solution.

Alternative drivetrain technology	**Part of OEMs' strategy since**		
	BMW	**Daimler**	**Volkswagen Group**
HEV	2005	Before 2004	2005
BEV	2007	2007	2007
FCEV	Before 2004	Before 2004	Before 2004

Table 17: Comparison of OEM's alternative drivetrain strategies (own creation)

All three OEMs started to consider BEVs a viable solution for future individual mobility for the first time in 2007, which is the same year when first legally binding CO_2 emission goals were announced by the European Commission for 2012.

OEM	Alternative drivetrain technology	
	Currently offered	**Only R&D**
BMW	BEVs; PHEVs; Optimized ICEs	FCEVs
Daimler	BEVs; PHEVs; Optimized ICEs; FCEVs	-
Volkswagen Group	BEVs; PHEVs; Optimized ICEs	FCEVs

Table 18: Current and future drivetrain strategy of BMW, Daimler and Volkswagen Group (own creation)

Due to the fast progress in lithium-ion battery development and technological problems correlated with hydrogen fuel cell technology, currently BEVs, PHEVs and optimized ICEs are included in the official short- and medium-term drivetrain strategy of all considered OEMs. Daimler even offers an FCEV, whilst BMW and Volkswagen Group at the moment do not manufacture FCEV models. Nevertheless, fuel cell-powered cars are part of all considered OEM's long-term powertrain strategy, which is why they perform R&D activities in this area. All considered OEMs expect a slow change towards battery electric drivetrains and the parallel existence of a myriad of different drivetrain concepts for the coming years.

In the face of the needed development effort in many different drivetrain technologies at the same time, BMW, Daimler and Volkswagen Group consider cooperation with other companies a necessary step.

9.6.2 BEV Projects

Although BMW, Daimler and Volkswagen all incorporated BEVs into their official drivetrain strategy in 2007, the first actual vehicles were not presented and marketed at the same time by the three OEMs. As can be seen in Figure 30, Figure 39 and Figure 48, the latest wave of BEV projects started in 2006. Daimler and BMW had already developed, presented and tested first concepts earlier; Volkswagen's experience was only limited to lead acid battery technology at the time.

Table 19 shows the sequence of first cars of this latest wave of BEV development. All dates are quite similar to each other. The only exception is the fact, that BMW produced its first purpose designed BEV much earlier than Daimler and Volkswagen Group. Again, it has to be mentioned, that only the Smart fortwo electric vehicle concept car was presented before the European Commission presented its proposal for legally binding CO_2 emission goals for 2012 in 2007. However, this might be explained by the fact, that the car had already been intended to feature an electric drivetrain by Nicolas Hayek when the joint venture with Daimler was started in 1994.

Although purpose designed concept cars had already been presented before, the first purpose designed series production cars have only been manufactured since 2018 and 2019 at Daimler and Volkswagen Group.

Regarding production of BEVs, all three OEMs bet on flexible electric powertrain architectures for their electric cars that can be scaled to a variety of different car segments. Daimler and BMW both intend to manufacture their electric vehicles within their existing production networks after some modifications in the future. Although this allows flexible reaction to demand and high utilization rates, it at the same time necessitates compromises in the design of their BEVs. In contrast to BMW's and Daimler's manufacturing strategy, Volkswagen Group dedicates one of its biggest vehicle production plants to the exclusive production of battery electric cars. A high utilization rate is intended to be achieved by only concentrating on a small number of different platforms that are used as a basis for many different models of all its brands.

	BMW	Daimler	Volkswagen Group
First concept study of BEV	2009	2006	2009
First short run of BEV	2008	2007	2010
First series production of BEV	2013	2012	2013
First series production of purpose-built BEV	2013	2018	2019

Table 19: First BEVs developed by BMW, Daimler and Volkswagen Group after 2006 (own creation)

9.6.3 IORs in Complete Vehicles

Daimler already started to include other companies in the development and manufacturing process of its BEVs at a very early stage, beginning in 2007. Since then, Daimler has been involved in partnerships, strategic alliances and joint ventures almost without any interruption. Additionally, the intensity of relationships increased over the years, starting with a market relationship in 2007 and leading to two joint ventures and one strategic alliance at the moment.

Interestingly, quite the contrary is the case for BMW and Volkswagen Group. Except for one Chinese joint venture that will take up exclusive manufacturing of the new BMW iX3 in 2020 for the world market, BMW has not been and is not involved in any market relationships, partnerships, strategic alliances or joint ventures regarding complete vehicles and involved knowledge. The step of outsourcing the exclusive manufacturing of a whole vehicle to China however, can rather be understood a strategic move that underlines the importance of the Chinese market for BEVs than the explicit will to cooperate on this topic. Foreign companies are only allowed to operate subsidiaries in China if they form joint ventures with domestic companies.

Volkswagen Group shows a similar situation: Until 2018, Volkswagen only relied on internal competencies for the development and manufacturing of whole BEVs. Nevertheless, system suppliers in many singular areas are closely involved in Volkswagen's BEV projects at an early stage through its FAST program. Since 2018, the subsidiary Porsche is engaged in a partnership with Rimac. However, this can rather be seen to affect the segment of sports cars only and not the volume car business. The most important strategic move of Volkswagen in this context is its decision to open up its MEB platform to other companies as well. This way, Ford, another volume car manufacturer, can be considered Volkswagen's customer. On the one hand, the decision seems to be very bold, as Volkswagen invested billions in the development of this new modular electric drive matrix. On the other hand, however, this is probably the only way to achieve production volumes that are high enough to allow competitive pricing of BEVs.

Interorganizational relationships at this high level only occur with other OEMs, which are accounted to the business ecosystem sphere of the business ecosystem.

9.6.4 IORs in Raw Materials

In the face of the high price volatility of rare raw materials like cobalt, lithium and rare earths, BMW, Daimler and Volkswagen Group all signed long-term contracts for their supply. However, not all suppliers are known by name, and most IORs in this area are simple market transactions.

The only exception are components made from carbon-fiber reinforced plastics. In this area, BMW and Daimler have formed joint ventures with their suppliers. BMW even entered a strategic alliance with Toyota and a partnership with Boeing on the topic. However, the high costs of manufacturing could not be reduced sufficiently so that a wide scale adoption of the technology to the volume car segment is not very probable in the future. For this reason, both BMW and Daimler ended their respective joint ventures in 2014 and 2017. The BMW i3 stays the only BEV in series production to include large parts made from carbon-fiber reinforced plastics, but the topic is not considered a strategic necessity any more.

9.6.5 IORs in Battery Cell Technology

Daimler was the only company of the three considered OEMs to be engaged in battery cell manufacturing themselves. This effort dates back at the beginning of Daimler's BEV activities, when they formed a joint venture with Evonik Industries in 2008, when automotive lithium-ion battery cells were expected to be a differentiating technology that would be hard to obtain on world markets in the future. However, the opposite turned out to be the case: an overcapacity of battery cells exists on the market today, making production costs the single most important factor. Due to its low production volumes, Daimler's joint venture was not economically viable and ceased production subsequently.

Like all other OEMs had already done before, Daimler now sources battery cells from the world market using long-term supply contracts. Partnerships, strategic alliances or joint ventures only exist for research and development of future battery cell technology. Consequently, the number of closer relationships in this area is growing as market maturity of new technologies approaches. The only exception to this trend is Northvolt, which tries to establish a European lithium-ion battery cell supply chain. Both BMW and Volkswagen Group are involved in this project, which is intended to start production in the middle of the next decade. It has to be mentioned, that although no OEM is directly involved in lithium-ion battery cell manufacturing, all have internal R&D units for developing battery cell prototypes. This way, the strategic dependence from battery cell manufacturers is reduced.

Almost all IOR partners in the area of battery cells belong to the core business sphere of the business ecosystem, as those companies are direct suppliers to the OEMs.

9.6.6 IORs in Battery System Technology

BMW, Daimler and Volkswagen Group relied on other companies for battery system technology at the beginning of their BEV development and internalized development and manufacturing as the trend towards BEVs intensified. This is mainly due to the fact that battery system technology is considered the main differentiation instrument for BEVs by all examined OEMs. Except for Porsche's Taycan, which features a battery system supplied by Dräxlmaier Group, all OEMs develop and manufacture their battery systems in-house. As part of its decision to manufacture the BMW iX3 in China and export it to all other countries from there, BMW will also build battery systems in their joint venture with Brilliance. However, this can rather be considered a strategic move following the importance of the Chinese market in BEVs than the explicit decision to cooperate in this area.

Closer relationships in battery system technology existed either with direct suppliers, which are accounted to the core business sphere of the business ecosystem or in some cases also with other OEMs, which belong to the business ecosystem sphere. Daimler's former joint venture partner Evonik Industries stems from outside the automotive business ecosystem.

9.6.7 IORs in Electric Drivetrain Technology

In the area of electric drivetrain technology, all three OEMs follow different strategies:

BMW started its BEV activities by buying electric drivetrains through a market transaction. Since then, with only one short joint venture with PSA, BMW developed and built the electric drivetrain of its cars on its own. This status was kept until 2019, since when BMW is engaged in a strategic alliance with Jaguar Land Rover for electric drivetrain development. As part of its decision to manufacture the BMW iX3 in China and export it to all other countries from there, BMW will also build electric drivetrains in its joint venture with Brilliance. However, this can rather be considered a strategic move following the importance of the Chinese market in BEVs than the explicit decision to cooperate in this area.

Daimler never regarded electric drivetrains a differentiating factor in BEVs, which is why they never manufactured electric drivetrains in-house. Instead, they were sourced through a joint venture with Bosch, a strategic alliance with Tesla or through market relationships. After having ended the joint venture with Bosch in 2019, Daimler is expected to only acquire its electric drivetrains through long-term market transactions in the future.

Except for a short partnership with Toshiba, Volkswagen Group have always developed and manufactured the electric drivetrains of its cars in-house.

Partners in the area of electric drivetrains are only stemming from the core business sphere or the business ecosystem sphere of the business ecosystem.

9.6.8 IORs in Charging Infrastructure

The situation for charging infrastructure did not change much over time. Daimler was the first to enter the business area, followed by BMW. Volkswagen's activities in this area started after 2016, probably as a consequence of the new strategy introduced the same year. Additionally, Volkswagen Group is the only company to be engaged in charging infrastructure installation and operation on a broad scale without partners. Altogether, a trend towards increased cooperation in charging infrastructure can be identified for charging infrastructure.

In general, market transaction, partnership and strategic alliance partners in charging infrastructure originate from the extended enterprise, whilst joint ventures are mainly formed with other OEMs, which belong to the business ecosystem sphere of the business ecosystem.

9.6.9 IORs in Mobility Services

BMW already entered mobility services quite early with its DriveNow service in 2011. However, its activities in the area are less far-reaching than those of the other companies, who started later. The main trend for all three OEMs in mobility services was the acquisition of successful start-ups through own venture capital subsidiaries in the past. Those still exist, but since 2019, BMW and Daimler have bundled almost all of their activities in mobility services in a common joint venture. In comparison to its internal activities, Volkswagen Group's partnerships, strategic alliances and joint ventures with other companies in mobility services can be considered to be of minor importance.

Except for the joint venture between Daimler and BMW, cooperation in mobility services is restricted to companies in the extended ecosystem sphere of the business ecosystem.

9.6.10 IORs in Battery Reuse and Recycling

Due to the small scale of production in the past and the relative novelty of BEVs, not many activities can be noticed in this area yet. All OEMs are researching battery reuse and recycling internally. BMW additionally is involved in a joint venture and partnerships. Daimler uses partnerships as the main instrument in this area, together with one joint venture. Volkswagen almost entirely relies on internal activities.

Besides one exception, all joint ventures, strategic alliances and partnerships in battery reuse and recycling include companies accounted to the extended enterprise sphere of the business ecosystem.

9.6.11 Overall Tendencies

Following the last sections, a general tendency in all areas can be deducted for the three examined OEMs, which can be taken from Table 20. This table shows the latest trends, which are deducted from the latest changes in IOR strategy noticed for the respective area. In battery cell technology, only current technology is considered, as it is unclear, when future technologies will be available for automotive applications. Here, the superordinate category of cooperation is used to describe partnerships, strategic alliances and joint ventures.

Area	BMW	Daimler	Volkswagen Group
Complete vehicles	Internal activities	Internal activities and increased cooperation for development and manufacturing	Changed from internal activities to platform supplier for other OEMs
Raw materials	Changed from cooperation to long-term market transactions	Changed from cooperation to long-term market transactions	Long-term market transactions
Battery cell technology	Long-term market transactions	Changed from cooperation to long-term market transactions	Long-term market transactions
Battery system technology	Changed from cooperation to internal activities	Changed from cooperation to internal activities	Changed from cooperation to internal activities
Electric drivetrain technology	Changed from internal activities to increased cooperation for development	Changed from cooperation to long-term market transactions	Changed from cooperation to internal activities
Charging infrastructure	Increased cooperation	Increased cooperation	Internal activities and cooperation
Mobility services	Increased cooperation	Changed from primarily internal to cooperation	Internal activities
Battery reuse and recycling	No clear tendency	Increased cooperation	Internal activities

Table 20: Tendency of OEMs in all examined areas (own creation)

The differences in raw materials can be explained by the fact, that Daimler and BMW have ended their joint ventures for sourcing carbon-fiber reinforced plastic components and now also buy these components via market transactions.

The differences in battery cell technology can be explained by the fact that Daimler initially did not expect battery cells to become a commodity. However, the current market overcapacity for battery cells explains why all OEMs source battery cells through market relationships today.

Battery systems are today considered a main differentiation technology and therefore internally developed and manufactured. Cooperation at the beginning of OEM’s activities in BEVs can be explained by the necessity to build-up knowledge as fast as possible.

The same phenomenon of cooperation for building up knowledge can also be assumed to exist for electric drivetrain technology. The only exception is BMW who did not believe that another company could deliver an electric engine that would fulfil all of its requirements.

Battery reuse and recycling have not yet evolved to leading topics due to the small amounts of old BEV batteries existing today. For this reason, the category is excluded from further considerations.

Areas marked in grey in Table 20 show differences that cannot be explained with the data collected for case studies. For this reason, these differences will be further discussed in chapter 10.

Part IV: **INTERPRETATION OF RESULTS**

10 Discussion of Results

This chapter aims to discuss the results of all three research questions against the background of the underlying theoretic framework of this thesis. First, the lifecycle phase of the business ecosystem for BEVs is assessed. Second, the roles that OEMs play in this business ecosystem are analysed. Furthermore, an underlying mechanism for the observed changes and differences is proposed.

10.1 Assessment of Involved Technology

According to section 4.4, different kinds of innovation can be distinguished that can be classified along a continuum with two polar types. On the one side of this continuum, there are innovations that arise from regular innovative activities and which only have a limited impact on companies, industries and business ecosystems. The other side of this continuum consists of innovation concepts that cause far reaching changes in companies, industries or business ecosystems. Without closer examination of intermediate categories between the two polar types, it can be said, that electric mobility can be considered to belong to the second category of innovation. This is concluded from the fact that the assessed structure of the automotive business ecosystem for BEVs determined in section 7.3 includes many companies that are not considered to be a part of the automotive business ecosystem for conventional cars. Additionally, the wide-reaching consequences that follow from the shift towards BEVs for all involved players and which are described in detail in chapter 8 suggest that an allocation of BEVs at the lower end of the innovativeness continuum would not do justice to the technology's disruptive potential.

If the technology really can be considered a disruptive innovation according to the exact definition of Bower & Christensen (1995) is a question that exceeds the scope of this thesis. Additionally, the concept is considered to rather allow ex-post than ex-ante identification of innovations that fulfil all criteria, which further complicates an assessment (Christensen et al., 2018, p. 1051).

Regarding the technology lifecycle concepts described in section 4.2, assessment has to be split up in the three categories electric drivetrain technology, battery cell technology and battery system technology.

Taking into account the external technology sourcing strategy chosen by all three OEMs that were examined in the case studies in chapter 9, lithium-ion battery cell technology can be categorized as being in the basic technology lifecycle phase as described by Arthur D. Little. It is considered a commodity by all three OEMs. However, all next-generation battery cell technologies that have not yet been marketed for automotive purposes like lithium-air or solid state battery technology can be considered to be in the pacemaker technology stage of the technology lifecycle.

Battery systems clearly are a key technology following the technology lifecycle concept. All companies have internalized their efforts in the area as a consequence of the high significance of the technology for the range of BEVs. Since range is one of the most important differentiation instruments of BEVs and therefore the technology holds the potential of competitive advantages, access to it is highly strategically relevant, although development still is continuing.

A clear assessment of electric drivetrains according to the technology lifecycle is not possible due to the different strategies chosen by the examined OEMs in this area. However, as Daimler and BMW chose to reduce their development effort in this area by either ending an existing joint venture to source electric motors on the world market or starting to cooperate with other companies in this area, it can be concluded that the technology most probably is becoming a commodity as well. Thus, the technology can most appropriately assumed to be in the basic technology lifecycle phase.

10.2 Lifecycle Phase of the BE for BEVs

Applying Moore's (1996) concept of business ecosystem lifecycle phases to the results of the previous chapters of this thesis delivers an interesting picture. In general, the business ecosystem for BEVs shows many characteristics that can be regarded as belonging to business ecosystem lifecycle stage two. After the rollout of charging infrastructure that has already started in many regions a couple of years ago, the whole possible value of BEVs is already delivered to customers today and the general viability of BEVs for everyday individual mobility has already been proven, at least for short distances and urban areas. The main competition does not exist between different companies but between different drivetrain concepts: BEVs have to battle over market share against ICE-powered cars. The next necessary step for the business ecosystem is to gain critical mass. However, this is a vicious circle, as high costs lead to low demand and low demand does not allow cost reductions and technological advances for improving range and charging speed of vehicles. These problems are addressed by incentives granted by governments to foster growth in the newly created niche. Up to now, demand is highly dependent on these incentives in many countries.

When leaving the high-level point of view and only considering the business ecosystems that have evolved around BMW's, Daimler's and Volkswagen Group's BEV products, the differences in the strategic approach towards gaining critical mass is quite interesting. BMW and Daimler have reacted to the low demand for BEVs and the high uncertainty resulting from the dependence on government incentives by modifying their existing production network to also accommodate manufacturing of BEVs on the same production line as conventionally powered cars. However, this can be considered a passive reaction that does not allow full exploitation of the potential inherent in purpose designed BEVs. In order to address the problems of high costs, the Volkswagen Group dedicates whole production facilities to the exclusive manufacturing of its BEV platform. Additionally, Volkswagen Group does not only rely on internal synergies for reducing costs, but also opened its modular electric vehicle matrix MEB to third parties in an attempt to reach economies of scale. By doing this, Volkswagen Group is actively trying to expand and absorb the highest possible share of the existing demand for individual mobility.

10.3 Roles of OEMs in the BE for BEVs

Regarding the different roles that hub companies can play in a business ecosystem according to Iansiti & Levien (2004b), a profound change can be observed as a consequence of the shift towards BEVs and the problems that arise from it. Traditionally, OEMs have always been considered to be the keystone players in the automotive business ecosystem. This has been proposed for example by Rong et al. (2017, p. 234) and in similar fashion also by Moore (1996), although he did not use the terminology which was introduced later by Iansiti and Levien.

The results of chapter 7 and 8 clearly support the idea that OEMs are keystone players in the business ecosystem for BEVs: OEMs only constitute a small share of all identified companies engaged in this business ecosystem but have a high number of connections to other companies. However, this is not the whole story. Whilst Daimler and BMW seem to still hold on to their traditional role in their respective business ecosystems, Volkswagen Group's approach is fundamentally different.

By creating a platform architecture, that is offered to third parties and this way can be leveraged by niche players, Volkswagen Group's strategy can be compared with the approach Microsoft took when deciding to open up its API to other software companies. This very closely resembles the most fundamental characteristics of a keystone player's role within a business ecosystem. According to Iansiti & Levien (2004b, p. 82), it is exactly this approach that allows increased diversity and productivity of an ecosystem, which ultimately lead to increased ecosystem health. For this reason, Volkswagen Group can not only be considered to fully exploit the potential of its node position within the business ecosystem for BEVs but as acting out of a real interest to foster this business ecosystem. Although platform sharing is not a new move in the automotive business ecosystem, it is the fact that the Volkswagen Group developed the platform in-house before offering it to other OEMs and the high strategic relevance of the technology for its future economic success that renders this decision a paradigm shift.

In comparison to Volkswagen Group, Daimler's and BMW's approach is marked by partial commitment only. They seem to only react to the external pressure to reduce their fleet's CO_2 emissions by introducing a higher number of purely battery-electric vehicles. However, their commitment and belief in the success of the new technology seems to be only limited.

The most important implication of Volkswagen Group's consequent adherence to a true keystone player strategy, however, is another. As Volkswagen Group takes over the role of a platform provider for other OEMs, this means that those other OEMs give up their role of being a keystone player in the business ecosystem for BEVs. Instead, they act as niche players that only develop some parts which allow differentiation of their products and assemble them on the basic platform that is supplied to them. They specialize in those areas only that enable them to leverage the potential of their brand's reputation as a renowned provider of mobility, but source the technological basis of their products from keystone players. This is a fundamental shift in the structure of the automotive business ecosystem that is caused by the shift to BEVs.

10.4 Proposed Underlying Mechanism

In order to explain the differences observed in the findings of the case studies in Table 20 in section 9.6.11, an underlying mechanism is proposed that is depicted in Figure 57. It is assumed that the difference lies in the different perception that OEMs have regarding the potential inherent in BEVs.

The proposed mechanism consists of two different steps. In step 1, OEMs reacted to government pressures for reducing the fleet CO_2 emissions of their offered vehicles. This can easily be shown with the timelines of BEV projects in Figure 30, Figure 39 and Figure 48: OEM's BEV activities started right at the same time as the European Commission publicly announced legally binding CO_2 emission goals starting in 2012 for the first time in 2007. Although previously also fuel cell cars had been considered a possible future solution for sustainable individual mobility, the faster technological progress of BEVs finally brought the decision for BEVs. The three considered OEMs chose to cooperate with their suppliers from the automotive industry or another industry at the beginning of their activities in BEVs (see Table 20). Therefore, it is concluded that these relationships served to gain necessary technological knowledge in the areas needed to develop and manufacture BEVs. This first step most probably coincides with business ecosystem lifecycle phase one, in which the new business ecosystem is formed and the product offering is defined and its viability is assessed. Moore (1993) especially stresses the importance of cooperation at the pioneering stage.

The second step, which shows the mechanism of cooperation during business ecosystem lifecycle phase two, tries to explain the differences in cooperative behavior of companies while trying to gain critical mass. Companies that have a strong belief in the potential of BEVs and their market breakthrough within the next couple of years choose what is proposed to be called an "Active keystone player strategy". They actively promote electric mobility and try to reach critical mass by following a true keystone strategy: they create platforms that are shared with niche players in order to create economies of scale, at the same time fostering business ecosystem growth and health. This strategy is believed to be rather followed by OEMs in the volume segment, as the basis of this strategy are affordable BEVs that have the potential to achieve sales numbers that are higher than in the premium segment. Of the three companies considered in the case studies, this strategy can be observed for the volume brands of Volkswagen Group, which are Volkswagen, SEAT, SKODA and partly also Audi. As a consequence of the high belief in the new technology, those OEMs are also covering areas in the downstream value-added chain like charging infrastructure and mobility services internally.

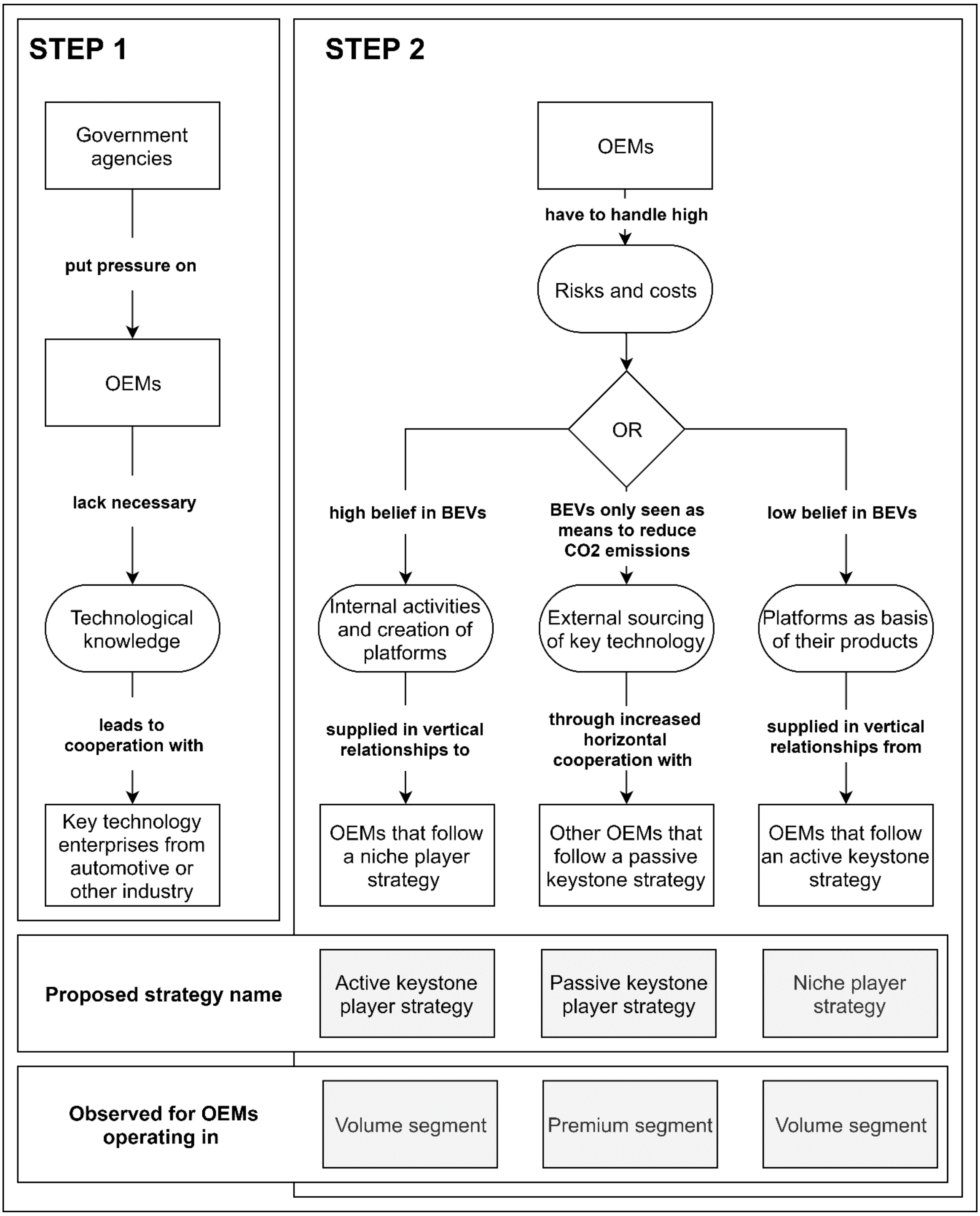


Figure 57: Proposed underlying mechanism for OEMs' roles in the BE for BEVs (own creation)

The second strategy observed in the case studies is a strategy that is proposed to be called a "Niche player strategy". OEMs following this strategy can be considered to be the counterparts to OEMs following an active keystone player strategy: they source the technology platform from active keystone players and develop their products based on it. Consequently, their main focus does not lie in technology, but has to lie in leveraging their brand's reputation and finding ways to differentiate their products from other OEMs' offerings. As these companies use the same technology platform as active keystone players, they are also assumed to belong to the volume segment. This is only a logical conclusion, as reasonable prices are very important in the volume segment, which can only be achieved if production volumes are high enough. However, if a company does not really believe in the large-scale adoption of BEVs, and does not want to make high investments in the technology, choosing this strategy is a viable choice. Of the companies considered in the case studies, this role type is only briefly mentioned in Volkswagen Group's case. Ford is considered to be an example for this strategy type as its future EVs planned to be offered in Europe will be designed upon Volkswagen's MEB platform.

Finally, another strategy type could be observed in the case studies that is proposed to be called "Passive keystone player" strategy. Those companies do not source platforms from other OEMs after development has finished, but rather cooperate with other OEMs for development and possibly even manufacturing of their battery electric car platforms and important systems. They do not open their platforms to other companies, which is why their strategy does not exactly match the keystone player archetype. For this reason they are proposed to be called passive. This approach is supposed to be chosen primarily by companies that first and foremost consider BEVs as a viable solution to reduce the fleet emissions of their sold cars. Those companies will most probably be OEMs operating in the premium segment, as their cars are more expensive than the products accounted to the volume segment. The higher price level reduces the price awareness of customers in the premium segment. As a consequence, economies of scale are not as important as for volume manufacturers, as higher production costs can be forwarded to customers without affecting customer demand too much. Additionally, cars accounted to the premium segment often feature more powerful engines which consequently leads to higher CO_2 emissions and necessitates low-emission cars to still meet the strict emission targets. Lastly, customers of premium vehicles might put more emphasis on the exact technology of their car which makes buying a predeveloped technology platform from another OEM less attractive. Of the three OEMs considered for the case studies, Daimler, BMW and Volkswagen Group's premium brands Porsche and to some extent even Audi are considered to belong to this strategy type. However, this does not mean that this strategy is not open to be chosen by volume manufacturers. Although BMW develops its BEV platforms internally, they rely on cooperation for electric powertrain development and many downstream parts of the value-added chain like mobility services and charging infrastructure. Daimler has already been relying on cooperation for the development and manufacturing of battery systems, battery cells, electric drivetrains and complete vehicles for a long time. Additionally, many downstream parts of the value-added chain like mobility services and charging infrastructure are covered by Daimler via cooperation. Porsche and Audi formed an internal cooperation for the development of three different electric car platforms; additionally Porsche cooperates with other companies and even sources battery systems from an external supplier through a long-term market transaction.

10.5 Comparison with Other Authors' Results

Interestingly, the result of this thesis as outlined in section 10.4 is exactly the opposite of what Sovacool et al. (2019) propose in their paper. They regard Volkswagen's efforts in BEV development as being *"conservative-sustaining"* without having belief in the breakthrough of the technology, whilst BMW was considered to follow a *"transformative change-shaping"* innovation style. However, this paper is limited to BEV models that were introduced until 2014, which could explain said differences. At the time, BMW had recently presented its first purpose designed BEV with the BMW i3 and it was expected that BMW would expand its BEV portfolio in the following years, which did not happen. Volkswagen's only BEVs at the time were conversion design cars, namely the e-Golf and e-up! (see Figure 48 and Figure 30). In the meantime, both OEMs have introduced new strategies and therefore entirely changed their approach. Sovacool et al. (2019) also see government regulations the main driver behind OEM's increased efforts in BEV development and manufacturing.

Enrietti & Patrucco (2011) argue that the adoption of BEVs – which they consider a *"radical or systemic innovation"* - *"depends on the ability to organize and manage networks, alliances and coalitions"* and mention that stronger ties between companies are more appropriate for knowledge transfer in these networks, which definitely was true at the beginning of the BEV trajectory of the three examined OEMs. This point in time is referred to by Step 1 in the proposed underlying mechanism shown in Figure 57. Today, alliances and coalitions seem to be part of the chosen strategy of OEMs and express their belief and commitment in the new technology. Nevertheless, the general statement that a breakthrough of BEVs is only possible through the orchestrated efforts of a myriad of different actors, of which some are even alien to the automotive industry definitely holds true. This fact is also underlined by the high number of different groups of players identified in the business ecosystem for BEVs (see chapter 7).

Rong et al. (2017) propose that OEMs are keystone players in the EV business ecosystem. Although this can be regarded true for the automotive business ecosystem of conventional cars and still holds true for some OEMs in the business ecosystem for BEVs, it is not true for all of them, as shown in this thesis. Additionally, they describe markets to be the driving force for BEVs in Europe and government initiatives in China. However, government regulations were identified as the main driving force for BEVs in Europe as well in this thesis.

Spieth & Meissner (2018) mention that some European OEMs might reduce their operations on being *"brand ambassadors, designers, and part producers"* in the future. Following the argumentation of this thesis, this scenario is realistic. This might be the future situation of OEMs that decide for a strategy as niche players as proposed in Figure 57. In their paper, Spieth & Meissner (2018) argue that a stable future for German OEMs can only be reached through cooperation. However, this depends on the exact definition of cooperation. Following the definition used in this thesis, other options seem to be a viable choice as well – like in Volkswagen Group's case.

Hensley et al. (2009, p. 92) point out that value will most probably shift from the battery cell to the electronics and software of the management systems needed to control batteries and electric drivetrains. Although they formulated this vision already in 2009, this is exactly what happened according to the results of the case studies. For this reason, Daimler stopped the battery cell production they operated in Kamenz in a joint venture with Evonik Industries in 2015. The same phenomenon had also been predicted by Dinger et al. (2010, p. 11) in 2011.

The research design of this thesis stands in the same tradition as Moore's (1996) analysis of the three big American automotive OEMs Ford, General Motors and Chrysler, which he analyzed for assessing their strategies in the course of the different ecosystem lifecycle phases. A similar concept is followed in this thesis by choosing the three biggest German OEMs and their efforts towards BEVs. Interestingly, it is Ford, who is described by Moore as betting on global economies of scale for its conventional vehicles. Although Moore's analysis is more than 20 years old, it is quite interesting that Ford today chose the exactly opposite strategy for BEVs in Europe. Volkswagen Group is the company that tries to reach economies of scale with BEVs, whilst Ford is only its platform customer.

In the same book that laid the foundation for business ecosystem theory in general, Moore (1996) also gave an outlook on his vision of a possible future car that can be considered to be a hybrid electric vehicle. Interestingly, he expressed doubts over the concept's ability to reach critical mass in ecosystem lifecycle phase two. As this is exactly the phase in which BEVs are determined to be located at the moment, it will be especially exciting to see whether Volkswagen Group's initiative will lead to the expected economies of scale and in the end to the breakthrough of BEVs on mass markets. Moore additionally stresses the importance to have a portfolio of investments in different – old and new – business ecosystems at the same time in order to increase the chances of right positioning for all possible future scenarios. This is exactly what all examined OEMs do as they all invest in BEVs, FCEVs, (P)HEVs and improved ICEs at the same time.

Morche et al. (2018, p. 242) state that battery systems are the most importance core competence of BEVs and can be compared to ICEs in conventional cars. This definitely can be confirmed with the results of this research. However, they mention that – whilst ICEs are most often developed and manufactured by OEMs in-house – battery systems are developed and manufactured by supplier companies as black box systems. This cannot be confirmed by the results of this thesis. The opposite seems to be the case for the examined OEMs: except for Porsche, all OEMs and their brands develop and manufacture battery systems in-house. This is a consequence of the fact that they are well aware of the importance of those systems for differentiating their products from the competition.

Kaspersk et al. (2018, p. 144) point out that the in the long term a new industry structure is likely to evolve through the shift to BEVs. Although for the scope of this thesis the business ecosystem concept serves as a substitution for the industry concept, the general statement is confirmed by the results of this thesis. The authors additionally state that cooperation is necessary for gathering of knowledge and to handle economic risks associated with the development of BEVs. However, this thesis separates those two motives for cooperation. Cooperation at the beginning of the BEV trajectory at the end of the last decade mainly included vertical relationships with suppliers; the goal of these relationships is concluded to have been knowledge build-up. Today, cooperation mainly exists in horizontal relationships between OEMs, which is concluded to serve the purpose of risk and cost sharing (see the timelines in chapter 9 and Figure 57).

Pinske et al. (2014) point out that systemic innovations like BEVs lead to significant changes in the whole network that is involved in their creation, like suppliers, customers and complementors. This can be approved by the results of all empirical chapters of this thesis. Additionally, they describe the process of vertical integration of companies with suppliers of necessary new technology, which could also be observed in the case studies. According to them horizontal relationships can serve to protect disruptive innovations by sharing risks and knowledge. This is also taken into consideration in the explanation of the underlying mechanism of OEM's cooperative behavior in Figure 57.

Mazur et al. (2013) propose that although external pressure is existing, disruptive changes need to be triggered by internal events like a change of CEO. This can be perfectly supported by the insights gained through this thesis. BMW changed its strategy towards holistic development of a purpose design BEV after appointing a new CEO; Volkswagen used the Diesel Scandal and the resulting change of CEO for switching its strategy towards a high commitment to BEVs. First Smart cars were equipped with battery electric drivetrains shortly after a new CEO had taken over control over Daimler as well. The same authors additionally suggest that knowledge on disruptive technologies is sourced externally. This assumption can be confirmed as well by the results of the case studies that are summed up in Figure 57.

On a higher level, the impact of innovations that are located at the higher end of the innovativeness continuum is described by many authors. Phillips et al. (2006, p. 451) state that discontinuous innovations necessitate new relationships that go beyond those included in the current supply network of a company. Rice et al. (1998, p. 57) conclude, that partnering with a wide variety of different partners can be used to reduce risks inherent in discontinuous innovations. Both phenomena were observed in the case studies in chapter 9 and summarized in Figure 57.

Lambe & Spekman (1997, p. 102) stress the importance of alliances for allowing incumbent companies fast access to new technology. They propose that alliances can therefore be observed much more often for technology acquisition in situations of discontinuous technological change than mergers, acquisitions or internal development. This cannot be confirmed entirely, as internal development also was observed in the case studies for knowledge generation at the beginning of BEV activities. However, the importance of partnerships, strategic alliances and joint ventures with other companies for fast access to new technology could be shown in the timelines in chapter 9.

Fixson & Park (2008, p. 1307) describe the connection between changes in product and industry structure. Although electric mobility can be considered to be a systemic innovation rather than a simple product innovation according to (Enrietti & Patrucco, 2011), the fact that changes in product architecture can lead to changes in industry or business ecosystem structure is also assumed as a result of this thesis.

11 Conclusion

This chapter contains the final conclusion resulting of the insights gained in the previous chapters of this thesis. Next, the generalizability of results is discussed, before finally limitations are outlined and further possible directions of research are proposed.

11.1 Summary of Results

Summarizing all insights gained from this thesis, a number of statements could be gained regarding the effect of the shift towards battery electric individual mobility in the automotive business ecosystem. This concerns the structure, roles and origin of players of the newly created business ecosystem.

The results of research question R1 show, that the business ecosystem for BEVs contains a high number of new players that have not been a part of the business ecosystem for conventional cars previously. All players and the structure of the business ecosystem for BEVs are assessed within the scope of this thesis for the first time using information gained through a database analysis. The results of this analysis indicate that OEMs fulfil many criteria of keystone players as described by Moore.

According to the results of research question R2, for many of those identified players, the trend towards BEVs signifies a shift in paradigm and induces a number of consequences. The most clearly visible trends in this context on the one hand are a diversification of OEMs' product and service portfolio in order to keep their share of value added and on the other hand is the high share of cooperation in many areas that occurs between OEMs and other ecosystem players in an attempt to generate knowledge and share risks and costs.

Thorough assessment using case study research for answering research question R3 showed that the impetus for OEMs to take up development work for BEVs came through external pressure exerted by governments. Additionally, cooperation between OEMs and suppliers mostly occurred in business ecosystem lifecycle stage one in order to get fast access to needed new technology. The cooperation decision in business ecosystem lifecycle stage 2 is proposed to depend on the type of strategy chosen by an OEM for risk and cost sharing, which mainly depends on the belief and commitment to the new technology. In this context, three different strategy types for cooperation in value creation and knowledge generation were identified which are called "Active keystone strategy", "Passive keystone strategy" and "Niche player strategy" based on the roles defined by Iansiti & Levien (2004b). Furthermore, the motives of companies to choose one of those strategy archetypes are described and connected to the segment in which OEMs most probably will operate when deciding for one specific strategy.

Finally, a number of additional general insights could be gained. First, BEVs can be considered to belong to the higher end of the innovativeness continuum due to the far reaching effects they have on a number of different players within the automotive business ecosystem and the roles companies play within this business ecosystem. Moreover, the business ecosystem for BEVs is determined to be in business ecosystem lifecycle stage two at the moment, which is indicated by the problem to reach critical mass.

The most important general insight gained through this thesis is that technological innovations which belong to the upper end of the innovativeness continuum have the power to change the role and strategy that keystone players follow. Results show that such innovations can even lead to a shift from being a keystone player to taking a niche player role in the newly developed business ecosystem. This discovery does not just stand for itself but at the same time imposes, that big OEMs in terms of sales volumes cannot always be considered keystone players in the business ecosystem of BEVs anymore although this was their commonly acknowledged role in the business ecosystem for conventional cars.

11.2 Generalizability of Results

As this thesis is only aimed at the automotive industry and further limited to one specific technological trend, the generalizability of its results is hard to determine. According to (Langley, pp. 702–703), visual mapping techniques often result in theory that is hardly applicable to other areas. However, it is concluded that the general statement that technological changes belonging to the higher end of the innovativeness continuum can cause changes in the roles of hub companies within a business ecosystem is still viable when considering other economy branches.

The rest of the thesis should be generally applicable to the business ecosystem for BEVs, as all chosen OEMs for the case studies belong to this category.

11.3 Limitations

In order to be able to evaluate the quality of the results and their generalizability, a number of limitations has to be considered. As also shown by the comparison with Sovacool et al.'s work (2019), it can be seen that the automotive business ecosystem for BEV is a very dynamic one. Changes in strategy can happen very fast and lead to profound changes. However, as the commitment to BEVs is closely connected to very high investments, it is concluded that OEMs will follow their chosen strategy at least in the short- and medium-term future.

The whole thesis only relies on secondary data without having any access to involved people or companies themselves. However, this can also be considered an advantage, as the risk of getting lost in a high number of low-level details can be avoided. Additionally, the potential risk of personal bias of data sources could be eliminated. By relying on secondary data stemming from four different sources (press releases, business reports, news portals, databases and written interviews with top-level management), data triangulation and construct validity was reached.

The database analysis carried out to answer research question R1 does have some clear limitations that have to be considered when assessing its results. Although the selection of companies delivered by the database can be assumed to be of high quality due to GlobalData's reputation as industry leader and the size and success of its business, chances are that the list does not picture all parties involved in electric mobility activities. Additionally, as publicly available company information sometimes is fragmented, the following categorization might consequently as well hold the risk of lacking accuracy. Finally, the actual size of a specific actor group does not have to be proportionate to the size of the identified actor groups in this analysis. However, regarding the use of the information as a source of identifying relevant actor groups and not individual actors, the approach can be considered valid for answering research question R1.

An analysis as used for answering research question R2 holds the risk of biased selectivity in case of incomplete collections and reporting bias by the creators of the used literature. Those limitations were addressed by aiming to reach theoretical saturation as described in chapter 2 (Eisenhardt, 1989, p. 545). Additionally, a wide range of different data sources - namely scientific papers, business reports, press releases, industry reports and books - was used to prevent reporting bias. Due to the dynamic nature of the business ecosystem for BEVs, a dependence of information on publication date might be possible. For this reason, newer publications were preferred over older ones during data collection.

An application of categorization schemes like in research question R3 always holds the risk of missing consistency. To avoid this problem, a classification framework was defined together with clear properties of each included category. Additionally, intracoder checks were carried out, which included recoding of some interorganizational relationships and vehicle projects. By comparing the results, the quality of the categorization could be assessed and improved. (Mayring & Fenzl, 2014, p. 550)

Although the definition of categorization schemes allowed a classification of interorganizational relationships and vehicle projects, differences between entities that were accounted to the same category could not be assessed. However, it is assumed that those do not play a major role for a high-level examination like in this thesis.

11.4 Possible Directions for Further Research

Further research is proposed to assess the generalizability and viability of the underlying mechanisms and other results of this thesis. This could either be done by including additional data sources, like expert interviews that are carried out with standardized questionnaires or by assessing additional companies with similar methods (Patton, 1987). In order to gain further insights into the cooperation strategy of OEMs, it is additionally suggested to extend the scope of analysis to other alternative drivetrain technologies and other trends that play a role in the transformation of the automotive industry, like automated and autonomous driving and digitalization. This way, a holistic picture of an OEM’s cooperation landscape could be gained.

Future assessment of the impact of BEVs on the structure of the automotive business ecosystem could furthermore concentrate on a deeper understanding of OEM’s motives for single strategic actions noticed in the case studies and cooperation with other companies on a deeper level.

Additionally, the chosen approach using timelines for assessing interorganizational relationships can be applied to other areas as well, even outside the automotive industry. For the scope of this thesis, it proved a very effective instrument for comparison between cases and deduction of tendencies that allowed theory formulation.

Finally, further research could focus on closer examination of the connection between ecosystem lifecycle stages and the intensity of or motives for cooperation.

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Part V: **APPENDIX**

A. Identified Actors of the Automotive BE for BEVs through Database Research

Company	Country	Role
Efacec Power Solutions SGPS SA	Portugal	Charging Infrastructure Equipment Manufacturer
Electricite de France SA	France	Electricity Distributor, Electricity Producer, Charging Infrastructure Operator, Charging Infrastructure Distributor
Endesa SA	Spain	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator, Charging Infrastructure Distributor
Enel SpA	Italy	Electricity Distributor, Electricity Supplier, Battery Producer, Charging Infrastructure Operator
Bayerische Motoren Werke AG	Germany	Developer of BEVs, Developer of HEVs, Car Distributor, Provider of Financial Services, Provider of Mobility Services, Fleet Operator, Battery Recycling, Reuse and Remanufacturing
Energias de Portugal SA	Portugal	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator, Charging Infrastructure Distributor
E.ON SE	Germany	Electricity Distributor, Electricity Supplier, Electricity Producer, Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator, Charging Infrastructure Distributor
Iberdrola SA	Spain	Electricity Distributor, Electricity Producer, Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator, Charging Infrastructure Distributor
Nissan Motor Co Ltd	Japan	Developer of HEVs, Developer of BEVs, Provider of Mobility Services, Provider of Maintenance and Service, Provider of Financial Services
Renault SA	France	Developer of HEVs, Developer of BEVs, Provider of Mobility Services, Provider of Maintenance and Service, Provider of Financial Services, Fleet Operator
BYD Co Ltd	China	Developer of BEVs, Battery Producer, Electronics Producer
ChargePoint Inc	USA	Charging Infrastructure Operator, Charging Infrastructure Distributor, Charging Infrastructure Equipment Manufacturer
Daimler AG	Germany	Car Distributor, Provider of Mobility Services, Developer of BEVs, Developer of HEVs, Provider of Financial Services, Fleet Operator

European Commission	Belgium	Regulatory Body, Standardization Body
Red Electrica Corporacion SA	Spain	Electricity Distributor, Electricity Supplier
ABB Ltd	Sitzerland	Charging Infrastructure Equipment Manufacturer
Audi AG	Germany	Car Distributor, Provider of Mobility Services, Developer of BEVs, Developer of HEVs, Provider of Financial Services, Provider of Maintenance and Service
Engie SA	France	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator, Charging Infrastructure Distributor
Innogy SE	Germany	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator, Charging Infrastructure Distributor, Charging Infrastructure Equipment Manufacturer
Volkswagen AG	Germany	Car Distributor, Provider of Mobility Services, Developer of BEVs, Developer of HEVs, Provider of Financial Services, Provider of Maintenance and Service, Fleet Operator
Tata Motors Ltd	India	Developer of BEVs, Developer of HEVs, Provider of Financial Services
Toyota Motor Corp	Japan	Developer of HEVs, Provider of Financial Services, Car Distributor, Provider of Mobility Services
Continental AG	Germany	Electric Powertrain Supplier
Entega AG	Germany	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator, Charging Infrastructure Distributor
Hydro-Quebec	Canada	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator, Charging Infrastructure Distributor
Fraunhofer Institute for Systems and Innovation Research	Germany	Research and Development Provider
PwC Strategy& (Germany) GmbH	Germany	Strategy Consultant

RWE AG	Germany	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator, Charging Infrastructure Distributor
Schneider Electric SE	France	Charging Infrastructure Equipment Manufacturer
Siemens AG	Germany	Charging Infrastructure Equipment Manufacturer
SPIE SA	France	Charging Infrastructure Distributor, Charging Infrastructure Equipment Manufacturer, Charging Infrastructure Operator
Stadtwerke Munchen GmbH	Germany	Electricity Distributor, Provider of Mobility Services, Electricity Supplier, Fleet Operator, Electricity Producer
Technical University of Munich	Germany	Research and Development Provider
The Mobility House AG	Switzerland	Charging Infrastructure Distributor, Battery Recycling, Reuse and Remanufacturing
Valeo SA	France	Electronics Producer, Electric Powertrain Supplier
American Electric Power Co Inc	USA	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Distributor, Charging Infrastructure Operator
BorgWarner Inc	USA	Electric Powertrain Supplier
Electrovaya Inc	Canada	Cell Producer, Battery Producer
Mahindra & Mahindra Ltd	India	Developer of BEVs, Provider of Financial Services, Provider of Mobility Services, Car Distributor
Meridian Energy Ltd	New Zealand	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator
Umicore NV	Belgium	Battery Recycling, Reuse and Remanufacturing, Raw Materials Producer
EVN AG	Austria	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator
Mitsubishi Motors Corporation	Japan	Developer of BEVs, Developer of HEVs, Car Distributor, Provider of Financial Services, Provider of Mobility Services
N-ERGIE AG	Germany	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Distributor, Fleet Operator, Charging Infrastructure Operator
Alpiq Holding AG	Switzerland	Electricity Distributor, Electricity Producer, Car Distributor, Provider of Mobility Services, Charging Infrastructure Operator, Electricity Supplier

Grupa Lotos SA	Poland	Charging Infrastructure Operator
PSA Group	France	Car Distributor, Provider of Mobility Services, Developer of BEVs, Developer of HEVs, Provider of Financial Services, Provider of Maintenance and Service
Urja Global Ltd	India	Battery Producer
Honda Motor Co Ltd	Japan	Developer of HEVs, Car Distributor, Provider of Financial Services, Developer of BEVs
IBC Solar AG	Germany	Supplier of Manufacturing Equipment and Facilities
International Business Machines Corp	USA	Fleet Operator
Nexans SA	France	Cable Producer
TenneT Holding BV	Netherlands	Electricity Supplier, Electricity Distributor, Charging Infrastructure Equipment Manufacturer, Charging Infrastructure Operator
Total SA	France	Producer of Fluids for Evs, Charging Infrastructure Equipment Manufacturer, Charging Infrastructure Operator, Charging Infrastructure Distributor
U.S. Department of Energy	USA	Standardization Body, Regulatory Body
A2A SpA	Italy	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator, Charging Infrastructure Distributor
Bombardier Inc.	Canada	Charging Infrastructure Equipment Manufacturer
BSES Yamuna Power Ltd	India	Electricity Distributor, Electricity Supplier, Charging Infrastructure Operator
Building Energy SpA	Italy	Electricity Distributor, Electricity Producer, Charging Infrastructure Operator
Connected Energy	USA	Battery Recycling, Reuse and Remanufacturing, Charging Infrastructure Equipment Manufacturer
Duke Energy Corp	USA	Electricity Distributor, Electricity Producer, Electricity Supplier, Fleet Operator, Charging Infrastructure Operator
Empresa de Electricidade da Madeira SA	Portugal	Electricity Distributor, Electricity Supplier, Electricity Producer, Battery Recycling, Reuse and Remanufacturing, Charging Infrastructure Operator

EnBW Energie Baden-Wurttemberg AG	Germany	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator, Charging Infrastructure Distributor
Ente Vasco de la Energia	Spain	Public funding
European Investment Bank	Luxembourg	Public funding
Hitachi Ltd	Japan	Electric Powertrain Supplier, Electronics Producer, General component producer, Producer of Compound Materials, Battery Producer
International Energy Agency	France	Research and Development Provider
Linea Group Holding SPA	Italy	Electricity Distributor, Electricity Supplier, Electricity Producer
SMA Solar Technology AG	Germany	Charging Infrastructure Equipment Manufacturer
Tata Technologies	USA	Research and Development Provider
Telefonica SA	Spain	Provider of Mobility Services
The Hertz Corporation	USA	Provider of Mobility Services, Fleet Operator
Tractebel Engineering S.A.	Belgium	Charging Infrastructure Equipment Manufacturer
3M Co	USA	Battery Components producer, General component producer, Electric Engine Components producer
Adam Opel AG	Germany	Developer of BEVs, Developer of HEVs, Car Distributor, Provider of Financial Services, Provider of Mobility Services
Alliander NV	Netherlands	Electricity Distributor, Electricity Supplier, Charging Infrastructure Operator
ANI Technologies Pvt Ltd	India	Provider of Mobility Services, Fleet Operator
ASEAN Centre for Energy	Indonesia	Research and Development Provider
Azure Dynamics Corporation	Canada	Electric Powertrain Supplier
BASF SE	Germany	Battery Components producer, Fleet Operator

Centrais Eletricas de Santa Catarina S.A.	Brazil	Electricity Distributor, Electricity Supplier, Electricity Producer
CEZ Group	Czech Republic	Electricity Distributor, Electricity Producer, Charging Infrastructure Operator
Cognizant Technology Solutions India Pvt Ltd	India	Charging Infrastructure Operator
Compagnie Nationale du Rhone SA	France	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator
Eni SpA	Italy	Charging Infrastructure Operator
EWE AG	Germany	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Distributor, Charging Infrastructure Operator
Fabbrica Energie Rinnovabili Alternative Srl	Italy	Electricity Producer, Electricity Distributor, Charging Infrastructure Operator, Charging Infrastructure Distributor
FATH Solar GmbH	Germany	Charging Infrastructure Operator
Ford Motor Co	USA	Developer of BEVs, Developer of HEVs, Provider of Financial Services, Car Distributor, Provider of Mobility Services
Fortum Corp	Finland	Electricity Producer, Electricity Distributor, Charging Infrastructure Equipment Manufacturer, Charging Infrastructure Distributor, Charging Infrastructure Operator, Battery Recycling, Reuse and Remanufacturing, Electricity Supplier
Freudenberg Sealing Technologies GmbH & Co KG	Germany	General component producer, Battery Components producer
General Electric Co	USA	Charging Infrastructure Equipment Manufacturer
GP JOULE GmbH	Germany	Charging Infrastructure Equipment Manufacturer, Charging Infrastructure Operator
Infineon Technologies AG	Germany	Electric Components Producer, Electronics Producer
International Renewable Energy Agency	United Arab Emirates	Research and Development Provider
Istituto Italiano di Tecnologia	Italy	Research and Development Provider

Meridiam SAS	France	Investor, Charging Infrastructure Operator, Charging Infrastructure Distributor, Charging Infrastructure Equipment Manufacturer
Ministry of Finance, India	India	Fleet Operator, Charging Infrastructure Operator
Nova Scotia Power Inc	Canada	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator
NV Nuon Energy	Netherlands	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator, Charging Infrastructure Distributor
Polski Koncern Naftowy Orlen SA	Poland	Charging Infrastructure Operator
Portland General Electric Co	USA	Electricity Supplier, Electricity Producer, Electricity Distributor, Charging Infrastructure Operator
Poste Italiane Group	Italy	Electronics Producer
Qualcomm Incorporated	USA	Charging Infrastructure Equipment Manufacturer
Repsol SA	Spain	Research and Development Provider , Charging Infrastructure Operator, Provider of Mobility Services, Fleet Operator
Reseau de Transport d'Electricite	France	Electricity Distributor
San Diego Gas & Electric Co	USA	Electricity Distributor, Electricity Supplier, Charging Infrastructure Distributor, Electricity Producer
Tesla Inc	USA	Car Distributor, Developer of BEVs, Provider of Financial Services, Provider of Maintenance and Service, Charging Infrastructure Equipment Manufacturer, Charging Infrastructure Operator, Charging Infrastructure Distributor, Battery Recycling, Reuse and Remanufacturing, Electric Powertrain Supplier, Battery Producer
The Tata Power Co Ltd	India	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator
Vanderbilt University	USA	Research and Development Provider
ZF Friedrichshafen AG	Germany	Electric Powertrain Supplier
Acea SpA	Italy	Electricity Distributor, Electricity Supplier, Electricity Producer
Adient Plc	Ireland	General component producer

Administracion Nacional de Usinas y Trasmisiones Electricas	Uruguay	Electricity Supplier, Electricity Distributor, Electricity Producer, Charging Infrastructure Operator
Agencia Nacional de Energia Eletrica, Brazil	Brazil	Public funding , Research and Development Provider
Aixtron SE	Germany	Supplier of Manufacturing Equipment and Facilities
Albemarle Corp	USA	Raw Materials Producer
Atco Ltd	Canada	Electricity Distributor, Electricity Supplier
Aton-Solar GmbH	Germany	Charging Infrastructure Equipment Manufacturer
BEKO Holding AG	Austria	Research and Development Provider
Bharat Forge Ltd	India	Research and Development Provider
Bharat Heavy Electricals Ltd	India	Charging Infrastructure Equipment Manufacturer
Bollore SA	France	Developer of BEVs, Fleet Operator, Provider of Mobility Services, Charging Infrastructure Equipment Manufacturer
Canadian Tire Corp Ltd	Canada	Charging Infrastructure Distributor
China Southern Power Grid Co Ltd	China	Electricity Distributor, Research and Development Provider , Charging Infrastructure Operator
Christian-Albrechts-University of Kiel	Germany	Research and Development Provider
Chubu Electric Power Co Inc	Japan	Electricity Distributor, Electricity Producer, Electricity Supplier, Battery Recycling, Reuse and Remanufacturing, Charging Infrastructure Operator
CLP Holdings Ltd	Hong Kong	Electricity Distributor, Electricity Producer, Electricity Supplier, Fleet Operator, Charging Infrastructure Operator
Covestro AG	Germany	Producer of Compound Materials
Cypress Semiconductor Corporation	USA	Electronics Producer
Dassault Systemes SA	France	Engineering Software Publisher
Deutsche Post AG	Germany	Developer of BEVs, Fleet Operator, Charging Infrastructure Operator, Charging Infrastructure Equipment Manufacturer

DNV KEMA Energy & Sustainability	Netherlands	Technical Consulting, Certification and Training
Ecotricity Group Ltd	UK	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator
EirGrid Plc	Ireland	Electricity Distributor
Electric Power Research Institute Inc	USA	Research and Development Provider
Enercon GmbH	Germany	Charging Infrastructure Equipment Manufacturer
Enexis BV	Netherlands	Electricity Distributor, Electricity Supplier, Charging Infrastructure Equipment Manufacturer, Charging Infrastructure Operator
Envision Energy Ltd	China	Charging Infrastructure Equipment Manufacturer
ESB Networks Ltd	Ireland	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator
evn Naturkraft Erzeugungsgesellschaft mbH	Austria	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator
Federation of Indian Chambers of Commerce and Industry	India	Electronics Producer, Research and Development Provider
FedEx Corporation	USA	Fleet Operator
G4S Plc	UK	Charging Infrastructure Operator
GrabTaxi Holdings Pte. Ltd.	Singapore	Provider of Mobility Services, Fleet Operator
GreenYellow SAS	France	Electricity Supplier, Electricity Producer, Electricity Distributor
Hawaiian Electric Industries Inc.	USA	Charging Infrastructure Operator, Electricity Distributor, Electricity Producer, Electricity Supplier
Huber+Suhner AG	Switzerland	Electronics Producer, Electric Components Producer, Charging Infrastructure Equipment Manufacturer
Hydrogenics Corp	Canada	Producer of Fuel Cells
Hydro Ottawa Holding Inc	Canada	Electricity Distributor, Electricity Supplier

Hyundai Motor Co	South Korea	Developer of BEVs, Developer of HEVs, Provider of Financial Services, Car Distributor
Ingeteam Corporacion, S.A.	Spain	Charging Infrastructure Equipment Manufacturer, Fleet Operator
Indian Institute of Chemical Technology	India	Research and Development Provider
Inter IKEA Systems BV	Netherlands	Fleet Operator, Charging Infrastructure Operator
IREN SpA	Italy	Electricity Producer, Electricity Distributor, Charging Infrastructure Operator
Italian Vento Power Corporation SRL	Italy	Electricity Producer, Charging Infrastructure Equipment Manufacturer
Karlsruhe Institute of Technology	Germany	Research and Development Provider
Kia Motors Corporation	South Korea	Developer of BEVs, Developer of HEVs, Provider of Financial Services, Car Distributor
LG Chem Ltd	South Korea	Battery Producer, Cell Producer, Producer of Compound Materials
Magna International Inc	Canada	Electric Powertrain Supplier, Research and Development Provider , Vehicle Manufacturer, Electronics Producer
Mahle GmbH	Germany	Electronics Producer, Electric Powertrain Supplier
Manitoba Hydro-Electric Board	Canada	Electricity Supplier, Electricity Producer, Electricity Distributor
Mersen SA	France	Electronic Components Producer
MOL Hungarian Oil and Gas PLC	Hungary	Fleet Operator, Provider of Mobility Services, Charging Infrastructure Operator
MVV Energie AG	Germany	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator, Charging Infrastructure Distributor
Nanyang Technological University	Singapore	Research and Development Provider
NEC Energy Solutions Inc	USA	Battery Producer
NTPC Ltd	India	Electricity Producer, Charging Infrastructure Operator

ON Semiconductor Corp	USA	Electronics Producer, Electronic Components Producer
Oresundskraft AB	Sweden	Electricity Supplier, Electricity Distributor, Electricity Producer, Fleet Operator, Charging Infrastructure Operator
Panasonic Corp	Japan	Battery Producer, Charging Infrastructure Equipment Manufacturer, Cell Producer, Electronics Producer
Porsche Automobil Holding SE	Germany	Car Distributor, Provider of Maintenance and Service, Provider of Financial Services, Developer of HEVs, Developer of BEVs
REFU Elektronik GmbH	Germany	Electronics Producer
RENA Technologies GmbH	Germany	Battery Components producer
ReVolt Technology AS	USA	Battery Components producer, Battery Producer
Rexnamo Electro Pvt Ltd	India	Developer of BEVs, Battery Producer
RheinEnergie AG	Germany	Electricity Supplier, Electricity Producer, Electricity Distributor, Charging Infrastructure Operator, Charging Infrastructure Distributor
Rocky Mountain Power	USA	Electricity Distributor, Electricity Producer, Electricity Supplier, Public funding
Rosseti	Russia	Electricity Distributor, Electricity Producer, Electricity Supplier
Royal Dutch Shell Plc	Netherlands	Charging Infrastructure Operator, Producer of Fluids for Evs, Electricity Distributor
Ryder System Inc	USA	Car Distributor, Provider of Maintenance and Service, Fleet Operator, Provider of Mobility Services
SAP SE	Germany	Fleet Operator, Charging Infrastructure Operator
Schaeffler Technologies GmbH & Co. KG	Germany	Electric Powertrain Supplier, Electronics Producer, Supplier of Manufacturing Equipment and Facilities
ScottishPower Renewables (UK) Ltd	UK	Electricity Supplier, Electricity Producer, Electricity Distributor, Charging Infrastructure Operator, Charging Infrastructure Distributor
SEAS-NVE Holding A/S	Denmark	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator

Singapore Power Ltd	Singapore	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator
Slovenske elektrarne a s	Slovakia	Electricity Producer, Electricity Supplier, Electricity Distributor, Charging Infrastructure Operator
Sociedad Quimica y Minera de Chile SA	Chile	Raw Materials Producer
sonnen GmbH	Germany	Charging Infrastructure Distributor, Charging Infrastructure Equipment Manufacturer
Southern California Edison Co	USA	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Distributor
Stadtwerke Erfurt GmbH	Germany	Electricity Supplier, Electricity Producer, Electricity Distributor, Charging Infrastructure Operator
State Grid Corporation of China	China	Electricity Distributor
Stromnetz Hamburg GmbH	Germany	Electricity Producer, Electricity Distributor, Electricity Supplier, Charging Infrastructure Operator
Tauber-Solar GmbH	Germany	Charging Infrastructure Operator, Fleet Operator, Electricity Producer
TE Connectivity Ltd	Switzerland	Electronic Components Producer, Electric Components Producer
Terna SpA	Italy	Electricity Distributor
Transdev Group S.A.	France	Fleet Operator
Transport for London	UK	Charging Infrastructure Operator
Union des Groupements d'Achats Publics	France	Fleet Operator, Charging Infrastructure Distributor, Car Distributor
University of California San Diego	USA	Research and Development Provider
University of Duisburg-Essen	Germany	Research and Development Provider
U.S. National Renewable Energy Laboratory	USA	Research and Development Provider
VERBIO Vereinigte BioEnergie AG	Germany	Alternative Fuel Producer

Verbund AG	Austria	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator
Voltalia SA	France	Electricity Producer
Vorarlberger Kraftwerke AG	Austria	Electricity Distributor, Electricity Supplier, Electricity Producer, Charging Infrastructure Operator, Charging Infrastructure Distributor
Webasto SE	Germany	Battery Producer, Charging Infrastructure Equipment Manufacturer, Electronics Producer
Wieland-Werke AG	Germany	Raw Materials Producer
Wien Energie GmbH	Austria	Electricity Distributor, Electricity Producer, Electricity Supplier, Charging Infrastructure Operator
Plug Power	USA	Producer of Fuel Cells

Table 21: Identified actors through database research

B. BEVs Available in Austria in 2019

Company	**Nation**	**Model**	**Costs [€]**	**Range [km]**	**Power [kW]**
Audi	Germany	e-tron	83140	411	158
BMW	Germany	i3	38400	310	125
BMW	Germany	i3s	42050	310	135
Citroën	France	C-Zero	21990	100	49
Hyundai	South Korea	IONIQ Elektro Level 3	35490	280	88
Hyundai	South Korea	Kona Elektro Level 5	47790	449	150
Jaguar	United Kingdom	I-PACE EV 400 S	78770	470	294
Kia	South Korea	e-Niro	37490	289	100
Kia	South Korea	e-Niro Long Range	41890	455	150
Kia	South Korea	e-Soul	?	289	100
Kia	South Korea	e-Soul long range	?	452	150
Mercedes-Benz	Germany	EQC 400 4MATIC	75500	445-471	300
Nissan	Japan	e-NV200 Evalia	44200	280	80
Nissan	Japan	Leaf 40 kWh Acenta	36800	270	110

Nissan	Japan	Leaf 62 kWh e+ 3.Zero	46500	385	167
Opel	Germany	Ampera-e	42990	520	150
Peugeot	France	iOn Active	21990	100	49
Renault	France	Twizy Complete Life 45	11680	100	4
Renault	France	Twizy Complete Life 80	12380	90	13
Renault	France	Zoe Complete Life R90	33490	317	68
Renault	France	Zoe Complete Life Q90	33990	300	65
Renault	France	Zoe Complete Limited R110	35890	300	80
Smart	Germany	EQ fortwo cabrio	26380	145	60
Smart	Germany	fortwo EQ	23070	145	60
Smart	Germany	forfour EQ	23750	139	60
Tesla	USA	Model 3 Long-Range	58300	560	?
Tesla	USA	Model 3 Performance	69100	530	?
Tesla	USA	Model S 100D	111600	632	?
Tesla	USA	Model S P100D	148900	613	?
Tesla	USA	Model X 100D	115900	565	?
Tesla	USA	Model X P100D	158050	542	?
Volkswagen	Germany	e-up!	27590	160	60
Volkswagen	Germany	e-Golf	39990	215	100

Table 22: Battery electric cars available in Austria in 2019 (according to Mercedes-Benz Österreich GmbH, 2019; Nissan Center Europe GmbH, 2019a; Opel Automobile GmbH, 2019; Porsche Austria GmbH & Co OG, 2019; Skarics et al., 2019)

C. Producers of Battery Cells for BEVs

Company	**Nation**	**Cooperations with OEMs**
Sanyo	Japan	Honda, PSA, Toyota, Audi
Samsung	South Korea	BMW
BYD	China	VW, BYD, Daimler
LG Chem	South Korea / USA	GM, Kia
Panasonic	Japan	Honda, Toyota, Tesla

NEC	Japan	Renault-Nissan
Toshiba	Japan	VW
GS Yuasa	Japan	Honda, Mitsubishi, PSA
JCI Saft	France	Ford, Daimler
A123	USA	Think
Li-Tec	Germany	Daimler
CATL	China	BMW
SK Innovation	South Korea	VW, Kia

Table 23: Suppliers of battery cells for BEVs (according to Eckl-Dorna, 2018; Kampker et al., 2018, p. 50; Randall, 2019)

D. Examples for Producers of Electric Drivetrain Systems for BE

Company	**Nation**	**Associated OEMs**
Bosch	Germany	Daimler, Porsche, Fiat, Volvo, Peugeot
Tesla	USA	Tesla, Daimler
GKN	United Kingdom	BMW, Mitsubishi, Porsche, Volvo
Audi	Germany	Audi
Aisin Seiko, Denso	Japan	Toyota
ZF Friedrichshafen	Germany	e.Go
Nidec	Japan	GAC, PSA
Borg Warner	USA	Great Wall Motors
BMW	Germany	BMW
Magna	Canada	Ford, Mitsubishi, Volvo
Siemens, Valeo	Germany/France	?
Continental	Germany	Renault, Volkswagen
Nissan	Japan	Nissan
Renault	France	Renault
Volkswagen	Germany	Volkswagen
Dana TM4	Canada	Tata, PSA

Schaeffler	Germany	?
Hyundai Mobis	South Korea	Hyundai, Kia
Jaguar Land Rover	United Kingdom	Jaguar

Table 24: Suppliers of traction motors and drivetrains for EVs (BorgWarner, 2018; Dana TM4, 2019; Follmann, 2016; Groupe PSA, 2018c; Hyundai Mobis, 2019; JLR, 2019; Nash, 2019; Orlowski et al., 2019)

E. Production Facilities for EVs in Europe

OEM	**Plant**	**Nation**	**Produced vehicles**	**Type**
Audi	Brussels	Belgium	e-tron	Purpose-built
Daimler	Sindelfingen	Germany	EQC	Shared line with ICE models
Smart	Hambach	France	Fortwo EQ, forfour EQ	Shared line with ICE models
Renault	Valladolid	Spain	Twizy	Purpose-built
Jaguar Land Rover	Graz	Austria	I-Pace	Shared line with ICE models
Renault	Flins-sur-Seine	France	Zoe	Shared line with ICE models
BMW	Leipzig	Germany	i3, i8	Purpose-built
Nissan	Sunderland	United Kingdom	Leaf	Shared line with ICE models
Nissan	Barcelona	Spain	e-NV200	Shared line with ICE models
Porsche	Zuffenhausen	Germany	Taycan (from 2019)	Purpose-built
Tesla	Tilburg	Netherlands	Model S, Model X	Only assembly line
Volkswagen	Zwickau	Germany	ID.3 (from 2020)	Purpose-built
Volkswagen	Bratislava	Slovakia	e-Up!	Shared line with ICE models
Volkswagen	Dresden	Germany	e-Golf	Purpose-built (open-view manufacture)
Volkswagen	Wolfsburg	Germany	e-Golf	Shared line with ICE models

Table 25: EV production facilities in Europe (Audi Brussels NV/SA, 2019; Dr. Ing. h.c. F. Porsche AG, 2019; Ewing, 2010; Groupe Renault, 2013; Groupe Renault, 2019b; Magna Steyr, 2018; Mercedes-Benz Österreich GmbH, 2019; Nissan Center Europe GmbH, 2019b; Nissan International SA, 2014; Schmidt, 2018; Volkswagen AG, 2018c; Volkswagen AG, 2019a; Volkswagen AG, 2019e; Volkswagen AG, 2019g)

F. Examples for Partnerships between Research Institutions and OEMs / Suppliers

Research institution	OEM / Automotive supplier
TU Graz	Siemens, Magna Steyr, AVL List, Infineon, voestalpine, ams, Ventrex
FH Joanneum Graz	AVL List, Infineon, Magna Steyr,
FH Campus 02 Graz	AT&S, ams, AVL List, Infineon, Magna Steyr, Siemens,
TU Munich	BMW, Opel, Continental, Bosch, Volkswagen

Table 26: Examples for partnerships between research institutions and OEMS/suppliers (Department of Mechanical Engineering Technical University of Munich, 2018; FH Campus 02; FH Joanneum, 2018; TU Graz, 2019)

G. Comparison between German Automotive OEMs and Suppliers

OEM / Supplier	Automotive revenues [Mio. €]	Total employment
Volkswagen Group	105187	366769
Daimler	78924	258628
BMW	50681	96207
Audi	29840	58011
Bosch	30261	270687
Continental	26483	134434
ThyssenKrupp	11305	187495
ZF	11230	60480
BASF	6968	104779
Schaeffler	6104	61000
Mahle	5277	43489

Table 27: German Automotive OEMs and Suppliers (Barthel et al., 2015, p. 12)

H. Market Share of BEVs in Europe 2008-2018

Year	Finland	France	Germany	Netherlands	Norway	Portugal	Sweden	UK
2008	-	-	-	-	0.22	-	-	-
2009	-	-	-	-	0.15	-	-	-
2010	-	-	-	-	0.31	0.32	-	-
2011	-	0.12	-	0.15	1.32	0.12	0.05	0.06
2012	-	0.30	0.07	0.16	3.00	0.05	0.09	0.08

2013	-	0.49	0.18	0.54	5.67	0.13	0.15	0.12
2014	0.17	0.58	0.27	0.69	12.21	0.14	0.38	0.27
2015	0.22	0.89	0.37	0.57	16.11	0.34	0.82	0.38
2016	0.19	1.06	0.34	0.98	14.37	0.35	0.75	0.39
2017	0.42	1.21	0.73	2.08	19.66	0.82	1.34	0.53
2018	0.64	1.43	1.05	5.65	29.47	2.08	1.96	0.66

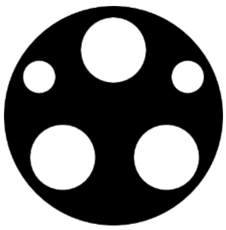
Table 28: Market share of BEVs in Europe [%] (International Energy Agency, 2019, p. 214)

I. Global BEV Stock 2008 - 2018

Year	Finland	France	Germany	Netherlands	Norway	Portugal	Sweden	UK	Globally
2008	-	0.01	0.09	0.01	0.26	-		1.22	5.15
2009	-	0.12	0.10	0.15	0.40	-		1.40	7.48
2010	-	0.30	0.25	0.27	0.79	0.72		1.65	14.59
2011	0.06	2.93	1.65	1.12	2.63	0.91	0.18	2.87	53.53
2012	0.11	8.60	3.86	1.91	6.81	0.96	0.45	4.57	112.92
2013	0.17	17.38	9.18	4.16	15.01	1.10	0.88	7.25	225.50
2014	0.36	27.94	17.52	6.83	33.10	1.29	2.12	14.06	415.74
2015	0.61	45.21	29.60	9.37	58.88	1.97	5.08	20.95	736.90
2016	0.84	66.97	40.92	13.11	83.10	2.78	8.03	31.46	1198.37
2017	1.35	92.95	59.09	21.12	116.13	4.67	12.39	45.01	1945.78
2018	2.12	124.01	95.15	46.18	162.27	9.10	19.54	60.75	3290.80

Table 29: BEV stock [thousand vehicles] (International Energy Agency, 2019, p. 210)

J. Interface Types for Charging EVs

Type	**Interface Name**	**Connector type**	**Power [kW]**	**Region**	**Manufacturers**
Slow charging	Type 1			Japan	Opel, Nissan, Mitsubishi, Peugeot, Citroën, Toyota, Ford, Renault

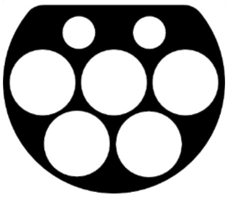
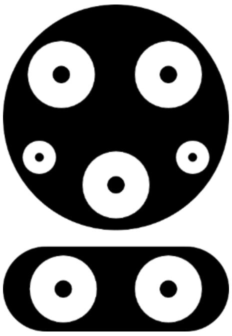
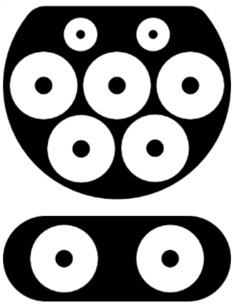
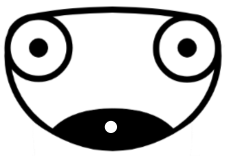
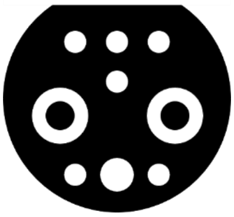
	Type 2		< 22 AC	Europe	Opel, BMW, Renault, Volvo, Volkswagen, Audi, Mercedes-Benz, Porsche
Fast charging	CHAdeMO		50 DC	Japan	Nissan, Mitsubishi, Toyota, Subaru, Peugeot, Citroën, Kia
	CSS Combo1		50 DC	USA	BMW, Mercedes-Benz, Volkswagen, Audi, Porsche, Ford, Tesla
	CSS Combo2		50 DC	Europe	
	Tesla Supercharger		120 DC	USA, China, Japan	Tesla
	GB/T			China	Geely, SAIC, BYD, Chery, GAC, …

Table 30: EV charging interface types (Dalroad, 2018; Visser, 2019)

K. Examples for Suppliers, Operators and Owners of Charging Infrastructure

Company	Country	Type	Associates	Background
Hubsta	UK	EMSP		IT
Chargemaster	UK	Supplier of charging infrastructure, CPO, charging infrastructure owner	British Petrol	Oil
Ecotricity	UK	Owner of charging infrastructure, CPO, EMSP		Electric utility
Chargepoint	USA	Supplier of charging infrastructure, CPO	BMW, Daimler, Chevron, Siemens, AEP	OEM, oil, electric devices, electric utility
Virta	Finland	Supplier of charging infrastructure		Electric utility
Pod Point	UK	Supplier of charging infrastructure, CPO		
ABB	Switzerland	Supplier of charging infrastructure		Electric devices
Bosch	Germany	Supplier of charging infrastructure, CPO		Tier 1 Supplier
ChargeNow	Germany	EMSP	BMW, Daimler	OEM
Tesla	USA	Supplier of charging infrastructure, CPO, EMSP, Charging infrastructure owner		OEM
E.on	Germany	Supplier of charging infrastructure, CPO, Charging infrastructure owner		Electric utility
Ionity	Germany	Supplier of charging infrastructure, Owner of charging infrastructure, CPO, EMSP	BMW, Daimler, Ford, Volkswagen, Audi, Porsche	OEM
Tesco	UK	Charging infrastructure owner	Volkswagen	Retailing; OEM
Vinci	France	Charging infrastructure installation, Charging infrastructure owner, CPO		Infrastructure

EnBW	Germany	Supplier of charging infrastructure, CPO, EMSP, Charging infrastructure owner		Electric utility
InCharge	Sweden	Supplier of charging infrastructure, CPO	Vattenfall	Electric utility
Innogy	Germany	Supplier of charging infrastructure, CPO	E.On	Electric utility
ESB ecars	Ireland	CPO, Supplier of charging infrastructure		Electric utility
Siemens	Germany	Supplier of charging infrastructure		Electric devices
Smatrics	Austria	Supplier of charging infrastructure, CPO, charging infrastructure owner, EMSP	Verbund, Siemens, OMV	Electric utility; Electric devices; Oil
Hubject	Germany	EMSP	BMW, Bosch, Daimler, EnBW, Innogy, Siemens, Volkswagen	OEM; Electric utility; Electric devices

Table 31: Suppliers, owners and operators of EV charging infrastructure in Europe (ABB, 2019; Bosch Automotive Service Solutions Inc., 2019; BP Chargemaster, 2019; ChargePoint, 2019; Crunchbase Inc., 2019; Daimler AG, 2019b; E.ON UK plc., 2019; Ecotricity, 2019; EnBW Energie Baden-Württemberg AG, 2019; ESB, 2019; Götze; Hubject GmbH, 2019; Hubsta, 2019; InCharge, 2019; innogy, 2019; Ionity GmbH, 2019b; Musk, 2012; Pod Point, 2019; Siemens, 2019; Smartrics GmbH & Co KG, 2019; Tesco PLC, 2018; VINCI Energies, 2019; Virta, 2019)

L. Largest B2C EV Car Sharing Fleets in Europe

Provider	Associates	Background	Number of EVs
ShareNow	Daimler, BMW	OEM	3200
Zipcar	AVIS	Car Rental	325
Flinkster	Deutsche Bahn	Public Transport	600
We Share	Volkswagen	OEM	1500
Sixt Share	Sixt	Car Rental	?
Free2Move	PSA	OEM	550

Table 32: EV Fleets Owned by Car Sharing Companies in Europe (Deutsche Bahn, 2019; Groupe PSA, 2018a; moovel, 2019; SIXT SE, 2019; Volkswagen AG, 2019h; Zipcar UK Ltd., 2018)

M. Providers of Financial Services and Leasing owned by OEMs

OEM	Total EBIT [Billion €]	Financing Institute	Segment EBIT [Billion €]
BMW	9.121	BMW Financial Services	2.190
Daimler	11.132	Daimler Mobility	1.384
Volkswagen	13.920	Volkswagen Financial Services	2.612
PSA	5.689	Banque PSA Finance	939
Ford	6.35	Ford Credit	2.310
GM	11.783	GM Credit	1.893
Renault	3.612	RCI Banque	1.204

Table 33: EBIT of financing institutes owned by OEMs in 2018 [billion €] (BMW AG, 2019; Daimler AG, 2019a; Ford Motor Company, 2019; General Motors Company, 2019; Groupe PSA, 2018a; Groupe Renault, 2019a; PSA Groupe, 2019; Volkswagen AG, 2019d)

N. Fleet CO_2 Emissions in 2016 in Comparison with 2021 Targets

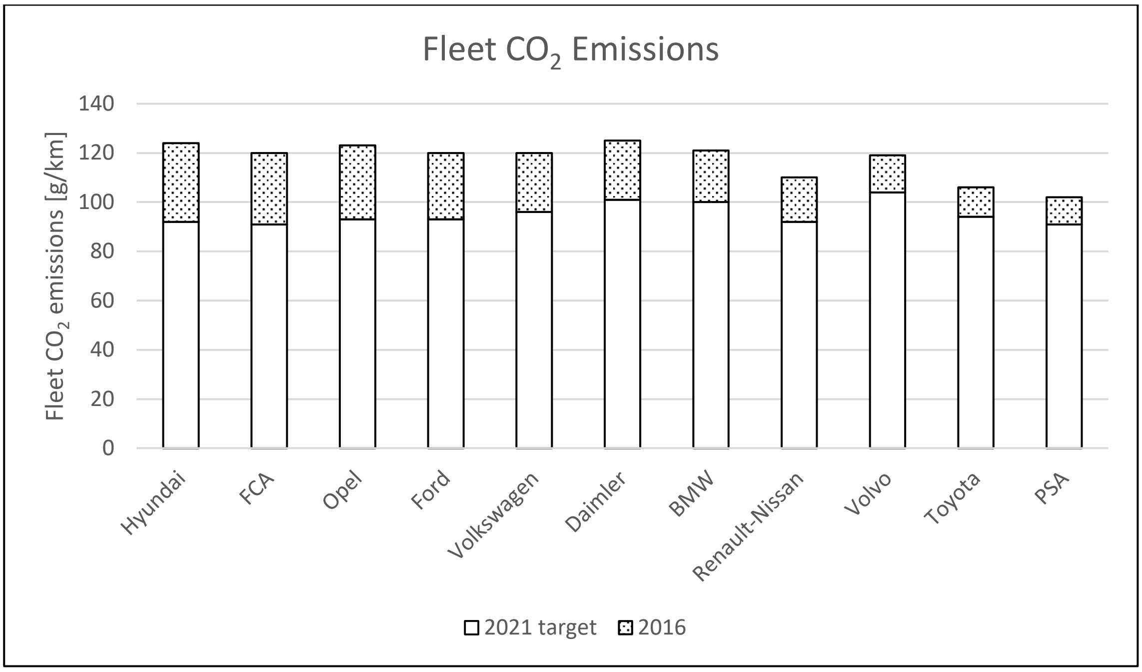


Figure 58: Fleet CO_2 emissions in comparison with 2021 targets (Gupta-Chaudhary et al., 2018, p. 80)

O. Incentives for Europe's Ten Largest EV Markets

	Austria	Belgium	France	Germany	Netherlands	Norway	Spain	Switzerland	UK
Purchase subsidies	✓	✓	✓	✓	✗	✗	✓	✗	✓
Registration tax benefits	✓	✓	✓	✗	✓	✓	✓	✗	✓
Ownership tax benefits	✓	✓	✓	✓	✓	✓	✓	✓	✓
Company tax benefits	✓	✓	✓	✓	✓	✓	✗	✗	✓
VAT benefits	✓	✗	✗	✗	✗	✓	✓	✗	✗
Other financial benefits	✗	✗	✗	✓	✗	✓	✓	✓	✗
Local incentives	✓	✗	✓	✓	✗	✓	✓	✗	✓
Infrastructure incentives	✗	✗	✗	✗	✗	✓	✓	✗	✓

Table 34: Incentives for Europe's ten largest EV markets (Gupta-Chaudhary et al., 2018, p. 82)

P. Case Study Protocols

Case study protocol – Case 1: BMW

Step 1: BMW's press portal

Key word: *"electric vehicle"*

Date: *14.09.2019*

Number of results: *?*

Step 2: Nexis Company and Financial database: Mergers and Acquisitions

Key word: *"BMW"; "electric"*

Date: *16.09.2019*

Number of results: *81*

Step 3: Reuters news portal

Key word: *"BMW; cooperation"*

Date: *17.09.2019*

Number of results: *626*

Key word: *"BMW; partnership"*

Date: *17.09.2019*

Number of results: *639*

Key word: *"BMW; joint venture"*

Date: *17.09.2019*

Number of results: *714*

Key word: *"BMW; alliance"*

Date: *17.09.2019*

Number of results: *517*

Key word: *"BMW; integration"*

Date: *17.09.2019*

Number of results: *366*

Step 4: Complementing results using industry reports and topic-related internet portals

Date: *18.09.2019; 19.09.2019*

Step 5: Scanning business reports for background information

Date: *18.09.2019; 19.09.2019*

Step 6: Case writing

Date: *20.09.2019*

Figure 59: Case study protocol for case 1

<u>Case study protocol – Case 2: Daimler</u>

Step 1: Daimler's press portal

Key word: *"electric vehicle"*

Date: *21.09.2019*

Number of results: *2974*

Step 2: Nexis Company and Financial database: Mergers and Acquisitions

Key word: *"Daimler"; "electric"*

Date: *25.09.2019*

Number of results: *446*

Step 3: Reuters news portal

Key word: *"Daimler; cooperation"*

Date: *25.09.2019*

Number of results: *724*

Key word: *"Daimler; partnership"*

Date: *25.09.2019*

Number of results: *686*

Key word: *"Daimler; joint venture"*

Date: *25.09.2019*

Number of results: *915*

Key word: *"Daimler; alliance"*

Date: *25.09.2019*

Number of results: *764*

Key word: *"Daimler; integration"*

Date: *25.09.2019*

Number of results: *392*

Step 4: Complementing results using industry reports and topic-related internet portals

Date: *26.09.2019*

Step 5: Scanning business reports for background information

Date: *27.09.2019; 28.09.2019*

Step 6: Case writing

Date: *28.09.2019; 29.09.2019*

Figure 60: Case study protocol for case 2

Case study protocol – Case 3: Volkswagen

Step 1: Volkswagen's press portals

Key word: *"electric vehicle"*

Date: *30.09.2019 (Audi, SEAT, Volkswagen); 01.10.2019 (Volkswagen, SKODA, Porsche)*

Number of results: *634 (Audi); 7 (SEAT); 854 (Volkswagen); 774 (SKODA); 5 (Porsche)*

Step 2: Nexis Company and Financial database: Mergers and Acquisitions

Key word: *"Volkswagen"; "electric"*

Date: *02.10.2019*

Number of results: *97*

Step 3: Reuters news portal

Key word: *"Volkswagen; cooperation"*

Date: *02.10.2019*

Number of results: *1249*

Key word: *"Volkswagen; partnership"*

Date: *02.10.2019*

Number of results: *963*

Key word: *"Volkswagen; joint venture"*

Date: *02.10.2019*

Number of results: *1336*

Key word: *"Volkswagen; alliance"*

Date: *02.10.2019*

Number of results: *1092*

Key word: *"Volkswagen; integration"*

Date: *02.10.2019*

Number of results: *621*

Step 4: Complementing results using industry reports and topic-related internet portals

Date: *02.10.2019; 03.10.2019*

Step 5: Scanning business reports for background information

Date: *04.10.2019; 05.10.2019*

Step 6: Case writing

Date: *05.10.2019; 06.10.2019*

Figure 61: Case study protocol for case 3