Competitiveness of the EU Automotive Industry in Electric Vehicles

Final Report

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Executive Summary

The European automotive industry has traditionally been the world leader in technology development. With the introduction of new technologies, changed market conditions and the entry of foreign competitors, EU manufacturers have been faced with new challenges. In the case of electric vehicles, Asian competitors in particular have well-established know-how, already offering highly competitive products. Having restructured after the financial crisis, the US automotive industry is also investing to secure a strong position in electromobility.

The aim of this project is to investigate opportunities for the automotive industry in the European Union in the field of electromobility. Initially, both the aim and scope of this study were discussed during the project kick-off. Afterwards, detailed results of the interim and the final report were presented by the project team in Brussels.

For the purpose of the study, two models were developed: a market model to assess the development of the global market for electromobility and a value added model to assess the development of value added in the EU automotive industry in transition to electromobility. These results were supplemented by analyses of the development of battery technology, patents and services linked to electromobility. Finally, the results were validated by interviews with 94 experts in five European countries (Germany, United Kingdom, France, Italy and Spain), three Asian countries (Japan, South Korea and China) and the US (see Appendix I).

As confirmed by the majority of experts in different regions, electric vehicles category can be further divided in four types: Battery Electric Vehicles, Plug-In Hybrids, Range Extenders and Fuel Cell Vehicles. On the other hand, (non-rechargeable) Full Hybrid Electric Vehicles tend to belong to the segment of vehicles with internal combustion engines where they play a role in improvement of fuel economy.

Altogether, 20 conclusions can be drawn from the study of the Competitiveness of the European automotive industry in Electric Vehicles:

1. Currently, registrations of new electric vehicles are very low with an average share of 0.06 percent in the countries considered, (EU, USA, Japan, South Korea and China). However, all market participants believe that there is “no going back” from electromobility. This belief can be contrasted with the situation in the U.S. in the 90s when the rapid progress of electromobility was suddenly stopped. In 1995, California passed a law that at least two percent of all registered vehicles have to be emission-free by the year of 2003. Due to a suit of the U.S. automotive industry in 2003, the law was cancelled.[1] Henceforth, the industry stopped offering zero-emission vehicles and refocused exclusively on the development and sales of internal combustion engines. This shows the importance of regulation in the transition to a new technology.

2. In the base case scenario of the market model developed in this study, which is based on purchase decisions in the private and commercial segments, and assuming business as usual without further business policy initiative, the development of the cost/benefit ratio for electric vehicles has been the key variable for the determination of market forecasts. Both the structure of the model and the (country specific) key assumptions were validated by experts.

3. According to this market model, in 2020, the European Union (EU-27) will have reached a total amount of 14.8 million new light duty vehicle registrations (passenger cars and light commercial vehicles), with a 7 percent market share in electric vehicles.

   Up until 2030, European new vehicle registrations will remain stable at approximately 15 million vehicles. In 2030, about 31 percent of EU-27 new light duty vehicle registrations will belong to electric vehicles.

   In 2020, market forecasts indicate that registrations of EVs in the EU will include approximately 5 percent Plug-In Hybrids, 1 percent Range Extenders and about 1 percent Battery Electric Vehicles. However, when this is compared with the offer (majority of European and foreign manufactures focus on battery electric vehicles), the share of Plug-In Hybrids might be exaggerated.

[1] WIWO (2006)

By 2030, the share of Plug-In Hybrids in new electric vehicle registrations will increase to 16 percent, with 3 percent in Range Extenders and about 11 percent in Battery Electric Vehicles. EU-27 registrations of Fuel Cell vehicles will be less than 1 percent. The chronological development of electrification in the automobile industry has been validated on the basis of expert estimates: Plug-In Hybrid vehicles will dominate up till 2030 followed by Battery Electric Vehicles. From 2040 onwards, Fuel Cell Vehicles will become more prevalent. Nevertheless, fuel cell technology is regarded with great scepticism by the majority of experts, particularly with regard to the timing of market penetration.

4. The base case scenario produced by the market model expects a global market development of 86 million vehicles up until 2020 and approximately 99 million vehicles in 2030 with a share of 9 percent of electric vehicles in 2020 and 31 percent in 2030.

   In 2020, global registrations of Plug-In Hybrids are expected to be around 7 percent, while registrations in Range Extenders and Battery Electric Vehicles will be approximately 2 percent. In 2020, the European, Japanese and U.S. markets are expected to be the leading markets in terms of electric vehicles sales. By 2030, the share in Plug-In Hybrids is expected to be 18 percent with 9 percent in battery electric vehicles and 4 percent in Range Extenders. Global registrations of Fuel Cell Vehicles will still be under 1 percent in 2030. There are large differences between the regions. The share of electric vehicles in Japan, with its declining market, will be about 16 percent in 2020 increasing to 34 percent in 2030. The strong growth potential in the Chinese market will allow for an approximate 9 percent share of electric vehicles in 2020 with a rapid increase to 40 percent in 2030. In the US, the market share of electric vehicles is expected to be 9.5 percent in 2020 and about 35 percent in 2030. In 2030, China is likely to join EU, Japanese and US as the key market in terms of electric vehicles sales.

5. The additional costs of Battery Electric Vehicles are expected to decrease by 50 percent by 2020 and 70 percent by 2030 due to cost reductions in main components of electric vehicles (such as batteries, electric motors and power electronics) which are mainly based on scale production, rising competition and increased efficiency of the manufacturing process (e.g. in battery technology, efficiency of cell manufacturing and battery assembly).

6. In terms of electric vehicle assembly, the survey results show two main differences. While one group of respondents - manufacturers and suppliers - will offer electric vehicles based on new vehicle architecture (“Purpose Design”), a second group is focusing on the integration of electric powertrains into conventional vehicle architecture (“Conversion Design”). From an economic perspective, a huge cost reduction potential, particularly from standardisation and modularisation, can be expected by focusing on the production of new vehicle concepts. A new vehicle concept with a new production method, such as BMW’s with its “i-brand”, however, is significantly more risky than the integration of electric propulsion into existing vehicle architecture. In contrast, new vehicle architectures allow new opportunities in terms of space usage, handling and weight.

7. Importantly, vehicles with internal combustion engines will have a large potential for fuel efficiency. The experts interviewed expect a 25 percent reduction in fuel consumption by 2030. This is also why the utility-cost index of Battery Electric Vehicles, indicating the relationship of benefits to costs of an EV relative to an ICE, will change slowly from 44 today to 65 in 2020 and 131 in 2030 compared to vehicles with internal combustion engines (100). Furthermore, the utility-cost index of Range Extenders will increase from 55 today to 78 in 2020 and 119 in 2030 compared to vehicles with internal combustion engines (100). The utility-cost index of Plug-In Hybrids will change from 67 today to 83 in 2020 and 128 in 2030 compared to vehicles with internal combustion engines (100). In addition, the utility-cost index of Fuel Cell Electric Vehicles will change from 1 today to 8 in 2020 and 54 in 2030 compared to vehicles with internal combustion engines (100).

8. The majority of experts interviewed for the purpose of the study consider that (innovative) fleets will be the real “early adopters” out of all customer segments. Registrations of fleets (e.g. local public transport, taxis or public vehicles) are therefore expected to be the key facilitator of economies of scale and scope. As soon as electric vehicles no longer have substantial cost disadvantages, private customers will enter the market. Presently, private customer acceptance is fairly low even in fast growing markets like China. In many markets, there is clearly a lack of "green enthusiasts" who would be willing to pay a higher price for an “environmentally-friendly” vehicle. For the majority of customers, price is the key criterion influencing their purchase decision.

9. In 2020 and 2030, the EU will still be a net exporter of internal combustion engine vehicles but will also be exporting electric vehicles. EU exports to Japan and South Korea will be, however, low in 2020 and 2030, partly due to consumer behaviour as well as regulations in these countries. The important considerations with that respect are the following: the EU and Japan are currently preparing a free trade agreement; Chinese foreign trade in automobiles has expanded rapidly and will continue to grow at a fast pace; OEMs from the EU will continue to capture more than 60 percent of the market for imported vehicles to China with luxury and executive cars and SUVs and they are well positioned to benefit from the recent trend towards purchases of higher grade cars by an increasing number of affluent consumers. Concerning possible Chinese exports of EVs to the EU, it will be most likely negligible up to 2020 but may rise after that; modern production facilities established by Sino-foreign auto joint ventures may want to escape an escalating industry glut and capitalise on their superior cost and quality position by serving Western markets.

10. The current value added in the automobile industry in the European Union amounted to 151 billion Euro in 2011. In the base case scenario, the value added in vehicle manufacturing is expected to remain stable at approximately 141 billion Euro in 2020 and 142 billion Euro in 2030. The rise of electric vehicles will likely reduce value added by 6 billion Euro in 2020 (4 percent) and 15 billion Euro in 2030 (10 percent) in the vehicle production because of the fact that battery manufacturing will most likely be located outside the EU. This will be, however, compensated by gains in valued added created by services surrounding electromobility.

11. Despite increasing capacities and progress in know-how in the BRIC countries, the majority of experts confirm stable competitiveness in the EU. The distribution of value added is not that relevant, please summarise here the findings of chapter 3.2.7

12. With regard to the key components of electric vehicles, Europe is less competitive in battery cell technology and has to catch up. According to the experts, the EU automotive industry has a stronger position than Asia or the USA in electric engines and power electronics. However, these factors are less relevant to becoming a competitive key player in electromobility because battery technology will be crucial. In addition, there is likely to be a significant progress in standardisation of electric engines, opening this industry segment further for competition. The batteries components such as cathodes, anodes, electrolytes and separators will mainly be manufactured in Asia while the assembly of battery systems and cell production in the EU will increase. Due to market proximity and manufacturers’ logistical requirements (e.g. JIT production), battery assembly in particular will be located close to the manufacturers. Furthermore, due to a high degree of automation, it will be possible to carry out large shares of R&D and power electronics production in the EU. On the other hand, the value added generated in the EU from electric motors in the future will not be more than one-third of the total for this area. The majority of experts surveyed in this study expect that electric motors will be produced globally even in the medium term. Overall, the European companies have shown a positive development in patent applications for EV technology in the last few years which is also reflected in increased public reporting. However, despite this noticeable upward trend in Europe, it is doubtful whether European companies will catch up with their Asian competitors in the field of batteries in the very near term.

13. The results of the survey underline the fact that the development of the automotive industry, especially the development of additional technologies, depends heavily on public policies. Productivity and cost development (e.g. labour costs, logistical costs) play a minor role, but should not be underestimated.

14. The automotive companies’ industrial plans show that most of the key players are focusing on both the optimisation of the efficiency of internal combustion engine technology and the development of the electric powertrain. While the Chinese automotive industry is focusing on the development and production of electric vehicles (particularly due to less developed skills in the field of internal combustion engine technology), the Koreans in particular are pursuing the optimisation of internal combustion engine technology. Particularly the experts from Korea and Japan surveyed in this study emphasise the high potential of internal combustion engine technology (especially in combination with hybridisation) which will slow down the market penetration of electric vehicles.

15. The industrial plans of the majority of the key players analysed show that most enterprises are operating in the (efficiency-oriented) optimisation of internal combustion engine technology and the (flexibility-oriented) development and production of electric vehicles (e.g. in terms of modularization, flexible production). This requires ambidextrous management of the diverging manage-

ment logics of an efficiency and flexibility orientation at the same time. In addition, many experts confirm that there is a shortage of capable and qualified employees needed to face the challenges of electromobility being a new disruptive technology. Since competent and skilled workers are not easy to find, entrepreneurs expect that this unfavourable situation will intensify. To make up for the lack of competencies, many companies will enter into alliances and joint ventures. In the near future, further alliances both between large companies and between large and small, medium-sized or start-up companies can be expected.

16. The transition to electromobility also requires new services, leading to new market opportunities for new entrants and for new business models. The recycling of electric vehicles will be the most relevant service followed by the deployment of charging infrastructure, car sharing and the maintenance and repair. However, this is an average estimated ranking and will vary by region. The experts from Asia surveyed, for example, emphasise that car sharing will have less potential in Korea and Japan in the medium term, as consumers do not like to share their vehicles.

17. On the whole, the total volume of the automotive service sector is likely to rise in the coming years, as the two automotive power devices (traditional engine and electric battery) will and exist and have to be serviced in parallel. For example, the installation of charging and service infrastructures for electric vehicles will be necessary while still retaining the traditional petrol, gas and service stations. Other developments such as the rising number of car sharers because of opportunities offered by the use of small electric vehicles in city centres will increase this trend even further. New opportunities could be offered by services enabling leasing or recharging of batteries. On the other hand, due to the decreasing complexity of electric vehicles in comparison to internal combustion engine vehicles, the after-market will decline in volume.

18. The survey clearly shows that different public policy areas (indirect support and direct support) will be required in order to push electromobility's breakthrough into the market. An analysis of public policy in the USA and Asia indicates that public policy on federal and individual state level is already fairly complex.

19. In this study, an upper- and lower end scenario ("Accelerated Path to Electromobility" versus "Long Run to Electromobility") were developed. The "Accelerated Path to Electromobility" scenario is based on: dynamic growth on the global vehicle market, an increase in the market penetration of electric vehicles up to 2020, rapid technological and business models development and further activities in terms of public policy support. This could lead to an additional EU-27 value added of approximately 40 billion Euro in 2020, 30 billion Euro in 2030 and the creation of 100,000 to 150,000 new manufacturing jobs in Europe. In the hypothesis that the development of electromobility is slow and the total market - especially in the BRIC countries - develops less dynamically, the European automotive industry's value added would be adversely affected (minus 20 billion Euro by 2020 and minus 40 billion Euro by 2030), leading to a significant loss of 150,000 to 250,000 jobs. The scenarios show that electromobility is the key to the development of value added and job-creation in the European automotive industry.

20. In addition to the recommendations of CARS 21 High Level Group, which are focusing on e.g. favourable framework conditions, an integrated policy approach, smart regulation and better global market access, we propose five more specific "no regret moves" for the European public policy:

- A European platform for battery technology to help to develop the missing capabilities in battery technology.
- A formal training initiative in the field of electromobility to reduce the lack of workers' competences related to electromobility
- Special depreciation regime to support investments in production technologies for electric vehicles and their components.
- Expansion of the charging infrastructure in order to enable charging of electric vehicles in the individual countries.
- Focused media campaigns to increase the level of information held by customers.

These five "no regret moves" are based on the analysis of opportunities (i.e. creation of new direct work-places through electromobility) and risks (like an unrealistic assessment of the development of electromobility) within the existing practical public policy constraints (like the need for a consistent multi-level strategy in Europe and the current context of limited possibilities for government spending).

Tables, Figures and Boxes

Tables and Figures in the Appendix

Abbreviations

ACEA	European Automobile Manufacturers’ Association
Ah	Ampere hours
ANFAC	Asociacíon Espanola De Fabricates De Automóviles Y Camiones
ANFIA	Associazione Nazionale Fra Industrie Automobilistiche
BEV	Battery Electric Vehicle
CAMA	Center for Automotive Management at University of Duisburg-Essen at the Chair for General Business Administration & International Automotive Management)
CCFA	Comité des Constructeurs Français d'Automobiles
CEPS	Centre for European Policy Studies
CO2	Carbon Dioxide
DOC	US Department of Commerce
DOE	US Department of Energy
EOP	End of Production
EUR	EURO (Currency)
EV	Electric Vehicle
FCV	Fuel Cell Vehicle
GM	General Motors
GTAI	Germany Trade and Invest
HEV	Hybrid Electric Vehicles
ICE	Internal Combustion Engine
IEA	International Energy Agency
IHK	Industrie- und Handelskammer (German Chamber of Industry and Commerce)
JAMA	Japanese Automobile Manufacturers Association
JRC	Joint Research Center
KAMA	Korea Automotive Manufacturers Association
KBA	Kraftfahrtbundesamt (German Federal Motor Transport Authority)
KIEP	Korean Institute for International and Economic Policy
KRC	Korea Resources Corporation
kWh	Kilowatt hour

LCV	Light Commercial Vehicle
LIB	Lithium-Ion Battery
Li-Ion	Lithium-Ion
OEM	Original Equipment Manufacturer
PHEV	Plug-in Hybrid Electric Vehicle
R&D	Research and Development
REEV	Range Extender Electric Vehicle
RMB	Ren Min Bi
SMMT	Society of Motor Manufacturers and Traders
SOP	Start of Production
TCO	Total Cost of Ownership
UDE	University of Duisburg-Essen
VDA	Verband der Automobilindustrie (German Association of the Automotive Industry)
VDE	Verband der Elektrotechnik Elektronik Informationstechnik (German Association for Electrical, Electronic & Infomation Technologies)

1 Introduction

1.1 Background

The European automotive industry has been a world leader in technology development for many decades. With the introduction of new technologies, changed market conditions, as well as foreign competitors, the EU vehicle manufacturers (OEM) and suppliers have been faced with new challenges. Concerning electric vehicles, Asian competitors have a well-established know-how. Whereas both Korean and Japanese companies occupy a leading position in lithium-ion battery development and manufacturing, Japanese firms, in addition, benefit from the know-how of having developed hybrid vehicles, such as the Toyota Prius, since 1997. Being restructured after the financial crisis, the U.S. automotive industry is also investing to build a strong position in electromobility.

This project is aimed to investigate the competitiveness[2] of the automotive industry in the European Union in terms of electromobility; particularly regarding the development of new products, innovation potential**,** technological leadership, market shares, production capacities, new workplaces, and related services. Furthermore, this study queries into whether the EU industry is currently well positioned to take advantage in electromobility. This study will analyse the current state of play and what industrial decisions have to be made in order to improve the competitive position in the near and medium term (2020-2030); and in particular, how public policy can facilitate development of electromobility and thus increase benefits for the EU automotive industry.

In this report, the term "EU automotive industry" covers both companies which have their headquarters in the EU and companies which have production and R&D facilities in the EU. According to a definition from CARS 21[3], the term "automotive industry", used in this report, is meant to cover the entire supply chain, such as vehicle manufacturers, suppliers, distribution and after-market services. An example of such a European dimension is the battery electric vehicle Nissan Leaf which is currently manufactured in Oppama/Japan. But Nissan is also currently investing in the EU automotive industry to manufacture electric vehicles in Sunderland (UK) by 2013. Furthermore, the term does not only include companies in terms of their production site but also their R&D activities. The GM subsidiary Opel, for example, launched its Ampera Range Extender in January 2012 which is identical to the Chevrolet Volt. Both vehicles are produced in Hamtramck (U.S.). The Ampera is a joint development by General Motors and its German subsidiary Opel. Approximately 250 engineers from the Opel R&D centre in Mainz-Kastel (Germany) have been playing a key role in the development of the 16-kWh battery pack.[4]Although the Opel Ampera is not being produced in the EU, research and development services for the vehicle have been provided by the European automotive industry.

This report focuses on passenger cars and light commercial vehicles with electric propulsion. Considered vehicles include: Plug-in Electric Vehicles (PEHVs), Range-Extender Electric Vehicles (REEVs), Battery Electric Vehicles (BEVs) and Fuel Cell Electric Vehicles (FCVs), see definitions adopted in Chapter 2.1.

[2] **According to the OECD**, competitiveness is a measure of a country's advantage or disadvantage in selling its products in international markets (OECD n.d.). There are many determinants driving competitiveness, e.g. macroeconomic environment, level of education, infrastructure, legal and administrative framework, la-bour market efficiency, financial market development, innovation and market size (Schwab, K. 2010).
Companies are considered to be competitive if they are able to generate sustainable profits and grow or maintain their market shares on domestic and international markets. Today's mass markets are characterised by a high intensity of competition. Therefore, companies need to compete in various terms, e.g. in terms of prices, costs and market shares but also in terms of tangible resources like technology, liquidity, capacities or intangible resources like know-how, competencies or reputation.

[3] See CARS 21 (2012e) - **Note: Further information on all sources will be provided in the references (p. 218 ff.)**

[4] Opel (2011)

1.2 Aims and Scope

The Service Request of European Commission, DG Enterprise and Industry under Framework Contract ENTR/2009/030 (Lot 3) comprises the following five objectives:

- Description and assessment of the **current market for electric vehicles** and competitive position supplemented by an analysis and forecast for a 2020 and 2030 perspective
- Description and assessment of the **industrial situation and technological leadership** of the EU automotive industry regarding electric vehicles and their components supplemented by an analysis and forecast for a 2020 and 2030 perspective

- Description and assessment of **new services relating to electromobility**
- Analysis of the **business environment of the EU automotive industry** compared with its main competitors supplemented by an analysis of the role of EU public authorities
- **Recommendations** for policy makers and industry actions based on the **main conclusions**

These objectives lead to the following structure of this report:

In Chapter 2, the market for electric vehicles will be analysed, including the four types of electric vehicles regarded (Plug-in Electric Vehicles, Range-Extenders, Battery Electric Vehicles and Fuel Cell Electric Vehicles). The study will look into the current sales and market shares for electric vehicles as well as conducting a market forecast (based on a base-case scenario assuming business as usual without further business policy initiative) for the world market, the European market, the U.S. market and the main Asian markets in 2020 and 2030. Forecasting is based on UDE own market model (for the methodology, see chapter 1.3).Market for micro cars as well as the second hand electric vehicles market will be analysed as well and the chapter concludes by looking into trade patterns (with Japan, Korea and China).

In Chapter 3, the industrial situation of the electric vehicles will be considered. In this case, the automotive value chain, the current competitive position of electric vehicle manufacturing in Europe will be analysed. The chapter features an overview on patent application in EV-related technology, joint ventures and alliances in the field of electromobility, comments on national platforms in the field of electromobility, drivers of the industrial situation and first mover advantages. Importantly, the evolution of the industrial situation will be analysed (covering industrial plans of EU automotive companies and the development of the value added to the EU automotive industry).

Services linked to electromobility will be addressed in Chapter 4. Following an overview, the main services will be analysed: maintenance and repair, car sharing services, charging technology as well as recycling of batteries from electric vehicles. In addition, the report provides a forecast on the development of the value added in the EU automotive service market.

Chapter 5 analyses the public policy framework – the current public policy framework of the EU, the US and of Japan, Korea and China as well as future regulatory needs and possible actions.

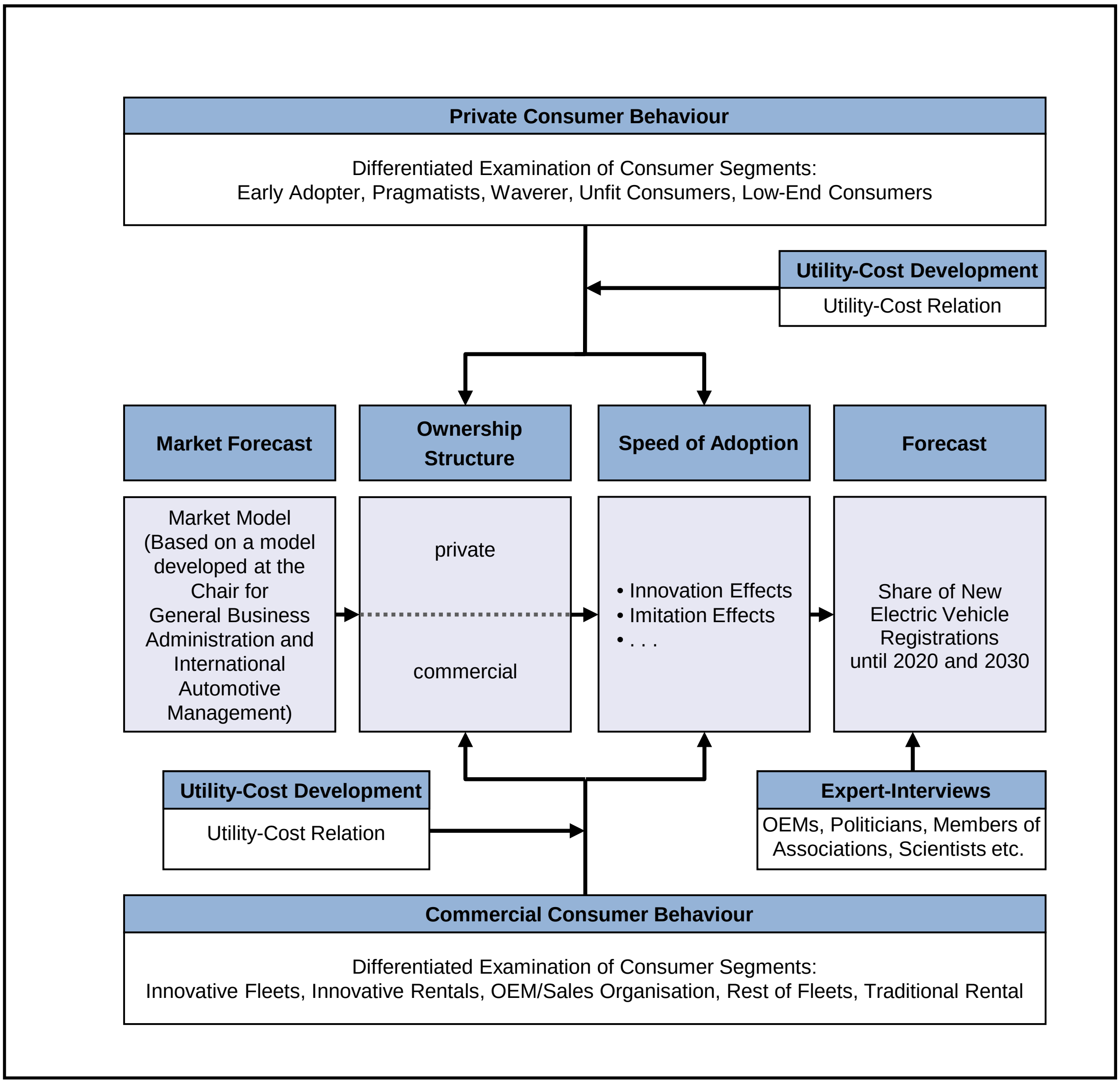
The report ends with conclusions in Chapter 6 summarising the main results of the study. Furthermore, an upper and a lower scenario for the market development will be discussed – an "accelerated path to electromobility" and a "long run to electromobility", followed by policy recommendations.

1.3 Methodology

At the UDE Chair for General Business Administration & International Automotive Management, a market forecast[5] has been developed which includes economic and vehicle-specific drivers. Based on this model an extension was created for this study in order to generate forecasts for different markets (see Figure 1and the general assumptions behind the model in Appendix II). This forecast assumes business as usual without any further business policy initiatives. Alternative (upper and lower) scenarios are discussed in Chapter 6.

[5] The market model is a further development of the forecasting model of the Center for Automotive Management (CAMA) developed in Friedrichshafen in 2008, which is regularly used as CEVF (CAMA Forecast Electric Vehicle) in CAMA market forecasts since spring of 2011.

Figure 1: Methodology of the Market Forecast



(Source: Own Research)

A forecast has been carried out for the EU markets in Germany, France, Italy, Spain and the UK. Along with these markets, the entire EU 27 market was also considered. Furthermore, market models for China, Japan, South Korea, and the U.S. were also conducted. The model distinguishes between private consumers and commercial consumers because of differences in vehicle usage, especially concerning annual mileage. Both customer groups have been split into various consumer segments with different consumer behaviour.

On one hand, private consumer segments are:

- Early Adopter,
- Pragmatists,
- Waverer,
- Unfit Consumers and
- Low End Consumers (see detailed information in Appendix III).

On the other hand, commercial consumers are separated into the segments:

- Innovate Fleets,
- Innovative Rentals,
- OEM/Sales Organisation,

- Traditional Rentals and
- Rest of Fleets (see detailed information in Appendix III).

Each of these groups has a slightly different attitude towards electric vehicles. This is showcased through different times of adoption as well as different speeds of adoption. For example, Early Adopters are more open to new technologies and will start buying electric vehicles earlier than segment members of Low End Consumers. To calculate the adoption time as well as speed **a utility-cost index** was developed (for detailed information see Chapter 2.3.1.2), which consists of benefit as well as cost elements of traditional internal combustion engine vehicles (ICEs) as compared to different types of electric vehicles (EVs - for the different types of EVs see chapter 2.1). The utility-cost index is based on the assumption that private consumers and commercial customers tend more likely to buy a vehicle with the highest utility-cost ratio in the market (for a detailed calculation of the utility-cost index see Appendix II). If an index value of an EV lies above the index threshold calculated for an ICE, this results in a gradual shift of a segment group to electromobility. This procedure leads to a forecast concerning the share of electric vehicles until 2030.

In parallel, key assumptions concerning explicit values of the model as well as the forecast itself were discussed and validated through expert interviews held in each country (for limitations of the model and validation of the methodology see Appendix II).

2 Market for Electric Vehicles

2.1 Types of Electric Vehicles

The electrification of the powertrain of vehicles can take different configurations. For this report the following abbreviations are adopted:

1. Internal Combustion Engine (ICE):

Vehicles with an internal combustion engine have a heat engine that converts the chemical energy of fuel combustion (e.g. gasoline or diesel) into mechanical work.

2. Non rechargeable (Full) Hybrid Electric Vehicles (HEVs):

Vehicles which utilize a combination of an internal combustion engine (ICE) and an electric motor. While the energy recuperation of the braking process is able to charge the battery, the external energy input is still entirely dependent on fuel for the internal combustion engine. Non rechargeable Hybrid configurations cannot be plugged to the electricity grid. Therefore, these types of vehicles will not contribute to the substitution of fossil energy sources. Non-rechargeable Hybrid technology is considered a fuel- efficiency measure.

Electric Vehicles (EVs):

- **Plug-in Hybrid Electric Vehicles (PHEV):** Vehicles which utilize nearly the same powertrain as a Hybrid Electric Vehicle, but the user has the opportunity of external battery charging by connecting the vehicle to the power grid (e.g. Toyota Prius Plug-In Hybrid or Ford C-MAX Energi)

- **Range Extender Electric Vehicle (REEV):** Vehicles which are driven mainly by electric propulsion. A combination of an internal combustion engine and an electric generator is used to recharge the battery. By incorporating an internal combustion engine the vehicle's range increases (e.g. Chevrolet Volt or Opel Ampera).

- **Battery Electric Vehicle (BEV):** Vehicles which are only driven by electric propulsion. The external energy input is supplied by a charging process of plugging the battery into the electricity grid (e.g. Nissan Leaf, Mitsubishi iMiev or Renault Twizy).

- **Fuel Cell Vehicle (FCV):** Vehicles which are only driven by electric propulsion. The external energy input is ensured by refilling the on-board hydrogen tank (e.g. Honda FCX Clarity), which is used to generate electricity in a fuel-cell.

As confirmed by the majority of experts interviewed in different regions, rechargeable electric vehicles comprise four categories described above, while the non-rechargeable Hybrid Electric Vehicles rather belong to the segment of vehicles with combustion engines. However, some of the experts interviewed emphasise that a distinction between PHEVs, REEVs, BEVs and FCVs has been especially evolved for marketing reasons. In addition, the term of "mild hybrid exists.[6].

2.1.1.1 Current Electric Vehicles

The following table (Table 1) provides an overview on current electric vehicles (including BEV, REEV, PHEV and FCV), which have been recently launched and are currently available on the market in Europe, Asia and the U.S. Additionally, a large number of non-rechargeable (full) hybrid vehicles have already been launched into the market, such as the Toyota Prius and the Toyota Auris Hybrid. As they are not covered by the definition of electric vehicles, they are not considered. With the exception of French manufacturers, particularly Renault, it becomes obvious that European car manufacturers are still underrepresented in the markets for electric vehicles.

Presently, the Nissan Leaf, launched in December 2010, and Mitsubishi iMiEV, launched in April 2010[7], belong to the Battery Electric Vehicles. Both are manufactured in Japan. In 2013 the Nissan Leafs for the European market will be produced at Nissan's factory in Sunderland (UK), instead of being imported from Japan. The Leaf will be produced on the same assembly line as the Nissan Qashqai with a potential capacity of 60,000 a year. For the U.S. market, Nissan will start the production of the Nissan Leaf at its production plant in Smyrna (Tennessee) later this year with a capacity to build 150,000 units a year.[8]**The Nissan Leaf is the first mass produced electric vehicle**. **More than 35,000 units have been sold globally since its introduction in December 2010, making Nissan Leaf the world's top selling battery electric vehicle.**[9]

Toyota currently launched its Prius as a plug-in version, produced in Tsutsumi (Japan). The Korean manufacturer Kia introduced its first Battery Electric Vehicle called Ray in 2012. Kia plans to produce 2,500 units of Kia Ray EV in 2012 in Dongee Seosan (Korea). All vehicles are to constitute the government fleet.[10]Currently, it is not yet clear when the vehicle will be sold to retail customers. In China, BYD and Chery are on the rise (see Table 1).

In Europe, particularly French volume manufacturers such as Renault and PSA have already been offering electric vehicles. **Renault** launched its Kangoo Z.E. in 2011. The Kangoo Z.E. is a light commercial vehicle with battery electric propulsion produced on the same assembly line as the Kangoo with an internal combustion engine in the production plant in Maubeuge (France). In 2012 Renault launched its new microcar Twizy Z.E (which however does not count for the registrations of electric cars as it belongs to L category vehicles), the Fluence Z.E. sedan and the Renault Zoe. While the

[6]Technically, more accurate is a distinction between **serial and parallel hybrid vehicles**. Focussing on the infrastructure of the hybrid electric powertrain, there are mainly two different types of vehicles: serial and parallel hybrid vehicles. The serial hybrid vehicle is completely electrically driven (e.g. Chevrolet Volt). Serial hybrid vehicles do not have a mechanical connection between the internal combustion engine and the drive shaft. The combustion engine is used in combination with an electric generator to recharge the propulsion battery during operation. In the parallel hybrid architecture the electric and the combustion engine act on the same drive shaft via a planetary gearbox (e.g. Toyota Prius PHEV). The electric motor is used for e.g. sup-port of the combustion engine during acceleration, recuperation of breaking energy and pure electric driving over short distances at low speeds. The propulsion system of **Mild Hybrid** and **Full Hybrid** vehicles is based on a parallel hybrid structure where the electric motor and the combustion engine act on the same drive shaft. The main **difference between the mild and the full hybrid is the size in respect to the maximum power of the electric engine used.** In mild hybrid vehicles small electric motors with a maximum power of 10kW (e.g. Honda Insight) are used to support the conventional engine during acceleration and for the recuperation of breaking energy, while in full hybrid vehicles the electric motors with a maximum power above 20kW are implemented (e.g. Toyota Auris Hybrid 60kW; VW Touareg Hybrid 38kW) to additionally support pure electric driving over short distances. Mild and non-rechargeable full hybrids are not connected to the electrical grid for recharging and are therefore not considered as electric vehicles in this study. Due to the fact that the classification between BEVs, PHEVs, REEVs and FCEVs is widely accepted by the majority of experts interviewed for this study, and even used in the service request by the EU commission, this classification will be used in this report.

[7] The i-MiEV was launched for fleet customers in Japan in July 2009; while retail sales started in April 2010.

[8] Autonews (2012a)

[9] EDTA (2012)

[10] Kia (2011)

Twizy is produced in Valladolid (Spain), the Fluence Z.E. is manufactured in Bursa (Turkey) on the same assembly line as the Renault Fluence with an internal combustion engine.

The **PSA group** launched the Citroen C-Zero and Peugeot I-On in 2010. Both vehicles are based on the Mitsubishi iMiEV and are manufactured in Mizushima (Japan).

Opel launched its Ampera Range Extender in 2012 which is identical to the Chevrolet Volt. Both vehicles are produced in Hamtramck (Michigan).

In addition, converted electric vehicles are offered, (e.g. Fiat 500 Karabag or German E-Cars). These vehicles are not offered by volume car manufacturers. **German E-Cars** have, for example, purchased the Opel Agila and Opel Corsa in order to modify them by installing an electric powertrain.

In the U.S., the Tesla Roadster and Fisker Karma are almost certainly the most well-known, premium Battery Electric Vehicles. Both are manufactured by new entrants.

From the side of Big Three, in 2012, Ford will launch five new electrified vehicles, i.e. the C-MAX Hybrid and C-MAX plug-in Energi, Focus Electric, Fusion Hybrid and Fusion Energi plug-in hybrid. Ford will produce the C-MAX Hybrid along with the Focus, Focus Electric and Focus ST at its assembly plant in Wayne (Michigan), while the Ford Fusion Energi will be built in Flat Rock (Michigan).[11]Ford recently launched the Focus Electric. By the end of June Ford had sold 97 units of the battery electric vehicle. Ford also reported that it has produced 763 units of the battery-electric vehicle which are waiting for distribution in the U.S.[12] Additionally, Ford offers the Transit Connect with battery electric propulsion.[13] The electric powertrain for the Transit Connect has been developed by Ford and Azure Dynamics, which specialises in proprietary electric and hybrid electric drive technology for light and heavy duty commercial vehicles. The vehicle production of the Transit Connect is currently located in a Turkish plant in Kocaeli. The vehicles for the North American market are equipped with an electric powertrain by AM General in its plant in Livona (Michigan)[14], while the vehicles for the European market are equipped by Lotus Lightweight Structures Ltd.in its Worcester plant in United Kingdom. Both companies are partners of Azure Dynamics.[15]

Furthermore, GM launched its Chevrolet Volt which is a Range Extender identical to the Opel Ampera. Therefore, the manufacturer invested $336 Million in its production facility in Hamtramck/Michigan. The production of the GM Volt started at the end of 2010.

Chrysler, for its part, is currently developing a fully-electrified version of the Fiat 500 with a 100 mile range, using battery technology developed by the Chrysler Group. Due to its compact vehicle size and weight, the Fiat 500 is well-suited for an electric powertrain. The Fiat-Chrysler group plans to manufacture and sell the electric version of the Fiat 500 in North America. Production is scheduled to begin in late 2012 in Toluca (Mexico).[16]

Table 1 and Table 2 provide an overview on current electric vehicles, production and sales figures, based on available data. It is clearly visible that European OEMs are currently preferring batter-electric vehicles.

[11]Autoblog (2011)
[12] Puregreencars (2012a)
[13] HybridCars (2012a)
[14]PRnewswire (n.d.)
[15]Auto Reporter (2011)
[16] Fiat 2011

Table 1: Current Electric Vehicles

OEM	Model	Segment	Propulsion	Market Launch	OEM's Headquarter	Production Site
Asia						
BYD	e6-Eco	Compact	BEV	2011	China	China
BYD	F3DM	Compact Sedan	PHEV	2008	China	China
Chery	M1EV	Mini	BEV	2010	China	China
Chery	QQEV	Mini	BEV	2011	China	China
Honda	FCX Clarity	Compact Sedan	FCV	2008	Japan	Tochigi (Japan)
Mitsubishi	iMiEV	Mini	BEV	2009	Japan	Mizushima (Japan)
Mitsubishi	Minicab MiEV	Mini Van	BEV	2011	Japan	Japan
Nissan	LEAF	Mini	BEV	2010	Japan	Oppama (Japan); Smyrna, Tennessee (U.S.); Sunderland (UK)
Toyota	Prius Plug-In	Compact	PHEV	2012	Japan	Tsutsumi (Japan)
Kia	Ray	Mini	BEV	2012	Korea	Dongee Seosan (Korea)
Europe						
Citroën	C-Zero	Mini	BEV	2010	France	Mizushima (Japan)
Groupe Bolloré	Blue Car	Mini	BEV	2011/2012	France	Assembly: Pininfarina Turino (Italy); Components: Quimper (France) and Montreal (Canada)
mia electric	mia	Microcar	BEV	2011	France	Cérizay (France)
Peugeot	iOn	Mini	BEV	2010	France	Mizushima (Japan)
Renault	Fluence Z.E.	Compact Sedan	BEV	2012	France	Bursa (Turkey)
Renault	Kangoo Z.E.	LCV	BEV	2011	France	Maubeuge (France)
Renault	Zoe	Mini	BEV	2012	France	Flins (France)
Renault	Twizy	Microcar	BEV	2012	France	Valladolid (Spain)
German E-Cars	CETOS	Mini	BEV	2012	Germany	Germany
German E-Cars	Stromos	Mini	BEV	2010/2011	Germany	Germany
Opel	Ampera	Compact	REEV	2012	Germany	Hamtramck (U.S.)
Smart	Fortwo Electric Drive	Mini	BEV	2012	Germany	Hambach (France)
FIAT	500	Mini	BEV	2012	Italy	Toluca (Mexico)
Tazzari	ZERO	Microcar	BEV	2010	Italy	Italy
TH!NK	City	Microcar	BEV	2009	Norway	Uusikaupunki (Finnland) - production stop in 03/2011; U.S. Production 2011: Elkhart (U.S.)
Volvo	C30 Electric	Compact	BEV	2012	Sweden	Gent (Belgium)/ EV- equipment in Göteborg (Sweden)
U.S.						
Chevrolet	Volt	Compact	REEV	2010	USA	Hamtramck (MI)
Coda Automotive	Coda	Sedan	BEV	2012	USA	Benicia (CA)
Fisker	Karma	Sedan (Premium)	PHEV	2010	USA	Uusikaupunki (Finland)
Ford	Fusion Energi	Sedan	PHEV	2012	USA	Flat Rock (MI)
Ford	Focus Electric	Compact	BEV	2012	USA	Wayne (MI)
Ford	C-MAX Energi	Compact/Family	PHEV	2012	USA	Wayne (MI)
Ford	Transit Connect EV	LCV	BEV	2012	USA	Kocaeli (Turkey); Valencia (Spain) 2013; EV-equipment in Worcester (UK) and Livona/Michigan for North American market
Tesla	Model S	Sedan (Premium)	BEV	2012	USA	Freemont (CA)
Tesla	Roadster	Roadster (Premium)	BEV	2008	USA	Chassis: Lotus Cars Hethel (UK); Powertrain: California

(Source: Own Compilation)[17]

[17] This list is not intended to be exhaustive since small and unknown market participants can also offer electric vehicles which can be hard to identify.Test fleets (e.g. Volkswagen Golf blue-e-motion or BMW Active E) are not considered.

Table 2: Current Electric Vehicles, Production and Sales Figures

OEM	Model	Capacity p.a. (EV)	Production	Sales Target	Sales	R&D
Asia						
BYD	e6-Eco	-	-	-	China: 607 (Jan-June 2012); 385 (2012)	China
BYD	F3DM	-	-	-	China: 601 (Jan-June 2012); 613 (2012)	China
Mitsubishi	iMiEV	1,400 (2009); 12,000 (2012)	2,500 (2011); 1,600 (Jan-June 2012)	-	1,406 in 2011 (Europe); ~600 from Jan-June 2012 (Europe); 333 from Jan-June 2012 (U.S.); ~3,000 from Jan-June 2012 (global)	Mitsubishi Motors: Okazaki (Japan); PSA: Vélizy (France),
Mitsubishi	Minicab MiEV	-	SOP 2011	-	849 (2011); 1,601 (Jan-June 2012)	Japan
Nissan	LEAF	Oppama: 50,000; Smyrna: 150,000; Sunderland: 50,000	23,000 (FY 2011)	9,000 in FY 2012 (Europe); 20,000 in FY 2012 (U.S.)	1,343 in 2011 (Europe); 9,700 in 2011 (U.S.); ~ 2,500 from Jan-June 2012 (Europe); 3,148 from Jan-June 2012 (U.S.); ~ 11,000 from Jan-June (global)	Atsugi (Japan)
Toyota	Prius PHEV	Tsutsumi: 40,000	about 13,000 - 15,000	global: 35,000 - 40,000 p.a.; EU: 10,000 (2013)	Global: 13,300 (Jan-July); U.S.: 5,000 (Jan-July); EU: 500 (June-July)	Japan
Kia	Ray	Donghee Seosan: 2500	600 (Jan-May 2012)	2,500 units in 2012 (only government fleet), launch 2014	Korea: 600 (Jan-May 2012)	Korea
Europe						
Citroën	C-Zero	-	1,800 (Jan-June 2012); 3,400 (2011); 300 (2010)	2011: 50% acchieved	1,200 units (Jan-June 2012); 1,200 units (Jan-June 2011); total: 2,074 (2011);	PSA: Vélizy (France), Mitsubishi Motors: Okazaki (Japan)
Bolloré	Blue Car	-	1,383 (Jan-June 2012)	3,000 units for Autolib; not data on retail sales targets available	~ 1,500 vehicles (Autolib)	EV-powertrain: Bolloré (France); Body: Pininfarina (Italy)
mia electric	mia	12,000 (Cérizay)	1,000 (09/2011- 02/2012)	-	-	-
Peugeot	iOn	-	1,800 (Jan-June 2012),; 3,300 (2011),; 350 (2010)	2011: 50% acchieved	900 units (Jan-June 2012); 1,400 units (Jan-June 2011); total: 2,400 (2011)	PSA: Vélizy (France), Mitsubishi Motors: Okazaki (Japan)
Renault	Fluence Z.E.	-	-	-	EU: 900 units (Jan-June 2012); global: 1,198 units (Jan-June 2012)	Guyancourt (France)
Renault	Kangoo Z.E.	-	-	-	EU: 2,672 units (Jan-June 2012); global: 2,678 units (Jan-June 2012)	Guyancourt (France)
Renault	Twizy	20,000	-	-	EU: 6,057 units (Jan-Jun 2012)	Guyancourt (France)
Renault	Zoe	150,000 p.a.	SOP: 2012	-	Launch: 2013	Guyancourt (France)
Opel	Ampera	-	-	10,000 (2012)	EU: 2,861 units (Jan-June)	Mainz-Kastel (Germany), Detroit (U.S.)
Smart	Fortwo ED	-	-	10,000 p.a. (global)	-	Daimler AG (Germany)
FIAT	500	-	SOP: 2012/2013	-	SOP: 2012/2013	Powertrain: U.S./Auburn Hills, Michigan (Chrysler)
Tazzari	ZERO	-	3,000	-	-	Italy
TH!NK	City	-		5,000	-	-
Volvo	C30 Electric	additional 150 in 2012/2013	200	350 (200 + 150 in 2012/2013)	200	Göteborg (Sweden)
U.S.						
Chevrolet	Volt	-	-	35,000 (2011); 60,000 (2012)	7,700 (2011), 10,666 (Jan-July 2012) U.S.	Mainz-Kastel (Germany), Detroit (U.S.)
Fisker	Karma	-	-	15,000 in 2012	1,000 units (12/2011 to 05/2012)	R&D Fisker (Irvini U.S.)/ Production Valmet (Finnland)
Ford	Fusion Energi	-	SOP 2012	-	-	Cologne (Germany) and Dearborn/Michigan (U.S.)
Ford	Focus Electric	-	SOP 2012	5,000 in 2012	Launch Volume: 350 vehicles in June 2012 (U.S.)	Magna: Steyr (Austria) Ford: Cologne (Germany) and Ford: Dearborn/Michigan (U.S.)
Ford	C-MAX Energi	-	SOP 2012	-	-	Cologne (Germany) and Dearborn/Michigan (U.S.)
Ford	Transit Connect EV	-	500 (since 2010)	-	2,200 orders	Cologne (Germany) and Dearborn/Michigan (U.S.)
Tesla	Model S	80 cars a day	target: 5,000 (2012); target: 20,000 (2013)	20,000 in 2013; 35,000 in 2014 (2014 including Model X)	Launch: June 2012 U.S. (Europe/China in 2013); 10,000 reservations	Palo Alto (CA)
Tesla	Roadster	-	EOP 2012	2,500	2,300 since start of production	Palo Alto/ Silicon Valley (CA)
SOP: Start of Production		**EOP: End of Production**				

(Source: Own Compilation)[18]

Since production began in 2010, the **Nissan Leaf** has become the **market leader in battery electric vehicles**. Until the first quarter of 2012, about 35,000 units had been sold globally.[19] The **Toyota Prius PHEV** is catching up; in the first half of 2012, about 13,000 units were sold globally. As for micro cars, the market development of the **Renault Twizy** has had a very surprising run; in the first six months, Renault sold 6,057 units of its battery electric Twizy in Europe. Altogether, the French manufacturer has sold about 10,000 electric vehicles in the first six months of 2012. In terms of current sales, Renault-Nissan has become the most successful manufacturer of electric vehicles, followed by Opel (2,861 units) and the PSA Group (~ 2,600 units).[20]

[18] Test fleets (e.g. Volkswagen Golf blue-e-motion or BMW Active E) are not considered.
[19] Own calculation, based on press releases and Global Insight.
[20] See also Chapter 3.2.7.

2.1.2 Future Generations of Electric Vehicles

Table 3 below provides an overview on certain electric vehicles (including BEV, REEV, PHEV and FCV) which will be launched into the market in the short and medium term:

Table 3: Future Generations of Electric Vehicles

Manufacturer	Model	Propulsion	Market Launch	OEM's Headquarter
Asia				
Shenzhen (Mercedes-Benz/BYD)	Denza	PHEV	2013	China
Honda	Fit EV	BEV	2012/2013	Japan
Honda	Accord	PHEV	2013	Japan
Infiniti	LE	BEV	2014	Japan
Mazda	2 EV	BEV	2012	Japan
Mitsubishi	Outlander	PHEV	2013	Japan
Nissan	e NV 200 (LCV)	BEV	2013	Japan
Toyota	RAV4 EV	BEV	2012	Japan
Toyota	IQ EV	BEV	2012	Japan
Toyota	FCV-R	FCV	2015	Japan
Hyundai	i10 BlueOn	BEV	2013	South Korea
Europe				
Citroen	Berlingo Electrique (LCV)	BEV	2013	France
Peugeot	Partner (LCV)	BEV	2013	France
Renault	Zoe	BEV	2012	France
Skoda	E-Citigo	BEV	2014	Czech Republic
Audi	A1 e-tron	REEV	2013	Germany
Audi	A2 concept	BEV	2016	Germany
Audi	A3 e-tron	PHEV	2014	Germany
Audi	R8 e-tron	BEV	2012	Germany
BMW	i3	BEV	2013	Germany
BMW	i8 Coupé	PHEV	2014	Germany
Mercedes-Benz	B-Class F-CELL	FCV	2014/2015	Germany
Mercedes-Benz	Concept B-Class E-CELL PLUS	REEV	2014	Germany
Mercedes-Benz	SLS E-CELL	BEV	2013	Germany
Mercedes-Benz	S-Class Plug-in-Hybrid	PHEV	2013	Germany
Volkswagen	E-Golf	BEV	2013	Germany
Volkswagen	E-Up!	BEV	2013	Germany
Lada	El Lada	BEV	2013	Russia
Volvo	C60 Diesel Plug-In	PHEV	2013	Sweden
U.S.				
Cadillac	Converj	REEV	2014	USA
Chevrolet	Spark EV	BEV	2013	USA
Fisker	Surf	PHEV	2013	USA
Fisker	Atlantic	REEV	2014	USA
Ford	C-Max Energi	PHEV	2013	USA
Ford	Fusion Energi	PHEV	2012	USA
Tesla	Model X	BEV	2014	USA

(Source: Own Compilation)[21]

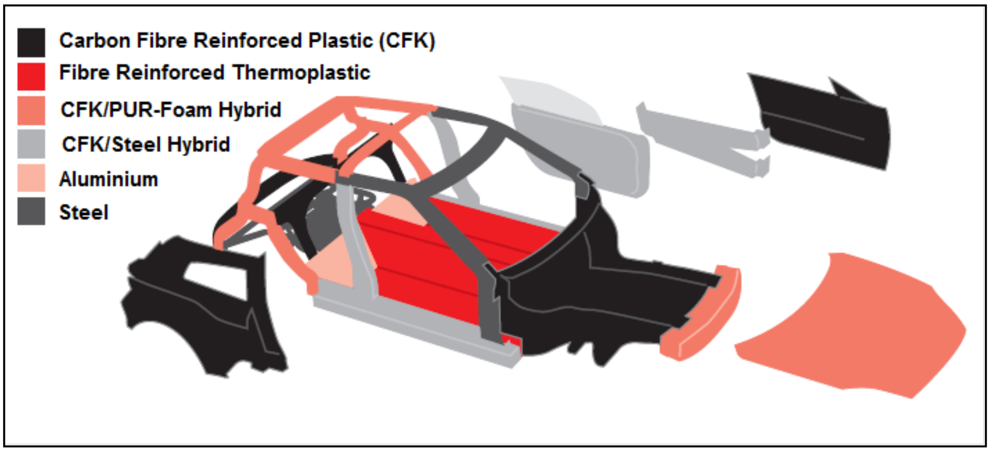
It has to be noted that many U.S. and EU manufacturers prefer the integration of electric propulsion systems into existing vehicle architecture (a so-called **"conversion design"**) in the medium term (e.g. Ford, Mercedes Benz, Volkswagen Group, Volvo). These vehicles (like e.g. the Renault Fluence Z.E vs. Renault Fluence ICE) are constructed on a conventional chassis where the combustion drive train

[21]This list is not intended to be exhaustive since small and unknown market participants can also offer electric vehicles which can be hard to identify.

is replaced by an electric one. This has an advantage concerning the production of these vehicles as identical production lines can be used.

An alternative route is so-called "**purpose design**". For example, BMW has developed a new architecture for its EV portfolio including the two vehicles i3 and i8. Renault also developed a new vehicle architecture for its Zoe. These vehicle architectures are independent from traditional vehicle concepts and specifically designed for electric driving. In order to compensate for the negative impact of battery weight on the driving range, most of the current electric vehicles using "Purpose Design" are using **lightweight construction**. This means that traditional parts of the chassis consisting of materials like sheet steel are replaced by lighter materials like carbon fibre. Considering the usage of lightweight construction for electric vehicles, SGL-Carbon produces, within a joint venture with BMW, semi-finished products of carbon fibre reinforced plastic for chassis parts in e.g. the new BMW i3 concept vehicle. The following figure presents the basic realisations of lightweight vehicle design reducing the vehicles overall weight – and therefore especially used in cars with "Purpose Design".

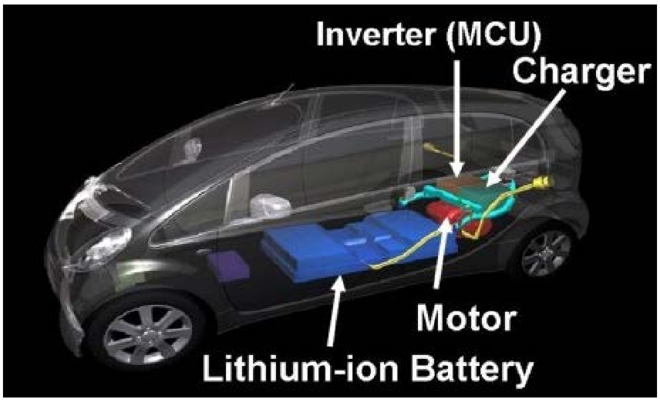
Figure 2: Basic Principle of Lightweight Vehicle Design especially used for cars with "Purpose Design"



(Source: Nationale Plattform Elektromobilität)

Furthermore, the construction of electric vehicles offers new opportunities concerning the vehicle design. Wheel hub motors enable new vehicle topologies.[22] It is not required that both the electric engine and the battery have to be placed at the front or at the end of the car. A specific engine compartment is no longer required (see Figure 3).In addition, vehicles with "Purpose Design" offer new possibilities for innovations in the field of ergonomics and new operating concepts.

Figure 3: Mitsubishi iMiEV with Purpose Design



(Source: Fallah, A. (2009): Mitsubishi iMiEV Review)

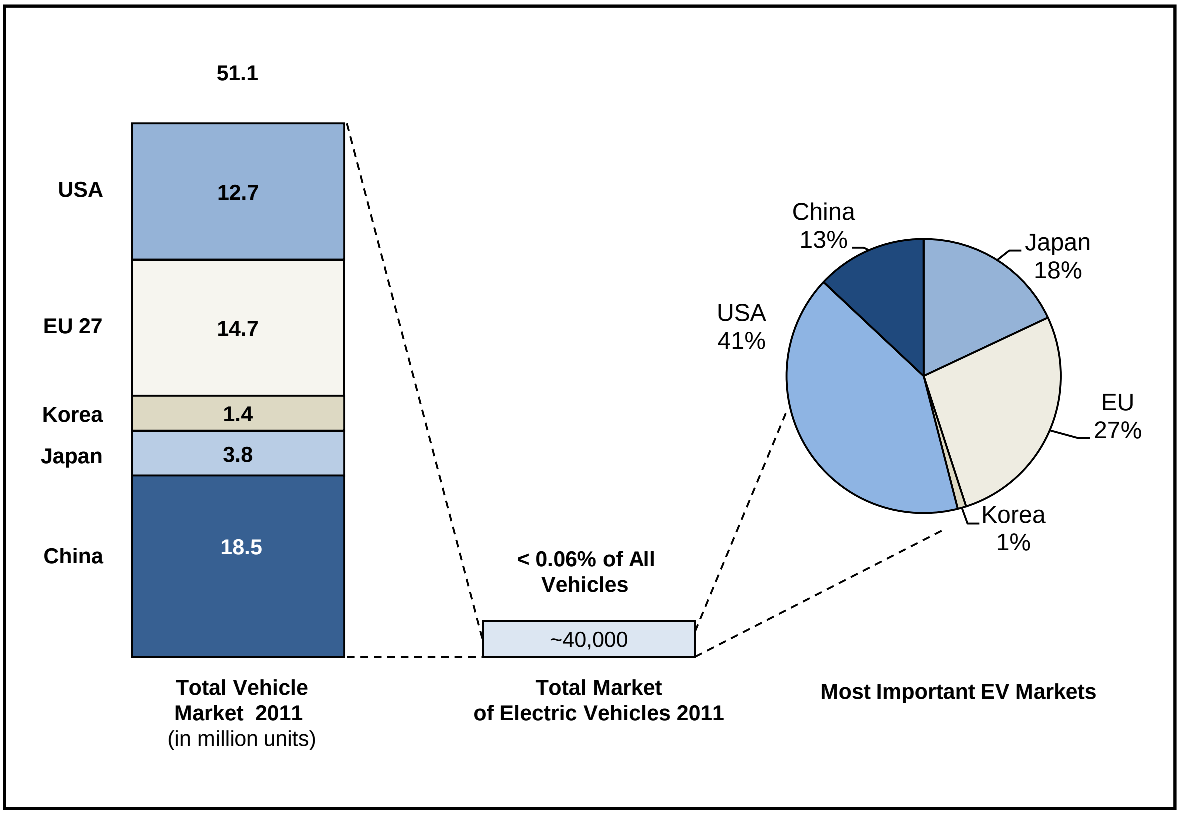
[22] Wallentowitz/Freialdenhoven (2011)

Due to high investments and market risks, most manufacturers are currently investing in the electrification of existing vehicle concepts ("conversion design"). According to experts interviewed for this study, electric vehicles with ("Purpose Design") will particularly gain importance by 2030.

2.2 Current Sales and Market Shares of Electric Vehicles

The following chapter provides a short overview on current sales in electric vehicles in different markets including the EU 27 markets, the U.S. and the most important Asian markets like South Korea, Japan, and China. In this project, categories of light commercial vehicles (LCVs) and passenger cars will be regarded. Figure 4 illustrates that **only 0.06 percent of the 51.1 million cars** and LCVs which were sold entirely within the global markets of EU, U.S., and key Asian markets, **are electric vehicles**. Currently, **the main markets for electric vehicles are Japan and the United States**.

Figure 4: Current Sales of Electric Vehicles



(Source: Own Calculation mainly based on the Data of National Associations)

The following table presents an overview on current registrations of electric vehicles in the most important markets:

Europe:

Table 4: Current Sales of Electric Vehicles

	Total Sales (Passenger Cars * LCV)	Electric Vehicles (BEV, PHEV, REEV)			Hybrid (non-rechargeable)		
	2011	2012*	2011	2010	2012*	2011	2010
Germany	3,400,000	1,419	2,154	541	9,232	12,622	10,661
France	2,600,000	2,271	2,630	184	3,691	13,289	9,655
United Kingdom	2,200,000	559	1,082	138	12,720	23,373	22,148
Italy	1,900,000	286	346	72	2,725	5,125	4,845
Spain	910,000	202	377	69	5,160	10,350	8,500
EU (EU 15 + EFTA)	14,700,000	~11,000	11,563	n.a.	n.a.	103,400	n.a.
China	18,500,000	3,444	5,579	1,466	n.a.	2,713	n.a.
Japan	3,800,000	n.a.	n.a.	7,719	n.a.	n.a.	434,569
Korea	1,400,000	n.a.	335	66	na.	38,482	19,167
USA	12,700,000	17,530	17,813	345	217,701	268,807	274,763

n.a. = not available

* Figures include data from the first six months of 2012, Figures for EU 2012 are estimated based on Opel (2012) and Detroit news (2012)

(Source: Own Calculation mainly based on the Data of National Associations or Press Releases)[23]

The figures indicate that **purchase premiums** for electric vehicles, which are provided in Spain, United Kingdom and France[24], **have not led to a significant increase in demand**, compared to countries where no purchase premiums are paid (e.g. Germany).

In the **European Union**, the EU-27 passenger car and LCV sales decreased by 7 percent in the first six months of 2012 compared to the previous year (7,371,113 units).[25] In the same period about 11,000 new electric vehicles were registered in the EU (Western Europe + EFTA)[26] which corresponds to the total European electric vehicle registrations of the previous year 2011 (11,563 units). Nevertheless, the total number of EV registrations remains marginal. The new electric vehicle registrations among the EU-27 Member States vary significantly. While some key European markets like France (the premiums for electric vehicles have been recently increased), Spain and United Kingdom have already been offering purchase premiums, markets like Germany and Italy are still yet to provide purchase premiums. Currently, however, **no significant correlation between the amount of purchase premiums and sales figures can be identified**. In Germany no purchase premium is paid, but the market has developed from approximately 500 electric vehicles in 2010 to 2,154 electric vehicles in 2011.

Due to the macro-economic situation, new vehicle registrations in Spain and Italy have decreased. Despite the financial incentives, the Spanish EV registrations remain low, even in the first month of 2012. The large Southern European markets like Spain and Italy have still not recovered since the decline in sales after the financial crisis in 2007/2008 and are currently confronted with the fall-out of the current Eurozone troubles. Whether these markets will recover in the short term remains uncertain.[27] Currently, the European market for electric vehicles is developing. Manufacturers entered the market in the last two years (see Chapter 2.1.1). It has to be, however, emphasised that several new electric vehicle models will be launched in the following years, the European market for electric vehicles will therefore become more attractive since customers can choose between a greater variety of vehicle types and models (see Chapter 2.1.2).

[23] KBA (2012); CCFA (2011); CCFA (2012); ANFIA (2012); SMMT (2012); Motornature (2012a); Plugincars (2012); ANFAC (2012); Motorpasionfuturo (2012)

[24] New electric vehicle registrations reached 2,271 units in the first six months of 2012. The majority of the vehicle registrations (1,383 units) belong to the battery electric vehicle Blue Car of Bollore group, while registrations of Peugeot Ion and Citroen C-Zero decreased by more than 50 percent compared to the first six months of 2011.

[25] Own calculation based on data of ACEA

[26] Own calculation based on data of Opel (2012) and Detroitnews (2012)

[27] The impact of the macroeconomic situation on the market development of electric vehicles is discussed in Chapter 2.3.1.2.1

In almost all European countries the registration numbers are mainly influenced by market launch- and test fleets from the OEM and their sales organisations. **Current sales do not reflect a reliable picture in order to discuss the market development of electric vehicles.** Table 5, for example, illustrates that most of the German new electric vehicle registrations belong to commercial customers.[28] It can be expected that most of these vehicles were registered by OEM or their sales organisations (e.g. test fleet, market launch fleet, showroom cars). **Private customer segments have in fact not been reached yet**.

Table 5: Share of Commercial Registrations in Germany
New Electric Vehicle Registrations by certain Manufacturers

Model	Type	Registrations in 2011	Commercial Registrations in Percent
GM Volt	REEV	25	100
Opel Ampera	REEV	241	100
Citroen C-Zero	BEV	200	91,5
Mitsubishi I-MiEV	BEV	683	91,8
Nissan Leaf	BEV	21	95
Peugeot ION	BEV	208	100

(Source: KBA 2011)

Rest of the world:

In **China**, about 18.5 million new vehicles were sold in 2011. Throughout 2011, a total amount of 5,579 Battery Electric Vehicles were registered. Additionally, 2,713 non-rechargeable Hybrid Electric Vehicles were sold.[29] In the first six months of 2012 pure electric vehicles accounted for 3,444 units.[30]

In Japan, approximately 3.8 million new vehicles were sold in 2011. Throughout 2010[31], a total amount of 6,905 Battery Electric Vehicles were registered. Additionally, 434,569 non-rechargeable Hybrid Electric Vehicles were sold. For 2011 similar registrations can be expected.

In Korea, about 1.4 million new vehicles were registered in 2011. Throughout 2011, a total amount of 335 Battery Electric Vehicles were registered. Additionally, 38,482 non-rechargeable Hybrid Electric Vehicles were sold.

In the **United States** approximately 12.7 million vehicles were sold in 2011. Throughout 2011, a total amount of 268,807 non-rechargeable Hybrid Electric Vehicles were registered.[32] Additionally, 17,813 Electric Vehicles were sold, including 7,671 Range Extenders (Chevrolet Volt). In the first six months of 2012, 17,530 electric vehicles had been registered, including 8,817 Range Extenders (Chevrolet Volt), 4,333 Plug-In Hybrids (Toyota Prius PHEV) and 2 Honda FCX Claritys (Fuel Cell). The highest market share among the Battery Electric Vehicles was reached by the Nissan Leaf with 3,148 units, accounting for a 19-percent decline compared to the first six months of 2011.[33]**In the first six months of 2012, U.S. sales of electric vehicles doubled compared to the previous year.** In many states purchase premiums are offered (also see Chapter 5.1). Nevertheless, purchase premiums should not be the only reason for increasing sales. Even in the U.S.,new vehicles have been launched on the market(e.g. Toyota Prius Plug-In, Ford Focus Electric), which also have an impact on the statistics (e.g. registrations of test fleets).

Although electric vehicles have been discussed in politics, science, and media for several years, the current registrations of electric vehicles point out that **EVs are currently far away from broad market**

[28] Only data for the German market available.
[29] Charged (2012)
[30] Autonews (2012b)
[31] Current Japanese New Electric Vehicle registrations for 2011 are not available
[32] HybridCars (2012b)
[33] Autoblog (2012a)

penetration. Despite the present decline in the interest of politics and media, all experts, managers, and politicians we spoke to in the past or who have been interviewed for this study have agreed that electromobility is on its way although it may progress more slowely than it was though at the height of the media hype.

The following section provides an outlook on the future market development of electric vehicles in selected regions.

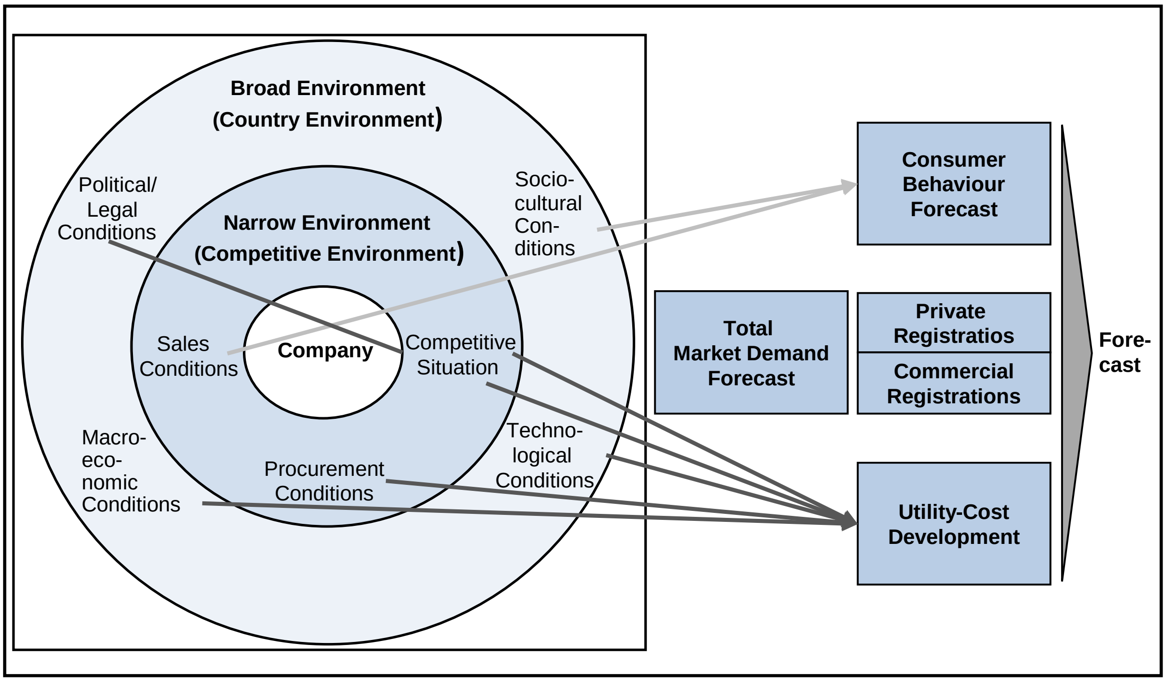
2.3 Market for New Electric Vehicles

2.3.1 Market Drivers and Market Barriers

The spread of new technologies is a complex process based on the market demand forecast, estimation of consumer behaviour and utility-cost development in electric vehicles. In general, it is the user (e.g. the private or commercial customers) who decides whether to adopt new technical concepts or not. The public authorities may try to influence these decisions by both supply- and demand-side measures.

The **internal combustion engine** is a technology that has been developing for over a hundred years. Thus, it has **reached a high level of development**. Modern gasoline and diesel engines are high-tech products which are difficult to surpass in their sum of positive characteristics. The utility-cost relation of different vehicle types, which determines the use and diffusion of new technologies, depends on a variety of macroeconomic and political factors that are beyond the influence of individual economic agents. The following figure illustrates the factors influencing alternative propulsion technologies.

Figure 5: Influence of Environmental Factors on Market Development



(Source: CAMA 2011)

Within each factor, both market drivers and market barriers exist which can promote or inhibit the use and dissemination of new drive technologies. Therefore, the market forecast for electromobility consists of three major components:

-Total Market Demand Forecast (Chapter 2.3.1.1)

- Utility-Cost Development (Chapter 2.3.1.2)

-Customer Segmentation (Appendix III)

2.3.1.1 Total Market Demand

In order to estimate a forecast on new electric vehicle registrations in the new vehicle markets (U.S., China, Japan, Korea, Germany, France, Italy, Spain and UK), the market demand in these countries (baseline) has to be initially calculated (see Table 6).

We expect an increase in global new vehicle registrations of passenger cars and light commercial vehicles (LCV) from 72.5 million in 2011 to 86.4 million in 2020 and 99.2 million 2030. Half of this growth will result from the market development in China while new vehicle registrations in Europe and the United States will remain largely stable. WardsAuto assumes a very similar market development of the European new vehicle market.[34] They expect that the European sales remain stable until 2020, amounting to 14.5 million units.[35] Lower registrations in the key European markets such as Germany, France, United Kingdom, Spain and Italy will be compensated by increasing sales in Eastern Europe.

In 2030, the Chinese new vehicle market will be as large as the EU-27 and U.S. markets added together. Furthermore, the Chinese new vehicle market will exceed the German and Japanese markets by 10 times. Due to the demographic development in Germany and Japan, we expect a decline in new vehicle registrations in the long-term.

Table 6: New Vehicle Registrations 2011, 2020F and 2030F

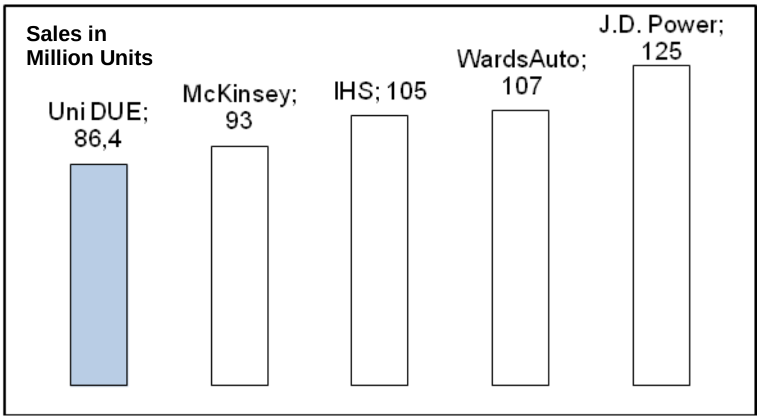
	2011	2020F	2030F
Germany	3,400,000	3,000,000	2,700,000
France	2,600,000	2,200,000	2,170,000
United Kingdom	2,200,000	2,100,000	2,000,000
Spain	910,000	1,200,000	1,200,000
Italy	1,900,000	1,700,000	1,500,000
Rest of EU	3,690,000	4,600,000	5,230,000
EU27 (total)	**14,700,000**	**14,800,000**	**14,800,000**
Japan	3,800,000	3,500,000	2,700,000
Korea	1,400,000	1,400,000	1,500,000
China	18,500,000	21,900,000	28,900,000
United States	12,700,000	14,800,000	14,300,000
Rest of World	21,400,000	30.000.000	37,000,000
Global Registrations	**72,500,000**	**86,400,000**	**99,200,000**

(Source: Own Calculation)[36]

In 2020, we expect global sales of 86.4 million vehicles. In comparison, McKinsey expects global sales of 93 million vehicles in 2020 while J.D. Power assumes 125 million units (see Figure 6).

[34] Including Passenger Cars and Light Commercial Vehicles
[35] WardsAuto (2011)
[36] EU-Figures of 2011 based on ACEA including Passenger Cars and Light Commercial Vehicles.

Figure 6: Global New Vehicle Registrations of Passenger Cars and LCV in 2020



(Source: Own Calculation, Global Insight 2011, J.D. Power (n.d.)[37], McKinsey 2011, WardsAuto 2011[38])

The Uni DUE global market forecast for 2020 is more pessimistic than other forecasts (see Figure 6). We share the scepticism of many of the experts interviewed concerning the market growth rates in the BRIC countries. For 2020, we expect a market increase to 21.9 million vehicles (passenger cars and LCV) in China. While Roland Berger (2012) assumes that the Chinese passenger car market will increase to about 33 million vehicles in 2018, recent analysis by Manager Magazin[39] and China News[40] reported a significantly more pessimistic mood in the Chinese auto market than a year ago. One important reason for a weaker growth could be the lack of infrastructure.[41] For example in China and Brazil, most cars owners are concentrated at the coastal areas, where a high percentage of the population lives. However, the mega-cities are bursting at the seams. According to Arthur D. Little (2011)[42], also the used-car business will become more important.[43] Due to a lack of awareness and motivation among customers together with a lack of trade-in and sales experiences at the dealerships, the current Chinese used-car business is modest. In 2010 only 3.6 million used cars were sold in China. Most OEMs have not yet managed to capture the full potential of this emerging market business. Arthur D. Little (2011) expects sales of 18.7 million used cars in 2017 (vs. 17.4 million new cars). The market forecasts of 2020 and 2030 represent an aggregation of individual country forecasts, which have been discussed and validated in expert discussions. Interestingly, the experts interviewed assume that the rest-of-world market (e.g. particularly Brazil, India, Russia, South Africa) will have a market potential of 30 percent in 2020 compared to today, while the market development of the Chinese market was calculated more pessimistic.

In 2030, we expect global sales of 99.2 million new vehicles, while McKinsey assumes 114 million vehicles. Our market assessment reflects the estimations of the majority of experts we interviewed.

According to their estimates, the global new electric vehicle registrations have been adjusted slightly. In Chapter 6, the Base Case Scenario of market development for electric vehicles will be extended by an Upper and a Lower End Case Scenario (see Chapter 6.2). In the following chapters, however, all results are based on the Base Case Scenario.

[37] J.D. Power (2011)
[38] WardsAuto (2011)
[39] Manager Magazin (2012)
[40] China News (2012)
[41] News Xinhuanet (2011)
[42] Arthur D. Little (2011)
[43] Arthur D. Little (2011)

2.3.1.2 Utility and Costs of Electric Vehicles
2.3.1.2.1 Factors influencing the Utility and Costs of Electrics Vehicles

The development of utility and costs depends on the different parameters based on the following factors/conditions: Technological Conditions, Macroeconomic Conditions, Political/Legal Conditions and Competitive Situation.

Technological Conditions: The improvement of technological features of electric cars is a very important aspect necessary to enhance market penetration. While electric motors for road vehicles are standard electric products which benefit from a mature technology, batteries are the main issue forbroad market penetration due to their low energy density and high cost.[44]**The battery, as the decisive component of electric vehicles, will be analysed in detail in Chapter 2.3.1.2.2 of this report.** A detailed analysis of the key components of electric vehicles is provided in Appendix IV.

Macroeconomic Conditions: In the coming years, the macroeconomic pressures in the automotive industry will remain high. In addition to the further development of existing technologies, particularly the development of new technologies requires considerable upfront investments in terms of research and development. The continued stress in financial markets and the considerable risk on premium loans, especially on the supplier industry, amalgamates into more challenges which will need to be faced in the years to come.[45] Especially in Southern Europe, new vehicle registrations have been declining since the economic crisis in 2008/2009, including new vehicle registrations of two large European markets, Spain and Italy, which have yet to stabilise. At present the industry is confronted with difficult economic situation on the EU market due to eurozone troubles.

In particular, the share of private customers is declining on the EU market and according to the experts interviewed in this study even the commercial customers save by purchasing cheaper vehicles (e.g. smaller vehicle classes, less equipment). The economic situation in Spain, Italy and Greece is characterized by high uncertainty. This is also reflected in the behaviour of car buyers. According to the European experts the key EU markets for new vehicles will recover to pre-crisis levels only by 2020 (see Table 6).

Whether the economic situation reflects a buying restraint on electric vehicles specifically can hardly be estimated because the market for electric vehicles is still developing. Electric vehicles have higher purchase costs, but purchase costs are not the only factor influencing a purchase decision. Most of the customers currently have a low level of information on the benefits of electric vehicles (see Chapter 3.2.5.4). According to the experts interviewed, commercial customers in particular will be the Early Adopter of electric vehicles. France is setting a good example with that respect. Recently, a group of French companies including Electricite de France, SNCF, Air France, France Télécom and La Poste have committed to purchase an initial order of 50,000 electric vehicles. Since Spain offers purchase premiums for non-rechargeable hybrids like the Toyota Prius, many commercial companies (e.g. taxi companies) have decided to purchase a Prius fleet. In Spain about 2,027 Toyota Prius have been registered since January. According to the Spanish experts interviewed, the registrations of electric vehicles are expected to rise with the launch of the Prius Plug-in.

Political/Legal Conditions: The political framework is probably the most important driver of electric vehicles. Political conditions (e.g. in forms of regulations or laws) may apply both at the national level (e.g. legislation on the level of Member States) as well as at the supranational level (e.g. legislation of the European Union for EU Member States). In this context, the most important issue is the optimal determination of the amount of the incentives, taxes or non-financial incentives (e.g. access to bus lanes, free parking zones, etc.). Aside from the restrictive aspects (e.g. taxes calculated according to CO_2 emissions), the political framework also includes tools which can be used in order to promote the market penetration of electric vehicles. Many states have already developed different programs for the direct promotion of electromobility (e.g. including subsidies, tax incentives, and sales incentives). The current public policy framework will be analysed in Chapter 5. At present, we assume a prolongation of the existing and already announced regulations.

Competitive Environment: The (narrow) competitive environment contributes to the development of **costs and utilities.** Different procurement conditions, sales conditions, and the general competitive

[44] European Expert Group (2011)
[45] IHK (2011)

situation of a company influence the cost at which products may be developed, or at what price they may be offered.

2.3.1.2.2 Analysis of the Propulsion Battery Price used in Electric Vehicles[46]

When looking at the future development of electrically propelled vehicles, **the most critical factor concerning the access of this technology in the international automotive market is the propulsion battery**.[47] This becomes clear when searching for purely electrically propelled vehicles in the market, for example the Nissan LEAF and the Mitsubishi i-MiEV using Lithium-Ion battery technology. The Nissan LEAF is equipped with a Lithium-Ion battery with a capacity of 24 kWh. With this battery the vehicle has a range of 150 km. The battery costs approximately 20,000[48] Euro, considering the sale price of the vehicle, which results in quite a representative actual price per kilowatt hour at 830 Euro/kWh. In terms of production costs, the London Times reports a value of 6,000 (GPB)[49] referring to an interview with the Executive Vice President of Nissan. In a second example, the battery of the Mitsubishi i-MiEV has a capacity of 16 kWh resulting in a driving range of approximately 150km. The price for this battery is 11,000 Euro[50] which results in a price of 700 Euro/kWh. The difference between these two examples with respect to the driving range and the capacity is caused by the fact, that the LEAF has a more powerful propulsion system than the i-MiEV.

In addition to Battery Electric Vehicles there are also non-rechargeable Full Hybrid Vehicles like the Toyota Prius, Honda Civic Hybrid and VW Touareg Hybrid which are using NiMH batteries. These batteries have disadvantages considering their lifetime and their substantial weight due to their low energy density. Nevertheless using NiMH batteries has advantages considering the safety of such a vehicle due to the less hazardous potential of these batteries. Due to the increased weight when using NiMH technology for large battery packs (e.g. 20kWh) full electric vehicles actually use lithium-ion technology.

However, **Lithium-Ion batteries used for electric propulsion have two significant problems**. The first problem is the **maximum range** of the vehicles which is limited by the available volume and the **maximum weight** when implementing the battery into the vehicle. To give an example, an actual battery using Li-Ion technology has an energy density of 110 Wh/kg on battery system level which results in a battery weight of 180 kg when building up a battery system with a capacity of 20 kWh, which is even less compared to a similar battery system using NiMH technology with a total weight of 330kg[51]. Due to the fact that the different battery producers are using different cell types (Cylindrical, Prismatic and coffee-bag cells) and different materials for their lithium-ion cells the energy densities vary between approximately 110Wh/kg (GS Yuasa LEV 50) and 150Wh/kg (Kokam Coffee-Bag cell) on cell level[52]. **With regard to future developments** focussing e.g. on new battery chemistries for propulsion, batteries such as lithium sulphur, **the energy density will increase**.[53]The second problem as mentioned before is the high price for such a battery which has a critical impact on the price for the overall vehicle compared with vehicles equipped with conventional combustion engines. Therefore, an analysis of future price developments is necessary for the estimation of the market development.

The following table provides an overview on current price determinations and on forecasts of battery prices in 2015 by different studies.

[46] Chapter 3.2.1.1 provides an overview on current key player in terms of battery production.
[47] Appendix IV provides an overview on the structure and function of the different technical modules of the electric powertrain.
[48] WIWO (2011)
[49] TIMES (2010)
[50] WELT (2009)
[51] Johnson Controls (2010)
[52] Sauer (2010)
[53] Further details considering the future development in battery performance are presented in Appendix V.

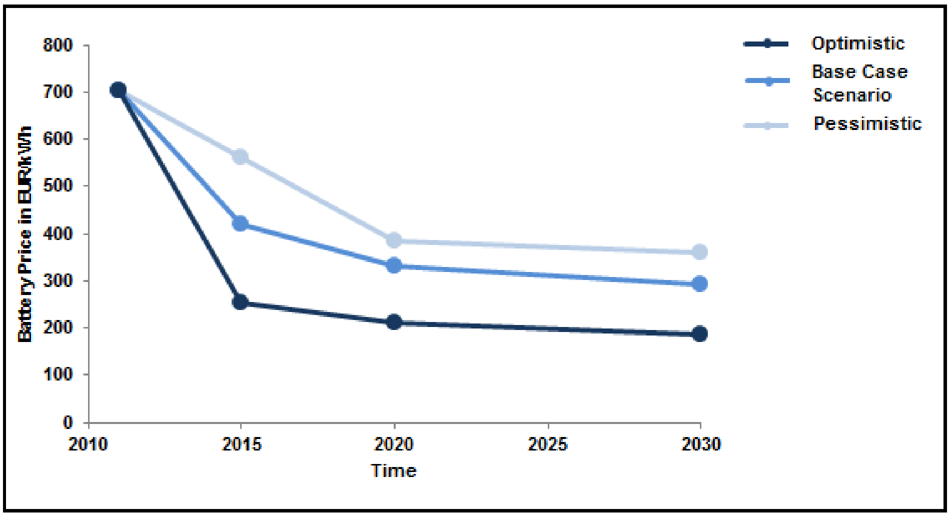
Table 7: Estimation of Battery Prices

Examples for the actual price determination		
Study or expert assumption	Cost in EUR/kWh	Single or multiple scenarios
Ford[54]	590	Single scenario
Karabag[55]	740	Single scenario
VDA[56]	800	Single scenario
Price Forecasts 2015		
Study or expert assumption	Cost in EUR/kWh	Single or multiple scenarios
EWI Institute[57]	250	Optimistic scenario
McKinsey[58]	275	Optimistic scenario
SB LiMotive[59]	350	Single scenario
Deloitte[60]	370	Single scenario
DB Research[61]	382	Single scenario
EWI Institute	600	Pessimistic scenario
McKinsey	750	Pessimistic scenario

Source: Own Compilation

For the 2020 forecast, **a total of 17 studies and expert references were considered**. They are predicting a further decrease of battery prices caused, mostly linked to a rising percentage of electric vehicles and economies of scale and technology development thus achieved. For example, Roland Berger predicts a price of 330 Euro/kWh for 2020.[62] Additionally, an actual study from ICF that distinguishes between different battery chemistries forecasts a price of 310 Euro/kWh in 2020 for batteries using actual technology.[63]Focusing on a forecast for the year 2030, three studies were considered in total. It is clear that the volume of data used for this forecast decreases with time. All data considered for the actual battery price estimation as well as the forecast for 2015, 2020, and 2030 are cited in the references. The following figure represents the price for electric vehicle propulsion batteries in Euro/kWh over time.

Figure 7: Development of the Battery Price for Electric Vehicles in EUR/kWh Over Time



(Source: Own Calculation)

[54] Ford (2011)
[55] Karabag (n.d.)
[56] VDA (2011)
[57] EWI (2010)
[58] McKinsey (2010)
[59] SB LiMotive (2010)
[60] Deloitte (2010)
[61] Deutsche Bank Research (2009)
[62] Roland Berger (2009a)
[63] ICF (2011)

The values for the years 2011, 2015, 2020, and 2030 were derived by considering all values extracted out of the collected data. The figure shows three curves depicting the price development of propulsion batteries for an optimistic and a pessimistic scenario. The base case scenario considers all data collected from studies and expert presentations that do not distinguish between different scenarios of future automotive markets but it can serve as an orientation for our UDE (Base Case) scenario forecast.

Based on the graphical representation, it becomes obvious that **for each scenario the price of the battery decreases with time**. The **largest price reduction occurs between 2011 and 2015** which is mainly caused by a decrease in the costs for the battery cells.[64] According to Bloomberg, the average price of lithium-ion battery packs for electric vehicles fell 14 percent in the past year as production capacity exceeded demand. Prices for batteries have dropped 30 percent since 2009, making electric vehicles less expensive.[65]

According to the experts interviewed, Lithium-Ion battery cells will be used in the battery systems of nearly all future electric vehicles and hybrid vehicles which will be launched in the following years (including new mild[66] and full hybrids[67]).[68] Considering the fact that the battery cells are currently the most expensive part of such a propulsion battery, an increased production of cells for all types of electrically propelled vehicles will result to further price reduction. As shown in Table 8 below, the determined battery prices for 2011, 2015, 2020, and 2030 are listed again accordingly. As a next step, selected forecasts out of the considered data are presented in the next three figures in order to compare the results with the estimated battery prices used in the market simulation model.

Table 8: Battery Prices in EUR/kWh for 2011, 2015, 2020 and 2030

	2011 (EUR/kWh)	2015 (EUR/kWh)	2020 (EUR/kWh)	2030 (EUR/kWh)
Optimistic	712	253	212	187
Base Case Scenario	712	419	331	294
Pessimistic	712	560	384	360

(Source: Own Calculation)

Comparing the UDE (Base Case Scenario)forecast with selected forecasts, it becomes obvious that our estimation is rather moderate (see Figure 8 a –c).

Focusing on the price development up until 2015, estimations of BWE-Study or in the presentation of Shmuel de-Leon at the IFCDC Conference 2010 predict a quite high battery price in 2015 (see Figure 8a). On the other hand, battery manufacturers like the joint venture group SB Li Motive or the vehicle manufacturer Ford are expecting a larger decrease of the battery price up until 2015. Considering the fact that the actual market shares of electric vehicles is quite small and the market shares of hybrid vehicles increase moderately, the UDE forecast is less optimistic compared to the battery manufacturers. But we have to consider the fact that in the near future, most electric and hybrid vehicles will be powered by lithium-ion batteries resulting in a decrease in battery price within approximately three years. Several vehicle manufacturers like Ford, VW, Volvo, and Toyota are already planning the introduction of new electric and hybrid vehicles using lithium-ion battery technology in the market. Thus, the **market success of these new electrically propelled vehicles has an immense impact in the development of battery price**.

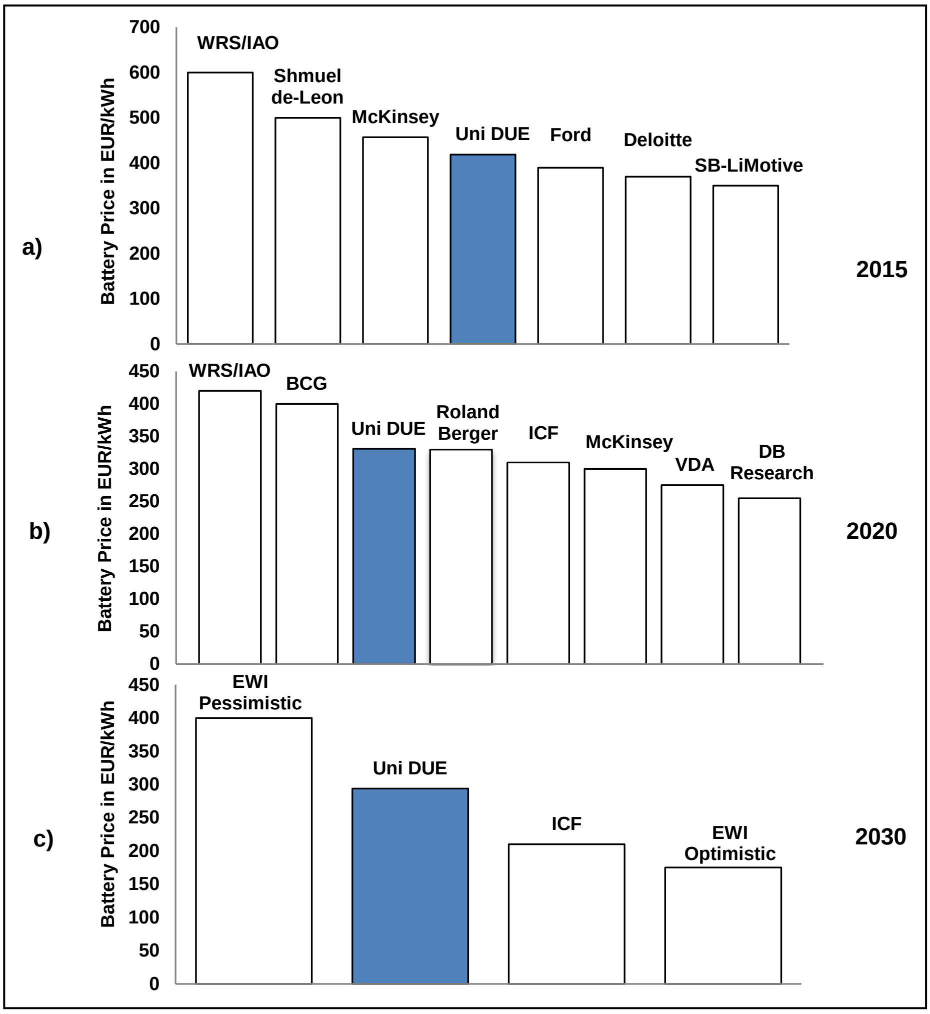
Figure 8b shows a comparison of selected forecasts in 2020 which illustrates a further decrease of battery price predicted in all studies and opinions from experts interviewed. Two different studies by the Boston Consulting Group (BCG) and the BWE study from Fraunhofer Institute predicts a battery price of 420 Euro/kWh and 400 Euro/kWh, respectively, in 2020. Both belong to a more pessimistic scenario. Other related studies by Roland Berger and expert opinions from the VDA assume a more optimistic view of price development: 330 Euro/kWh and 275 Euro/kWh, respectively. These are based on the assumption that there will be stricter emission limits causing a further increase of the

[64]See also EIA (2012)
[65] Eco-Business (2012)
[66]Johnson Controls (2010)
[67]Hybrid-Autos (2011)
[68]See EIA (2012)

market shares of electric and hybrid vehicles. These changes create a strong impact on the future battery price development since lithium battery cells are used in the propulsion batteries of both vehicle types. The UDE forecasts a future battery price of approximately 330 Euro/kWh.

Figure 8c provides a comparison of the different forecasts for 2030. Forecasting the battery price up until the year 2030 is difficult since the considered data basis is limited. The EWI-Study distinguishes between an optimistic and a pessimistic scenario for battery price development up until 2030 of 400 Euro/kWh and 175 Euro/kWh, respectively. A study by ICF predicts a battery price of 210 Euro/kWh for a propulsion battery with a capacity of 20kWh in 2030. Assuming a further increase of the electrification of individual traffic and public transport in the period from 2020 to 2030 due to e.g. strict emission limits, rising acceptance of electric vehicles caused by decreasing vehicle costs, rising gasoline costs and an increase of performance (range extension) caused by developments in battery technology, the UDE forecasts a future battery price of approximately 300 Euro/kWh. Up until 2030 the impact of new future battery technologies like the development of lithium air or lithium sulphur batteries, which would have an immense influence on the driving range of electric vehicles as well as customer acceptance, will not have a considerable effect on battery price. Although some companies like Sion Power, BASF and IBM are researching or respectively planning research on these new battery technologies. If they can develop a propulsion battery based on these new technologies, these batteries will not be produced in series until 2030.

Figure 8: Comparison of Selected Battery Price Forecasts for 2015, 2020, and 2030



(Source: Own Compilation based on BCG 2010; DB Research 2009; Deloitte 2010; ICF 2010; EWI 2010; Ford 2011; McKinsey 2010; Roland Berger 2009a; SB Li Motive 2010; Shmuel de-Leon 2011; VDA 2011; WRS/IAO 2010)

2.3.1.2.3 Utility-Cost Relation

The utility-cost relation depends on both utility and cost components. The utility components include both monetary and non-monetary parameters with the following examples:

Monetary utility parameter:

- Financial incentives
- Tax relief
- Exemption from tolls
- Free parking
- Free recharging stations

Non-monetary utility parameter:
- Range
- Use of bus lanes
- Charging time/Charging options
- Entry to city centre and zero emission zones
- Modern/new vehicle architecture (greater acceptance among younger people)
- Social/ecological benefits (environmental friendly cars, vehicle to grid communication)
- Additional functionalities (e.g. automatic driving)

The cost components mainly comprise of the operating costs of a vehicle:[69]
- Running costs (e.g. electricity costs, fuel costs)
- Maintenance and repair
- Additional technical cost (e.g. costs of components, production costs)
- Residual value/depreciation[70]
- Fuel efficiency of internal combustion engines

In the following section, assumptions on main input factors (costs as well as utilities) will be explained in detail:

1 Purchase premiums
2 Range
3 Fuel efficiency of Internal Combustion Engines
4 Additional technical costs

Ad 1. Purchase Premiums: Basically, purchase premiums represent a significant benefit component that affects the utility-cost index. Purchase premiums are expected to be paid by certain states in the initial period, in order to support the market penetration of electric vehicles. **We assume in our base case scenario that purchase premiums will no longer be offered after 2020**. Therefore, in order to forecast the market penetration of electric vehicles in2020and 2030no country-specific purchase premiums are taken into account in the base case scenario. The majority of experts who have been surveyed in this study consider this assumption as realistic.

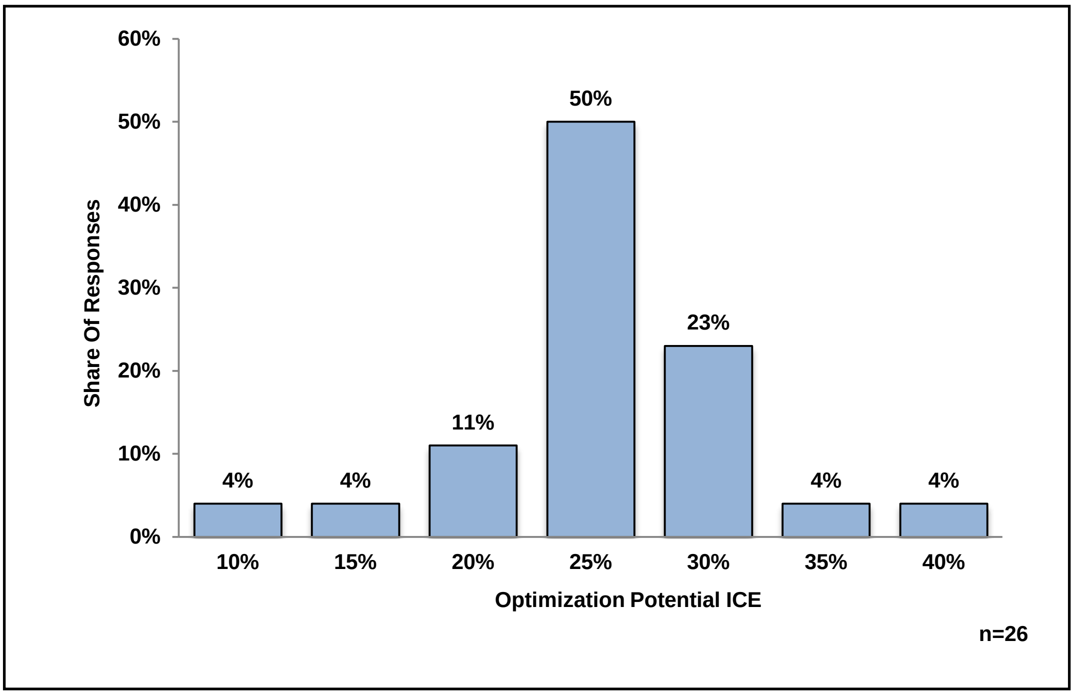
Ad 2. Range: For example, several studies such as BCG (2010) and Automotive World (2011) expect that the average driving range per charge of Battery Electric Vehicles will remain limited in the medium term. Today, Battery Electric Vehicles have an average range between 80 and 150 km, depending on battery performance and use.[71] The main limiting factor of the range is the dilemma between energy density and weight of the batteries.[72] Developing an electric vehicle with a range of 500 kilometres would lead to a battery weight requiring more than 800 kg given today's energy densities.[73] The improvement of range provides a benefit to the driver. It can be achieved due to new and/or improved battery technologies (e.g. lithium-air technology) or through reduced weight of the battery sys-

[69] See also CAMA (2010)
[70] See Methodology in Appendix II and Chapter 2.5 [Second Hand Electric Vehicle Market]
[71] IHK (2010); Winter (2010); Automotive World (2011)
[72] Winter (2010)
[73] IHK (2010)

tem.[74]Although most of the private consumers have driving patterns compatible with current battery range, they express concern about the range of electric vehicles.[75] According to our own investigation in the German market, a driving range up to 280 km equates great benefits to the customers.[76]Therefore, the improvement of the range is an important utility for the majority of customers. We assume that the energy density of battery cells will increase, leading to a maximum range of 300 km in the long term. Due to the continuous development of battery technology even customers with currently incompatible driving patterns (see Chapter 2.3.1.2) will enter the market in the long term.

Ad 3. Fuel Efficiency of Internal Combustion Engines: The improvement in fuel efficiency of internal combustion engines has a negative effect on the utility-cost relation of Battery Electric Vehicles, whereas vehicles with internal combustion engines, (i.e. Range Extender and Plug-in Hybrids) benefit from an improvement of fuel efficiency. Due to further technical improvements of the injection, lightweight components and downsizing we expect that the **fuel efficiency of vehicles with internal combustion engines will improve by 20 to 25 percent up until 2030**. As this improvement is not country-specific, it has been assumed for all forecasts. Almost half of the surveyed experts believe that fuel savings of 25 percent can be achieved by the year 2030 (see Figure 9). Altogether, the spectrum of responses ranges from 10 to 40 percent. The increase of the fuel efficiency of internal combustion engines has an effect on the utility-cost index as well. In this case, vehicles with internal combustion engines benefit from less fuel consumption. The running costs of ICE will decrease over time. This development will be, however, counteracted due to a larger increase in fuel costs over time - caused by increasing scarcity.

Figure 9: Future Fuel Saving Potential of Combustion Engines in Percent



(Source: Own Calculation)

It appears that conventional vehicles will be optimized in the future to reduce green-house emissions and fuel consumption. Japanese and Korean experts, who have been surveyed within this study, particularly expect enormous potential in ICE technology. Alongside the development of alternative powertrains, they also spend extensive R&D investments in the field of internal combustion technology. A detailed analysis of the energy saving potential of vehicles with internal combustion engines is provided in Appendix VI.

[74] Winter (2010)
[75] Fraunhofer/PWC (2010); Deloitte (2011)
[76] Fojcik et al. (2011)

Ad 4. Additional Technical Costs[77]: Based on the results of Chapter 2.3.1.2.2, we assume that the additional technical costs of the electric propulsion (e.g. batteries, electric engine, power electronics) for Battery-Electric Vehicles will decrease by 50 percent up until 2020 and by 70 percent up until 2030 (Base Case Scenario). These assessments have been supported by the majority of the experts interviewed. Furthermore, the additional costs of electric vehicles will decrease due to the production of new electric vehicle concepts. Even in the medium term, manufacturers and suppliers will offer electric vehicles based on new vehicle architecture (i.e. "Purpose Design"). Due to standardisation and modularisation, a huge potential of cost reduction can be expected, especially concerning the production of new vehicle concepts. BMW will be one of the first premium manufacturers offering vehicles with electric powertrains and new vehicle architecture (e.g. BMW i3 or i8).

Altogether, for the purpose of market forecast, different utility-costs were calculated for each vehicle type (i.e. An Internal Combustion Engine type vehicle, Hybrid Electric Vehicle, Range Extender, Plug-In Hybrid, Battery Electric Vehicle and Fuel Cell Electric Vehicle) using a cost-/benefit analysis reflecting the periods 2012, 2020, and 2030. Up until 2030, **electric vehicles will benefit from lower running costs** compared to ICEs such as low electricity costs,[78]**increasing residual values[79]** and **lower costs of maintenance and repair**. Furthermore, **subsidies** such as purchase premiums will support the market penetration of electric vehicles in the short term. Nevertheless, we assume in our base case scenario that purchase premiums will no longer be offered from 2020 onwards. In order to forecast the market penetration of electric vehicles in2020and 2030, no country-specific purchase premiums are taken into account in the base case scenario. Electric vehicles will, however, most likely continue to benefit from tax reliefs, exemptions from tolls, free parking/free charging options, and the permission to use bus lanes.

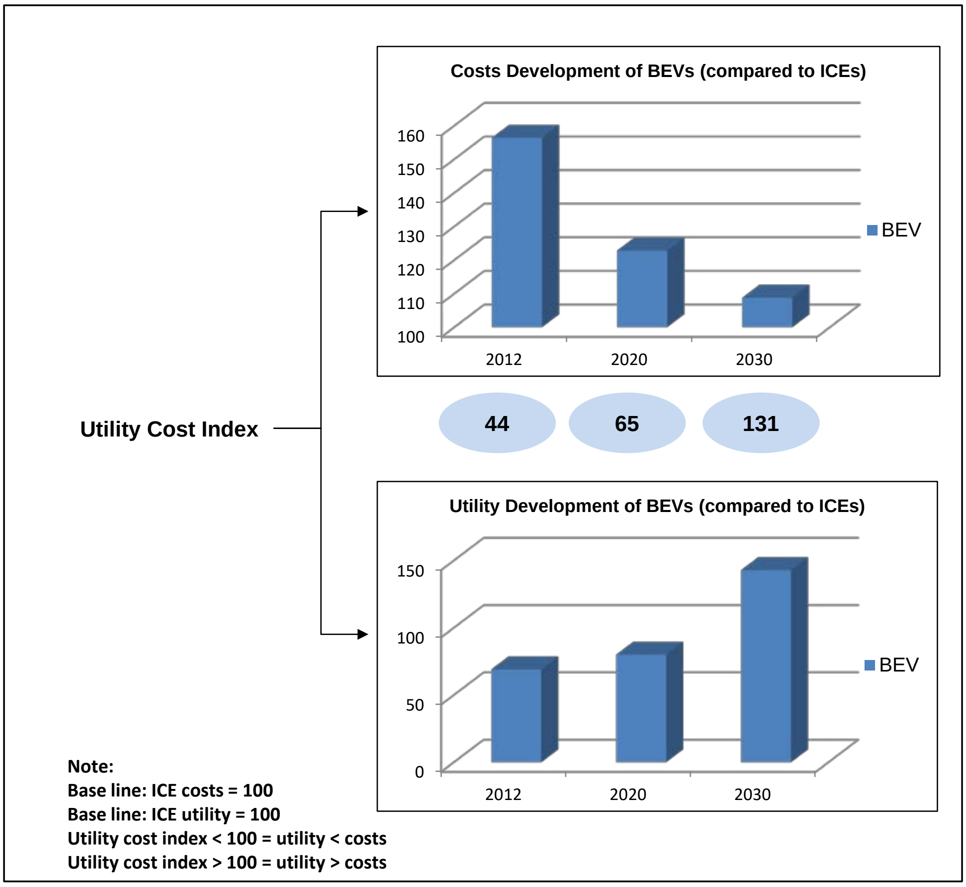
Additionally, the **improvement of range**, the expansion of charging infrastructure and **improvement of charging time** will lead to an increase of the perceived utility. **The additional costs of electric vehicles will decrease by 2030 due to lower costs of electric powertrain components** (see Chapter 2.3.1.2.2 and Appendix VII) i.e. lower production costs.

The **utility-cost index of vehicles with an internal combustion engine will decrease by 2030**. Presently, ICEs benefits from lower purchase prices, higher residual values, and range. Increasing fuel costs and higher taxes (e.g. penalty taxes) will lead to an increase of costs over time.[80] These utility aspects of electric vehicles will lead to a lower residual value of ICEs in the long term. Furthermore, the optimisation of fuel efficiency will not be able to compensate for increasing fuel costs in the long term. Additionally, we assume that fuel costs will rise more strongly in comparison to the cost of electricity (see Appendix VIII). Regulations such as entry restrictions in city centres (zero emission zones) will lead to a further decrease in the utility of ICEs.

The following figures, (Figures 10 to 13) provide an overview on the development of the utility-cost index of electric vehicles compared to vehicles with internal combustion engines (ICE).[81] The figures show a continuous improvement of the utility-cost relation of electric vehicles. The cost-benefit factors were determined by a cost-benefit analysis supplemented by studies and expert interviews. Figure 10 illustrates the continuous improvement of the utility-cost relation of Battery Electric Vehicles

[77] E.g. cost of battery, power electronics and electric engines which are in sum more expensive compared to a traditional powertrain with an internal combustion engine.
[78] Appendix V contains a list of assumptions concerning country specific electricity costs.
[79] Value after the car has been used, see Chapter 2.5.
[80] Appendix V contains a list of assumptions concerning country specific fuel costs.
[81] Calculation is based on the average utility-cost development of electric vehicles in the European market.

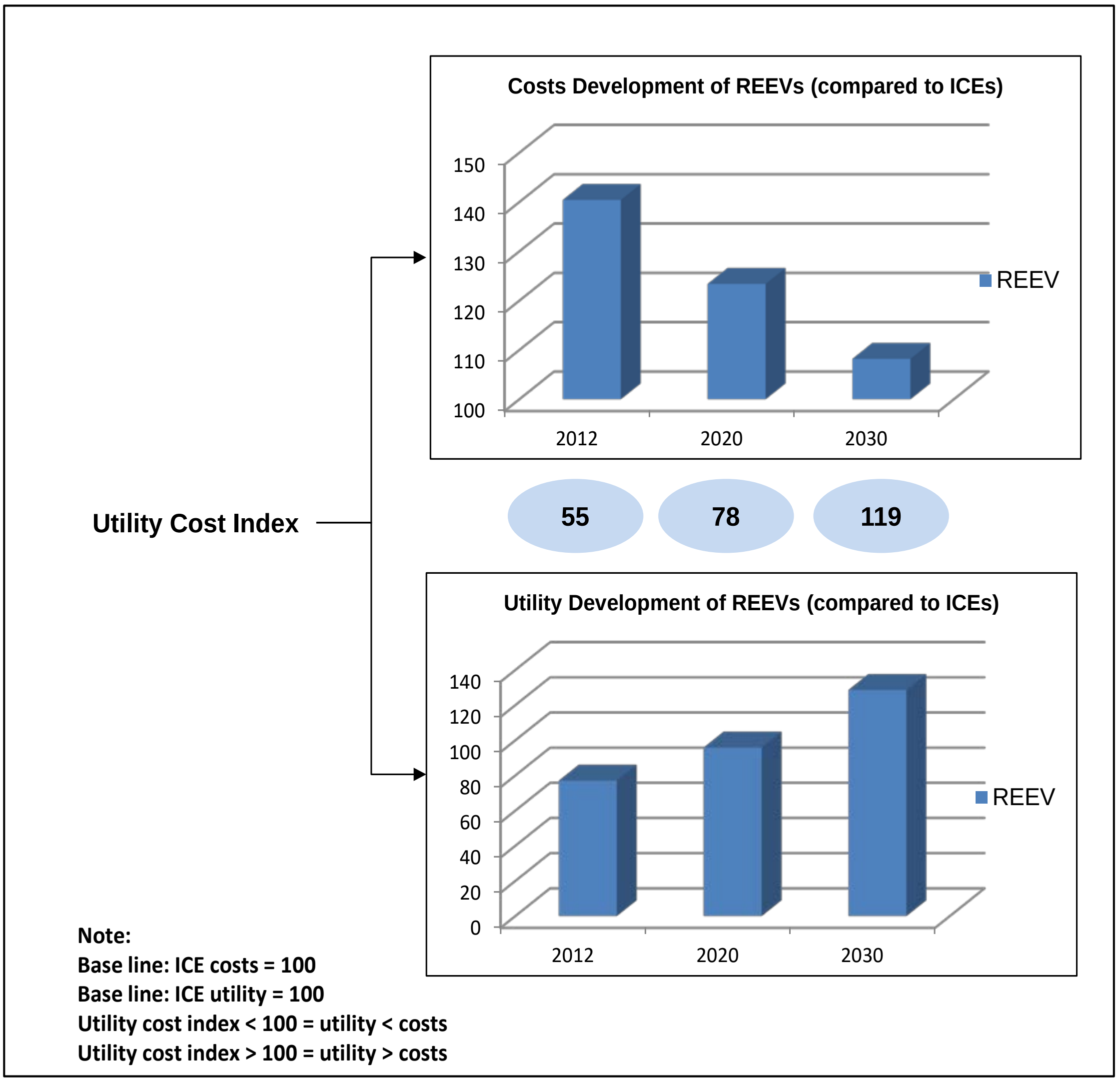
Figure 10: Utility-Cost Index of Battery Electric Vehicles Compared to ICEs



(Source: Own Calculation)

In 2012, Battery Electric Vehicles have 1.5 times higher costs compared to ICEs. Particularly due to higher costs of components (e.g. the battery system) current Battery Electric Vehicles have higher purchase costs than vehicles with internal combustion engines. Presently, the utility of Battery Electric Vehicles is half the size of ICEs. Battery Electric Vehicles will profit from their potential benefits over time, because several utility components such as regulations (entrance prohibitions for ICEs) or an expanding infrastructure will be implemented later on. **Altogether, Battery Electric Vehicles have a utility-cost index of 44 compared to ICEs in 2012.** That means that the utility-cost index of a BEV is less than half of the size of the utility-cost index of an ICE (100). Customers perceive the utilities of Battery Electric Vehicles to be less than the costs in comparison to ICEs. Therefore, the utility-cost index is less than 100. Up until 2030, the utility-cost index of Battery Electric vehicles will improve. In 2030, Battery Electric Vehicles will still have higher costs compared to ICEs but a strong increase in the utility will lead to an overall better utility-cost index of 131 compared to ICEs in 2030.Figure 11 illustrates the continuous improvement of the utility-cost relation of Range Extender.

Figure 11: Utility Cost Index of Range Extender Compared to ICEs

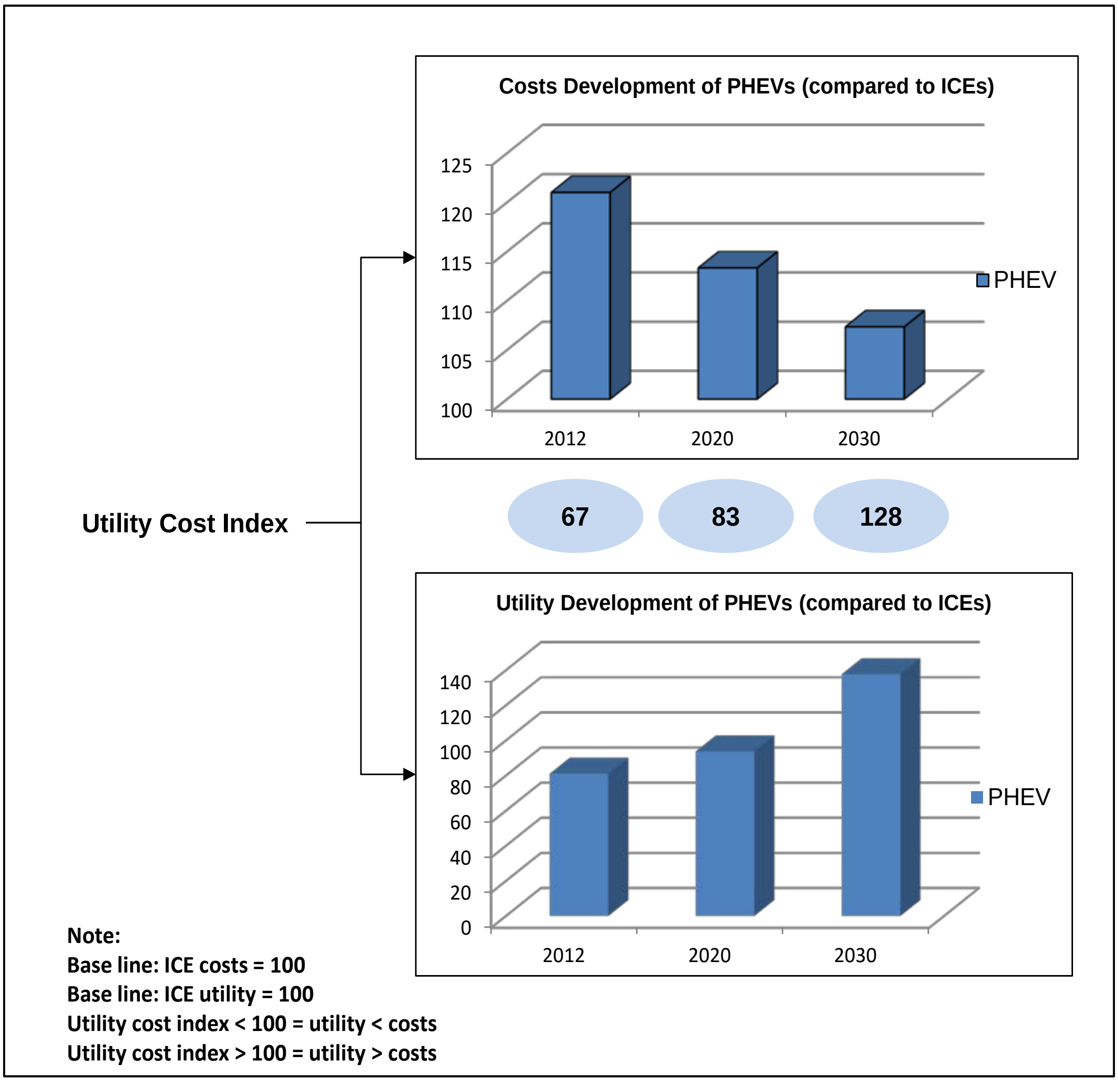


(Source: Own Calculation)

In 2012, Range Extenders have approximately 1.4 higher costs compared to ICEs. Particularly due to higher costs of components (e.g. additional electric powertrain), Range Extenders have higher purchase costs than vehicles with internal combustion engines. Presently, the utility of the Range Extender is less than the utility of ICEs. Since Range Extender can be easily refuelled at petrol stations, they do not have the disadvantages of a very limited range like Battery Electric Vehicles.

Therefore, a Range Extender has a better utility than a Battery Electric Vehicle when comparing both to ICEs. The Range Extender also enjoys essentially the same benefits as a Battery Electric Vehicle over time. Altogether, the Range Extender has a utility-cost index of 55 compared to ICEs in 2012. This means that the utility-cost index of the Range Extender is approximately half of the size than the utility-cost index of an ICE (100). By 2030, the utility-cost index of the Range Extender will have improved. In 2030, a Range Extender will still have higher costs compared to ICEs but a strong increase in utility leads to an overall better utility-cost index of 118 compared to ICEs in 2030. Due to the combination of an electric powertrain with an internal combustion engine, a Range Extender has higher costs than a Battery Electric Vehicle (e.g. purchase prices, costs of maintenance and repair). Therefore, the utility-cost index of Range Extender is lower than the utility-cost index of Battery Electric Vehicles in 2030.Figure 12 illustrates the continuous improvement of the utility-cost relation of Plug-In Hybrids.

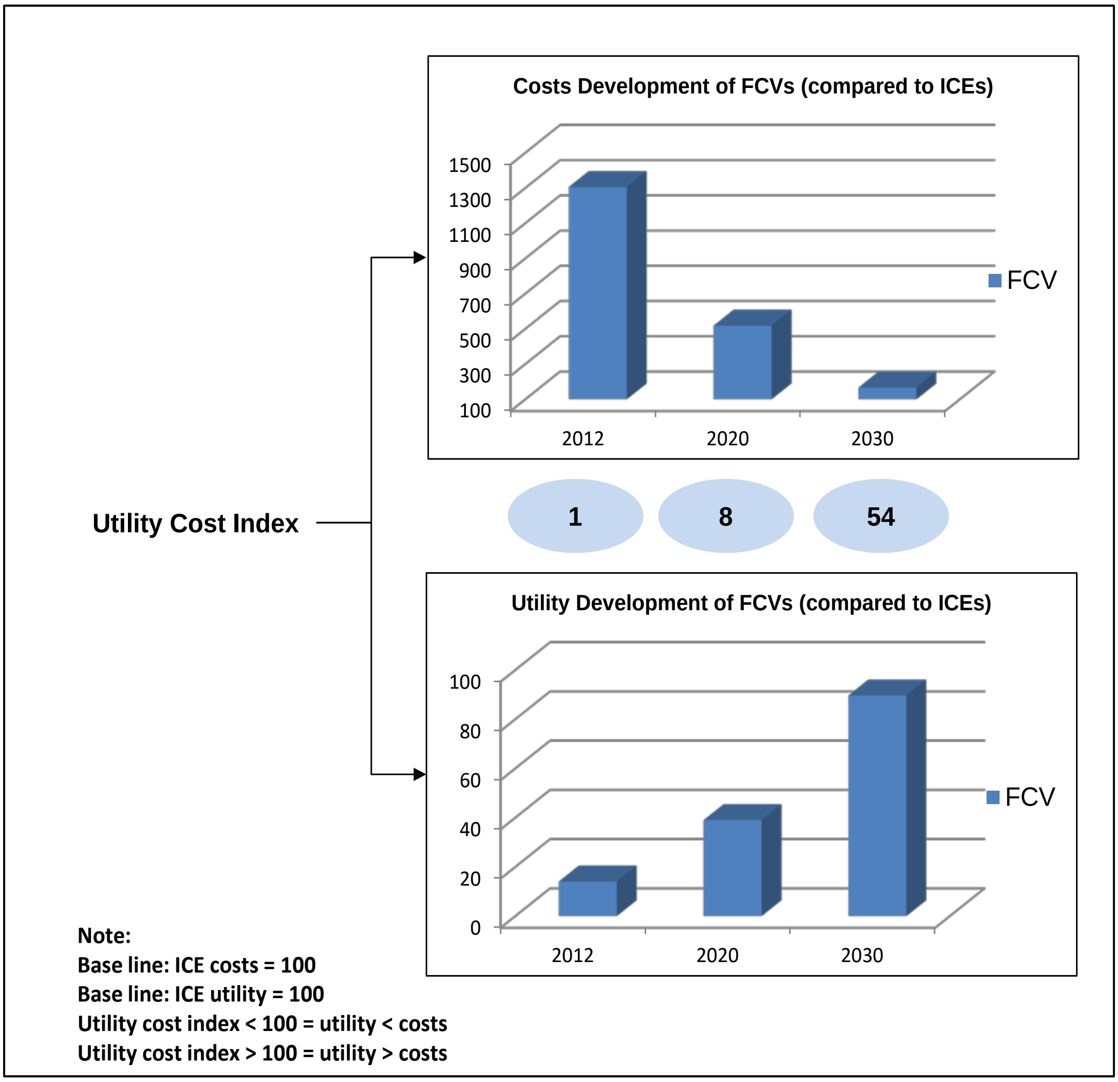
Figure 12: Utility-Cost Index of Plug-In Hybrids compared to ICEs



(Source: Own Calculation)

In 2012, Plug-In Hybrids have approximately 1.2 times higher costs compared to ICEs. Particularly due to **higher costs of components (e.g. additional electric powertrains),** Plug-In Hybrids have higher purchase costs than vehicles with internal combustion engines. Compared to Range Extenders and Battery Electric Vehicles, the component costs of the electric powertrain are less, particularly due to a smaller battery capacity (e.g. 6-10 kWh). Presently, the utility of Plug-In Hybrids is less than the utility of ICEs. The disadvantages of higher purchase costs cannot be compensated by lower fuel costs in the short term. ICEs currently benefit from lower purchase costs, stable residual values and a high acceptance among customers. Altogether, Plug-In Hybrids have a utility-cost index of 67 compared to ICEs in 2012. That means that the utility-cost index of Plug-In Hybrids is two thirds the size of the utility-cost index of an ICE (100). Up until 2030, the utility-cost index of Plug-In Hybrids will improve. In 2030, Plug-In Hybrids will still have higher costs compared to ICEs but the strong increase in utility will lead to an overall better utility-cost index of 128 compared to ICEs in 2030. Figure 13 illustrates the continuous improvement of the utility-cost relation of Fuel Cells.

Figure 13: Utility Cost Index of Fuel Cells Compared to ICEs



(Source: Own Calculation)

In 2012, Fuel Cells have a utility-cost index of 1 compared to ICEs at 100. The high purchase costs of Fuel Cells will not decrease in the long term. Presently, only a few manufacturers have been developing Fuel Cells. In November 2007, Honda revealed at the Los Angeles International Auto Show, the production-ready version of the FCX Clarity. In June 2008, serial production started in the former NSX factory in Utsunomiya. Currently there are no exact figures concerning the sales for 2012. Sales are expected to be far less than the sales target of 200 units[82] Honda had set for the year 2011. According to Reuters, Honda expects to launch Fuel Cells based on FCX Clarity up until 2018 in mass production.[83] Apart from that, Hyundai has confirmed the production of a "limited" number of Fuel Cells this year for testing purposes, with a production target of about 10,000 FCEVs annually until 2015.[84] Furthermore, Daimler has recently started producing a small series of the Mercedes-Benz B-Class F-CELL for testing purposes.[85] Daimler has been investigating the use of fuel cell technology in motor vehicles since 1994. The Group’s innovative activities are underscored by 180 patent applications in this field of technology.[86]

Nevertheless, according to the experts interviewed, the registrations of Fuel Cells will remain low even by 2030.Several reasons were mentioned: lack of infrastructure, safety concerns, expensive and so

[82] Honda (n.d.)
[83] Reuters (2010)
[84] Autoblog (2012b)
[85] At the present time no further data e.g. concerning the market launch and sales targets are available.
[86] Daimler (n.d.)

far minimal energy-efficient production of hydrogen, storage and transportation of hydrogen as well as the cost of the technical components of Fuel Cells. Up until 2030, the utility-cost index of Fuel Cells will improve by 50 times. Despite the rapid increase, the utility-cost index will still be much lower compared to ICEs.

Appendix IX provides an overview on single utility-cost factors of the different electric vehicles (BEV, REEV, PHEV and FCV) compared to ICEs.

2.3.2 Market Forecast

The market forecast has been developed in accordance with the procedure shown in Figures 1 and 5 (see Chapters 1.3 and 2.3.1) on the basis of estimation in the development of market demand, utility-cost relation and the customer segmentation/purchase behaviour. **Based on our market model and as validated in expert interviews, we were able to determine market forecasts on new registrations of electric vehicles (covering both passenger cars and light commercial vehicles**) concerning the World Market (Chapter 2.3.2.1), EU market (Chapter 2.3.2.2), the U.S. market (Chapter 2.3.2.3) and three main East-Asian markets (Chapter 2.3.2.4).

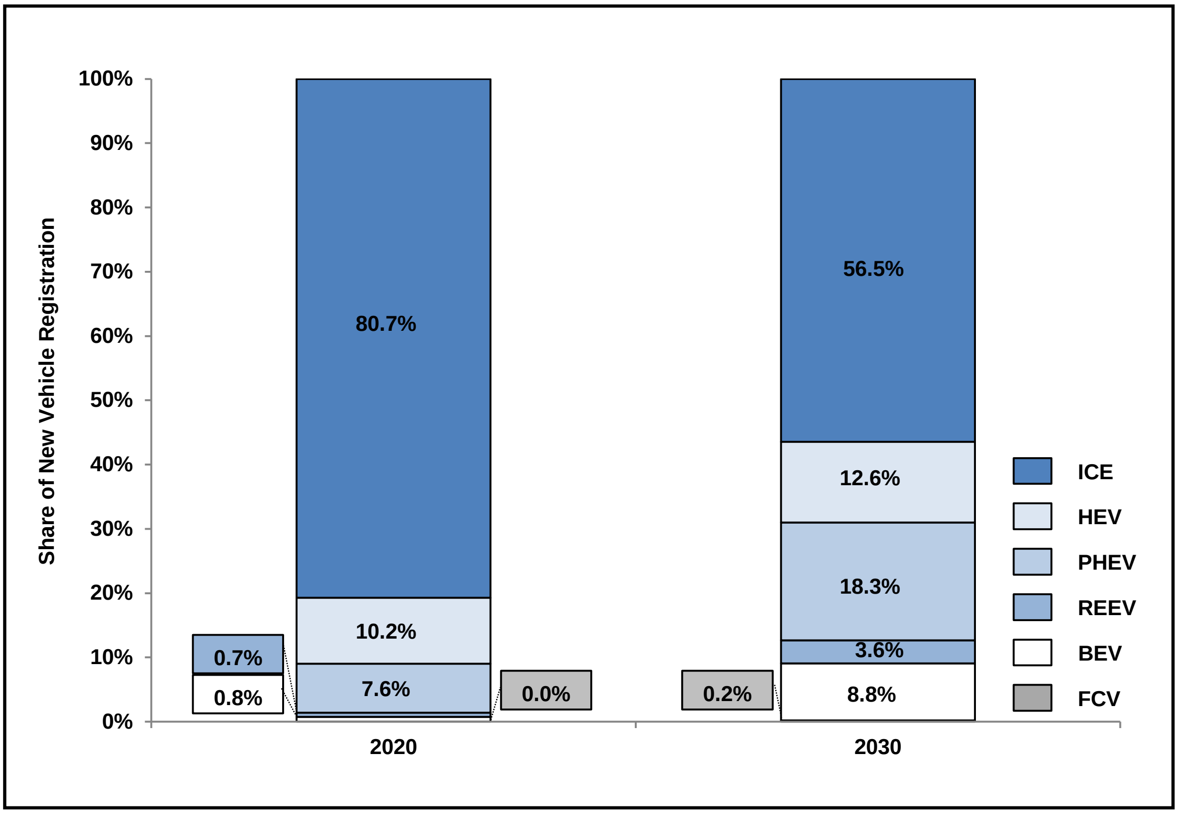
2.3.2.1 The World Market

The base case scenario expects a global market development of about 86 million vehicles up until 2020 and approximately 99 million vehicles in 2030. As Figure 14 summarizes, registrations of vehicles with traditional combustion engines will decline up to 2030 (with a share of almost 81 percent in 2020 compared with a share of 57 percent in 2030) while registrations of electric vehicles will increase (with a 9 percent share in 2020 compared with an approximate 31 percent share in 2030).

The estimation of the global market share of electric vehicles is based on aggregation of the results of the main markets considered in this study. For the “rest of the world market”[87] a market share of electric vehicles of 20 percent is assumed in 2030. This assumption has been confirmed by experts interviewed. The experts surveyed expect that electric vehicles in the “rest of the world markets” will have a lower market growth since vehicles with internal combustion will have a better utility-cost index.

[87]For example South America, Mexico, Canada, Russia, India, South Africa or Turkey.

Figure 14: Global Electric Vehicle Registrations in Percent up until 2030 (Passenger Cars + LCV)



(Source: Own Calculation)

In 2020, about 9 percent of the global new vehicles will be electric including 7.6 percent Plug-In Hybrids and less than two percent Battery Electric Vehicles and Range Extenders in total. Additionally, 10 percent of the global new vehicle registrations will be represented by Full Hybrids[88].

In 2030, approximately 31 percent of the global vehicle registrations will be Electric Vehicles. Approximately 18 percent of the new vehicle registrations will be Plug-in Hybrids, 9 percent Battery Electric Vehicles and 4 percent will be Range Extenders. The share of full hybrid electric vehicles will increase until 2030 up to a total share of 12.6 percent; but Plug-In Hybrids will gain more importance due to cost reduction and a smaller amount of fuel consumption. The market penetration of Fuel Cells will still be low with global registrations equalling less than one percent. Nevertheless, from 2030 Fuel Cells will gain more importance.

Most of the experts expect a **slow growth of new electric vehicle registrations in the medium term**. New global electric vehicles registrations are expected to have a market share lower than 10 percent by most of the experts interviewed. Most of these vehicles are expected to be Plug-in Hybrids which are going to be developed and produced in the next few years. A German premium manufacturer expects that in 2030, approximately 8 percent of the new vehicle registrations will be Battery Electric Vehicles. Another German premium manufacturer expects that in 2020 about 10 to 15percent of the new vehicle registrations will be already be Battery Electric Vehicles. Compared to the results of our market model and the discussions with many experts, we consider these estimations as quite optimistic. The majority of the OEM respondents expect a global share of approximately 10 percent BEV and about 50 percent ICE in 2030. The remaining share will be divided into Plug-Ins and Range Extenders. The proportion of Full Hybrids is expected to decrease over time.

China is often regarded as a **key driver of global market development in electromobility**. If China decides to reverse in terms of their activities in electromobility, there would be serious consequences for the global market development of electric vehicles. Still, many experts in our study pointed out that

[88] For reasons of comparison, an utiliy-cost analysis and forecasting was performed for non-rechargeable hybrids as well.

the market potential of China is overestimated. A representative in charge of electromobility for a global car manufacturer emphasized:

> "[…] most of the studies assume between 3 and 10 percent electrically chargeable vehicles for Europe between 2020 and 2025. On a global scale (including markets as India) this share might be lower. Given Asia (China/India) as key growth markets, low cost basic transportation needs need to be addressed, which will most likely focus on conventional propulsion systems."

Some experts interviewed therefore expect **a change in China from BEV technology to hybrid technology**. Similar results are presented in a study by McKinsey 2012. Furthermore, the **potential in emerging markets such as Russia and Latin America are evaluated by experts as rather low**.[89]

Most of the OEM interviewed in Europe expect **non-rechargeable Full Hybrids to become relevant in markets where gasoline engines are currently preferred** (e.g. USA and Asia). According to the manufacturers interviewed, **full hybrids have a lower potential in European countries, particularly due to diesel technology** as more than 50 percent of the total new vehicle registrations[90] of Western Europe belong to diesel engines.[91] According to ACEA (2011), in Member States like France, Spain, Luxembourg and Belgium the diesel penetration covers more than 70 percent of new vehicle registrations. According to the European manufacturers interviewed, **diesel engines have still a great optimization potential** e.g. using three-cylinder engines, optimized injection or turbochargers. In the past many customers considered the three-cylinder as too weak and too loud. But due to balance shafts, a three-cylinder can now compete with four cylinder engines even in terms of quietness and performance, not just in terms of consumption, emissions and efficiency. Fewer moving parts lead to less consumption, less weight - and can also reduce the production costs.

While **PSA group is currently pursuing a diesel-hybrid strategy**, other European manufacturers evaluate this technology as far too expensive.[92] In comparison to vehicles using a gasoline hybrid technology, diesel-hybrids produce higher torque and have enhanced efficiency which reduces the overall fuel consumption. Due to the reduced speed and the increased torque of a diesel engine only synchronous machines can be practically used in diesel-hybrids. These synchronous machines and also the diesel engine itself increase the overall costs of the vehicle compared to a vehicle using gasoline-hybrid technology. Since the diesel penetrations and thus the market potential is very low in countries like the U.S. and Asia, **manufacturers like e.g. BMW, Ford, GM, Honda, Mercedes Benz, Toyota and the Volkswagen Group are therefore currently pursuing the strategy of hybridization of gasoline engines**. Among these manufacturers, Toyota is so far the first that offers a rechargeable plug-in hybrid version of the gasoline engine on the mass market with its Prius plug-in.[93]

The base case scenario expects a global market development resulting in an annual increase of approximately 86 million new vehicle registrations in 2020 and 99 million in 2030, of which 9 percent in 2020 and 31 percent in 2030 will be electric vehicles.

Table 9 provides an overview of results from different studies concerning the global registrations of electric vehicles in 2020 and 2030 compared with the results of our study. Our (University of Duisburg-

89 The Russian expert Maksim Osorin recently explained in an interview with Germany Trade & Invest that a Russian market for electric vehicles "still does not exist" (GTAI 2011). Mitsubishi offers the i-MiEV for 1.8 million rubles (44,000 Euros), which is more than three times as much as conventional cars in this class. Volkswagen, for example, provides its market for the Russian-designed VW Polo Sedan with petrol engines starting at 420,000 rubles (GTAI 2011). According to GTAI, Volkswagen considers the Russian market for electric cars rather sceptical. Russia has an extreme price pressure in the automotive sector. The consumer interest for electric vehicles in the volume segments is very low. Only a small number of commercial customers and a small number of private buyers are expected to purchase electric vehicles in the following years (GTAI 2011). Even in Brazil, which is the most important new vehicle market of Latin America, the public interest in reducing vehicle emissions is lower than in many other countries. About 84 percent of new cars are equipped with flex-fuel engines, i.e. they allow a fuel mix of gasoline and ethanol. Investigations revealed that a large proportion of the Brazilian vehicle owners drive no more than 50 km a day and thus the limited range of electric vehicles would not be a restrictive factor. At present, however, the majority of Brazilians have a low intention to purchase an electric vehicle, particularly due to higher purchase costs. Germany Trade and Invest therefore expect that the Brazilian market of electric vehicles will not develop significantly in the next decade (GTAI 2009).

90 Passenger cars

91 ACEA (2011a)

92 See more details in chapter „Industrial Plans“

93 See chapter 2.1.1

Essen- UDE) forecast of the global electric vehicle registrations in 2020 is very similar to the results of the other global forecasts. In 2020 the majority of studies expect a market share of electric vehicles ranging from 6 to 11 percent, including BEV, PHEV and REEV (see Table 9). Our 2030 perspective corresponds to the market forecasts of the German Chamber of Industry and Commerce IHK, McKinsey, Worldbank and IEA; assuming a market penetration of electric vehicles by 30 percent. McKinsey and Worldbank expect a rapid decrease in vehicles with internal combustion engines by 2030, and assume a larger share of non-rechargeable hybrids instead (see Table 9).

Table 9: Global New Electric Vehicle Registrations in 2020 and 2030

2020	DB Research 2009	Uni DUE 2012	Worldbank 2011[1]	PRTM 2010	McKinsey 2011[2]	IHK 2010[3]
EV	11%	9%	9%	9%	8%	8%
HEV	9%	10%	10%	9%	27%	15%
ICE	80%	81%	81%	82%	65%	77%

2020	Bain&Company 2010[4]	IEA 2010[5]	BCG 2011[6]	EU Expert Group 2011	Fraunhofer/PWC 2010
EV	7%	7%	6%	3-10%	0,8-2,6%
HEV			9%		
ICE			85%		

2030	McKinsey 2011[2]	Uni DUE 2012	Worldbank 2011[1]	IEA 2010[5]	IHK 2010[3]
EV	34%	31%	30%	28%	28%
HEV	35%	12%	50%		13%
ICE	31%	57%	20%		59%

Notes:

EV: Including BEV, PHEV, REEV and FCV HEV: Including non-rechargeable full hybrid vehicles

1 Own Calculation based on figures in the report
2 Representing the scenario "40g/km"
3 Representing the scenario "Zeitenwende"
4 Representing the $100 scenario
5 Representing the "Blue Map" scenario
6 Representing the $130 scenario

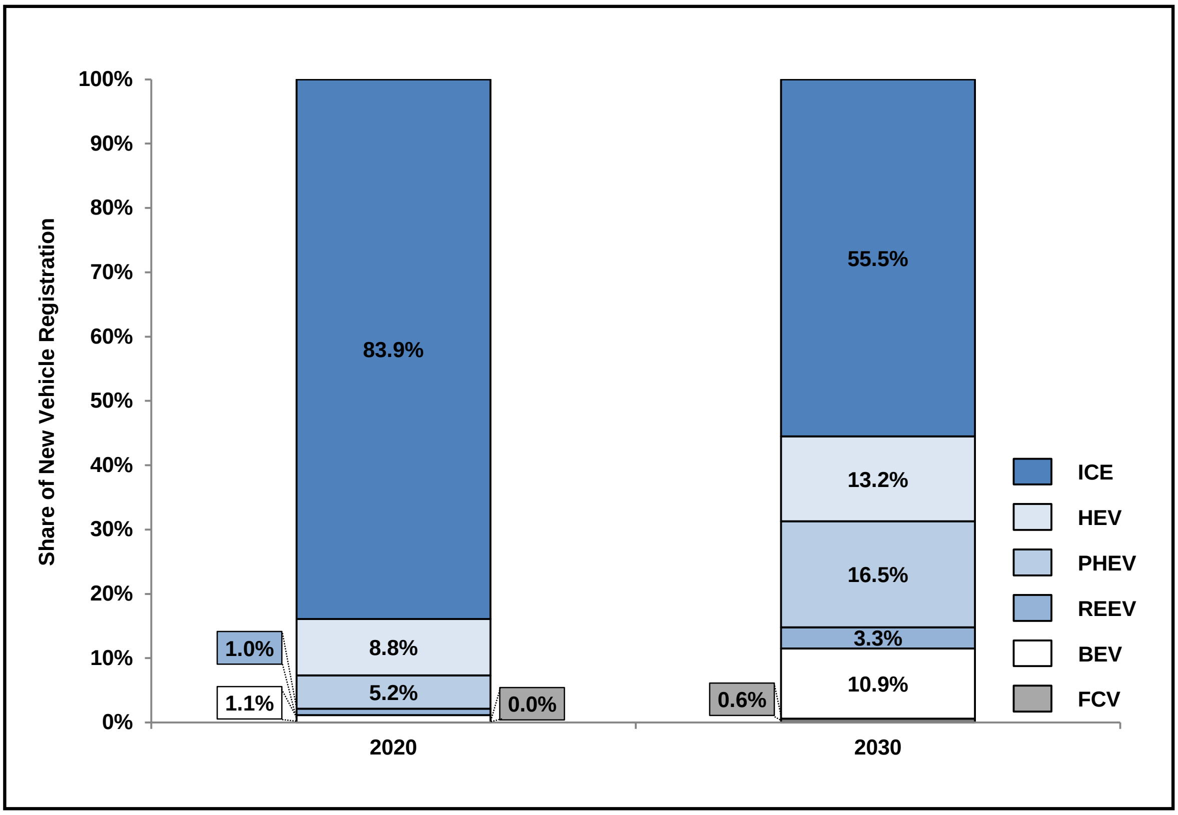
(Source: Own Compilation)[94]

2.3.2.2 The European Market

In order to estimate the forecast for all EU-27 Member States, five main markets (Germany, France, Italy, UK and Spain) have been analysed and an additional segment covering all other MS has been added and called the "Rest of EU". The input factors have been calculated for this segment (using average values from Eurostat regarding EU-27 inputs in terms of fuel or electricity costs or different assumptions concerning the customer segmentation based on studies, including for example, the East European customers in terms of their preferences in electromobility). Subsequently, the results of the "Rest of EU" markets have been aggregated with the results of the markets in Italy, France, Spain, Germany and United Kingdom. Based on our market model and validated in expert interviews, we were able to determine the following market forecasts concerning the EU electric vehicle market (Figure 15).

[94] This study compares the results from other extensive studies, particularly those that are publicly available and provide clear and conceivable explanations for their assumptions/scenarios respectively methodology.

Figure 15: EU-27 Electric Vehicle Registrations in Percent up until 2030(Passenger Cars + LCV)



(Source: Own Calculation)

As Figure 15summarizes, the registrations of vehicles with traditional combustion engines will decline up to 2030 (with a share of 84 percent in 2020 compared with a share of 56 percent in 2030) while **the registrations of electric vehicles will increase (with a share of 7 percent in 2020 compared with a share of about 31 percent in 2030**). The following chart illustrates the continuous increase in the registration of electric vehicles in the EU-27 Member States up to 2030.

In 2020, about **7 percent of the European new vehicles will be electric including 5 percent Plug-In Hybrids, and about 2 percent Battery Electric Vehicles and Range Extenders in total**. Additionally, about **9 percent of the EU new vehicle registrations will be represented by Full Hybrids**. **In 2020, altogether, approximately 1 million vehicles of the total new vehicle registrations in the will be electric.**

In 2030 approximately 31 percent of the EU vehicle registrations will be Electric Vehicles. Approximately 16 percent of the new vehicle registrations will be Plug-in Hybrids, 11 percent Battery Electric Vehicles and 3 percent will be Range Extenders. **The share of full hybrid electric vehicles will increase until 2030 up to a total share of 13 percen**t, but Plug-In Hybrids will gain more importance due to cost reduction and less fuel consumption. The market penetration of Fuel Cells will be still low with registrations less than one percent. Nevertheless, from 2030 Fuel Cells will gain more importance. **Altogether, approximately 4.6 million vehicles of the total new vehicle registrations in the EU-27 Member States will be electric vehicles in 2030.**

The following table provides an overview on the market development of electric vehicles in the main European markets France, Germany, Italy, Spain and United Kingdom. More detailed information on the different markets is provided in the Appendix X.

Table 10: Overview on Electric Vehicle Registrations in Percent up until 2030
in France, Germany, Italy, Spain and the United Kingdom (Passenger Cars + LCV)

		France	Germany	Italy	Spain	United Kingdom	EU 27
2020	ICE	82	84	87	86	86	84
	HEV (non-rechargeable)	9	7	10	7	7	9
	EV (REEV, BEV, PHEV)	9	9	3	7	7	7
2030	ICE	51	74	55	58	74	56
	HEV (non-rechargeable)	11	7	23	13	8	13
	EV (REEV, BEV, PHEV)	38	19	22	29	18	31

Note: Registrations in Percent

(Source: Own Calculation)

The important differences in market penetration are expected across the EU-27. The results of market model, but also almost all of the surveyed German experts, initially expect a slow development of electric vehicles in **Germany**. In contrast to the German market, new vehicle registrations in **France** will show significant differences in terms of vehicle types (BEV predominant). Aside from differing consumer preferences, this trend can be explained by the strategies of French car manufacturers. PSA group and Renault already offer different types of electric vehicles (see Chapter 2.1.1). In terms of the development of electric vehicles in France, both the results of our market model and the estimations, most of the surveyed French experts are very optimistic. Nevertheless, some experts doubt whether the French market will develop faster than the other European markets. In their opinion, the operating costs (e.g. electricity costs compared to high fuel costs) would not induce higher registrations of the private customers in general, due to the higher additional costs of electric vehicles. Therefore, even in France, the early adopters are expected to be primarily commercial customers. This assumption has been included in our model (see customer segments Appendix III). Recently, a group of French companies including Electricite de France, SNCF, Air France, France Télécom and La Poste have committed to purchase an initial order of 50,000 electric vehicles. Furthermore, Autolib started to offer microcars in Paris in December 2011 with its car sharing program. Parisians who are members can use small electric cars, for a small charge and for short trips.[95] The Bolloré Group, which is a family-owned industrial holding company behind Autolib, plans to have 3,000 battery electric cars of type "Blue Cars" circulating on the streets of Paris and its inner-ring in the short term.[96] This will help the French population (especially the Parisian metropolitans) to become accustomed to electric vehicles and experience the benefits of electromobility.

In **Italy**, the market for electric vehicles will develop slowly over time. The ICE technology is expected to dominate the new vehicle registrations for the next decade while registrations of Hybrid Electric vehicles and Plug-In Electric vehicles will increase rapidly from 2020 to 2030. This development can be explained with the rise in fuel costs on the one hand and the fuel savings of hybridisation on the other. Experts believe that both natural gas vehicles and full hybrids will gain importance as well as hybridisation of vehicles with natural gas. Due to the infrastructure (mountainous landscape, narrow streets) and high degree of urbanisation (many people live in or near large cities), the Italian experts, who have been surveyed in this study, expect that battery electric vehicles will not gain importance in Italy. Because of the deficiencies in the infrastructure, Italian key players are currently working on projects pursuing wireless charging for effective urban mobility (Italian Electrified Mobility Technological Platform).

Also the market of electric vehicles in the **United Kingdom** will increase slowly. Hybrids will dominate electric vehicle registrations by 2025. In the first six months of 2012, 12,720 full hybrids[97] were registered in the UK. The government offers purchase premiums, in order to stimulate the purchases of electric vehicles. These purchase premiums also relate to hybrids (depending on the extent of their

[95] Autolib (2012)
[96] IEA (2011a)
[97] Non-rechargeable vehicles

CO_2 emissions). The UK experts interviewed consider the commercial fleets as Early Adopters of electric vehicles in the medium term.

The **Spanish** registrations of vehicles with traditional combustion engines are expected to decline in 2030 perspective while registrations of electric vehicles will increase slightly. The high costs of electric vehicles, which will not fall significantly until 2020, are confronted with very low fuel costs in Spain. Therefore, the ICEs will dominate new vehicle registrations for the next decade. In recent years, new vehicle registrations of private customers have decreased. Due to the economic crisis, most of the experts interviewed rather consider commercial customers as the "Early Adopter" of electric vehicles and hybrids than compared with private customers in the medium term (differences in willingness to buy and purchase). Nevertheless, electric vehicles and hybrids are currently being strongly promoted by the Spanish government (see Chapter 5.1.1). Interestingly, among the taxi registrations, experts also pointed that while the Toyota Prius is gaining importance particularly due to the purchase premium which is offered by the government, most of the value added of the Toyota Prius currently resides in Asia.

Altogether, our forecast of the **EU-27** electric vehicle registrations in 2020 falls between the results of the Joint Research Center (JRC) of European Commission study and the CE Delft study commissioned by DG Clima of European Commission (see Table 11). Neither the JRC nor the CE Delft study distinguish between conventional vehicles (ICE) and non-rechargeable full hybrids. Therefore, the registrations of ICEs vary in these studies. Although one study - by A.T. Kearney - is very optimistic; expecting a share of approximately 23 percent electric vehicles in 2020 including 14 percent PHEV; **the majority of studies assume a market share of electric vehicle registrations ranging between 3 and 8 percent in 2020** (see Table 11a). Altogether, the European Roadmap for the European Green Cars Initiative assumes an accumulated number of 5 million electric vehicles in 2020 and about 15 million electric vehicles in 2025.[98]

Our 2030 perspective is very similar to the results of JRC, Global Insight and Roland Berger. The CE Delft study is more optimistic, assuming an electric vehicle market share of more than 50 percent in 2030, mainly due to a strong market increase of PHEV and REEV (see Table 11b).A.T.Kearney 2012 expects a strong market increase of Plug-In Hybrids by 2025. A CE Delft 2011 study also considers Plug-in Hybrids to be the most successful type of EV in its three market scenarios. Furthermore, a Joint Research Center 2010 study showed that PHEV registrations will increase rapidly as soon as they are launched, because battery and charging infrastructure represent higher constraints for BEVs.

[98]European Green Cars Initiative (2012)

Table 11: EU-27 New Electric Vehicle Registrations in 2020 and 2030

a) New Electric Vehicle Registrations by 2030 - Comparison of Different Studies

2020	A.T.Kearney 2012	BCG 2011[1]	JRC 2010[2]	Uni DUE 2012	Global Insight	CE Delft 2011[3]	J.D. Power 2010[4]
EV	23%	8%	9,8%	7%	7%[5]	5%	3,1%
HEV	15%	18%		9%			4,1%
ICE	62%	74%	90,2%	84%		95%	92,8%

2030	CE Delft 2011	A.T.Kearney 2012	JRC 2010	Uni DUE 2012	Roland Berger 2011[4]	Global Insight
EV	52%	40%	41,5%	31%	26%	16%[5]
HEV		11%		14%	11%	
ICE	48%	49%	58,5%	55%	63%	

b) New Electric Vehicle Registrations by 2030 by Vehicle Type

2020	A.T. Kearney 2012	Uni DUE 2012	CE Delft 2011
EV	23%	7%	5%
BEV	7%	1%	1%
REEV	2%	1%	1%
PHEV	14%	5%	3%
EV	23%	7%	5%

2030	CE Delft 2011	A.T. Kearney 2012	Uni DUE 2012
EV	52%	40%	31%
BEV	11%	12%	11%
REEV	11%	4%	3%
PHEV	30%	24%	17%

Notes:

EV: Including BEV, PHEV, REEV and FCV HEV: Including non-rechargeable full hybrid vehicles

1 Representing the $130 scenario A.T. Kearney 2012: no figures for 2030, table represents figures for 2025
2 Representing the "Batt1_Inf2" scenario
3 Representing scenario 1
4 Registrations of HEV including PHEV
5 Business-as-Expected Scenario, including BEV and PHEV (Own Calculation based on absolute numbers), share of EV registrations is low due to a very optimistic baseline of the total market demand, Global Insight expect total EU 27 new vehicle registrations of 24.5 million light vehicles in 2030

(Source: Own Compilation)[99]

In contrast to many other studies, UDE investigated different customer segments within Europe. Most of the existing studies assume that all customers will enter at a certain cost-benefit ratio equally. Our results show that the willingness to buy electric vehicles varies greatly across Europe. Furthermore, the different views of customer segments demonstrate that the French market will be characterized by a different development than the Spanish, Italian or even the German market. This can be explained by the different French consumer behaviour (e.g. higher share of smaller vehicle segments in French new vehicle registrations) and by the favourable ratio of cost of electricity to fuel costs (see Chapter 2.3.2.2).

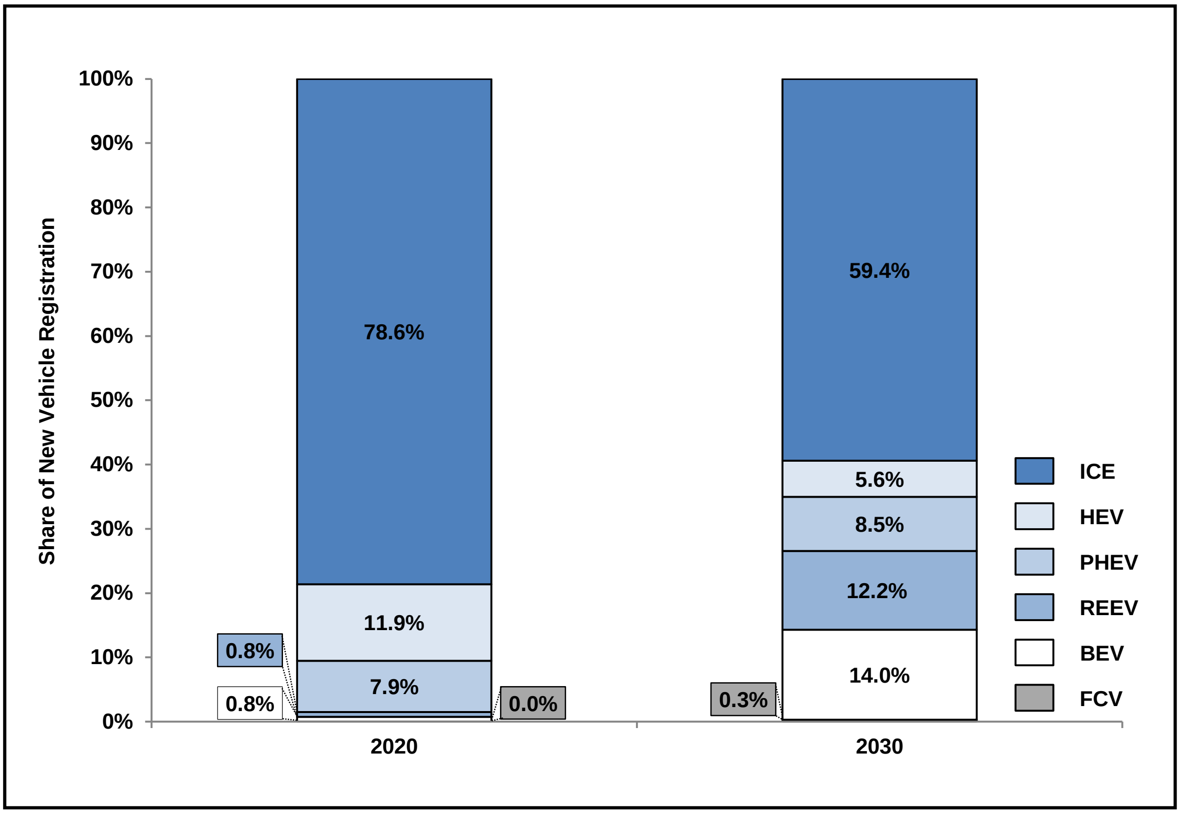
On the German market, which is currently still characterized by high proportions of upper vehicle segments, electromobility will deploy in the long term. This is due to the fact that premium manufacturers such as BMW, Daimler, and Audi will not enter the market until 2013 to 2015. Nevertheless, we expect that the German vehicle market will be faced with a trend toward smaller cars and a change in mobility behaviour as well, but just not in the short term. Even in the U.S. a trend towards smaller and more fuel-efficient cars can be expected. In 2005, about 43 percent of the new vehicles had a six cylinder engine, while 26 percent were equipped with four-cylinder engines. Today, more than half of the private customers choose a four-cylinder engine.[100]

[99] This study compares the results from other extensive studies, particularly those that are publicly available and provide clear and conceivable explanations for their assumptions/scenarios respectively methodology.
[100] Automobilwoche (2011a)

2.3.2.3 The U.S. Market

The **U.S. registrations of vehicles with traditional combustion engines will decline up to 2030** (with a share of about 79 percent in 2020 compared with a share of about 60 percent in 2030) while the registrations of electric vehicles will increase (with an approximate 9.5 percent share in 2020 compared with an approximate 35 percent share in 2030). **By 2020, the U.S. electric vehicle market is expected to be dominated by registrations of Hybrid Electric Vehicles**. This trend will continue but Plug-In Electric Vehicles will become more prevalent up until 2030, mostly due to rising fuel costs, which will also lead to a change in the purchase behaviour of U.S. customers, Battery Electric Vehicles and Range Extenders will gain importance in the long term. **In 2030, approximately 5,000,000 of the total new vehicle registrations in the U.S. will be electric vehicles (see Figure 16).**

Figure 16: U.S. Electric Vehicle Registrations in Percent until 2030(Passenger Cars + LCV)



(Source: Own Calculation)

A major difference between the U.S. and Europe is the annual mileage of the U.S. customers. This is also reflected in the results of our market model. The proportion of Range Extenders and Plug-in Hybrids will be 20 percent by 2030. Presently, U.S. green enthusiasts prefer the Toyota Prius and Toyota has succeeded with creating the brand “Prius” in the US. Experts, who have been surveyed in this study, consider the independent new design as responsible for the success of the Toyota Prius: “Those people, who purchase a Prius, they really want to show it off!”

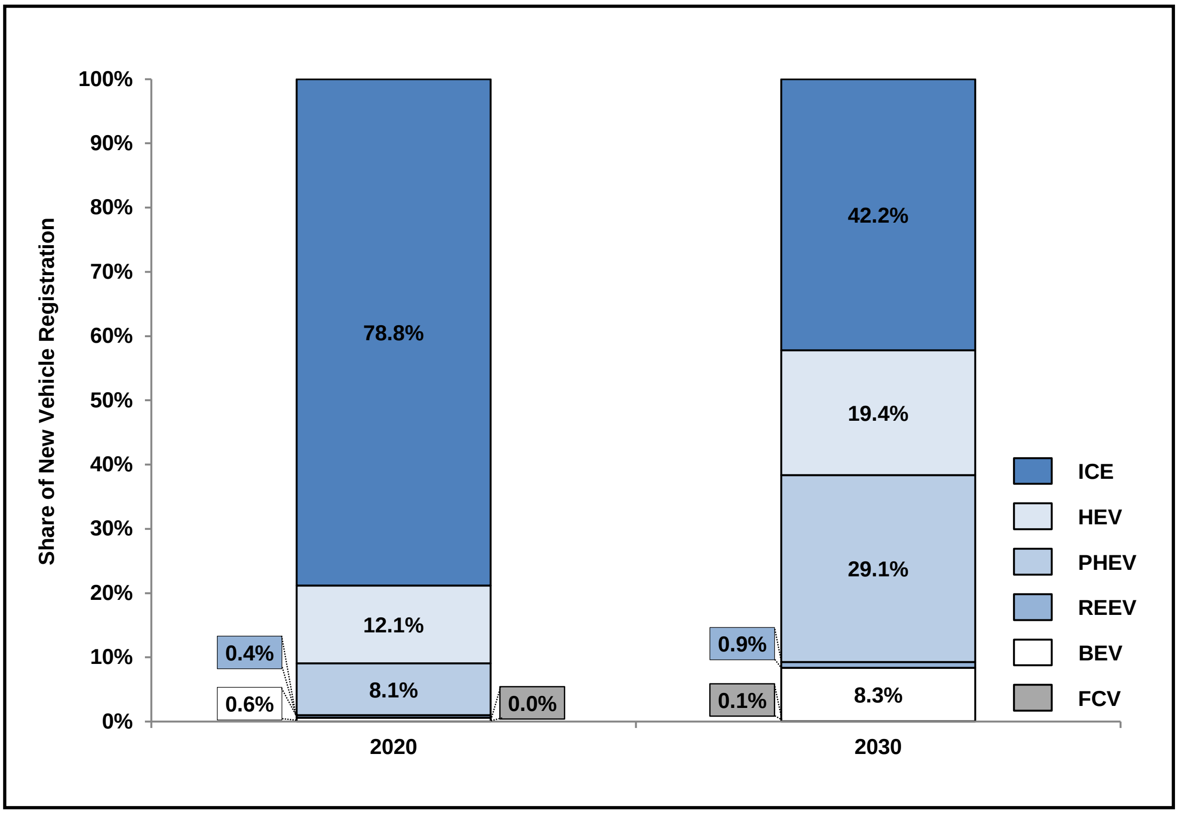
From this point of view, the development of new vehicle concepts would be a profitable strategy. However, not all consumers are "green enthusiasts". In 2011, almost 270,000 hybrid electric vehicles were registered in the U.S.; with the exception of Toyota’s Prius model, most of the vehicles were not promoted as environmental friendly but instead were marketed as powerful and comfortable. In the past, many manufacturers equipped hybrid electric vehicles with special accessories, supplementary equipment and additional power in order to justify the extra cost. Instead of curbing the performance of the gasoline engine, hybrid electric vehicles, particularly the large SUVs have been equipped with additional power instead. It becomes apparent that most of the hybrid electric vehicles hardly have significant lower emissions than similar vehicle types with internal combustion engines. Experts interviewed, indicated that from an environmental view, this strategy is not very attractive - but it is from an economical point of view.

2.3.2.4 Main Asian Markets

In Asia, the three main markets i.e. China, Japan, and South Korea have been analysed. In order to validate the results of the market model, several national as well as foreign (expatriate) experts in China, Japan, and Korea have been interviewed.

In **China**, the share of gasoline-powered vehicles in new registrations is expected decline significantly over the next 20 years as electric cars gain prominence. However, **up until the late 2020s the Chinese new vehicle market will continue to be dominated by cars with traditional combustion engines.** Hybrid electric vehicles are expected to experience particularly strong growth until 2020 and expand at a slower pace during the following 10 years. Plug-in hybrid electric vehicles, on the other hand, will show a less dynamic growth before 2020 but a more rapid expansion thereafter (see Figure 17).

Figure 17: Chinese Electric Vehicle Registrations in Percent until 2030(Passenger Cars + LCV)



(Source: Own Calculation)

Propelled by rising fuel costs and urbanisation levels, the share of battery electric vehicles will rise to about eight percent until 2030. In line with a recent study compiled by McKinsey,[101] we assume that the **combination of combustion engines and electric drives in the form of plug-in hybrids will prove successful** in China over the medium term. Two market segments will gain particular importance: low-cost and premium vehicles (e.g. SUVs, Sedans). **Consumer interest in battery electric vehicles will rise in the lower segments** (especially small-town cars, microcars and scooters, which are used in mega cities).

With the Chinese government driving the commercialisation and popularisation of electric vehicles, we expect that **by 2030 approximately 11,000,000 new electric vehicles will be registered annually**. Consequently, we expect market penetration to be particularly strong in areas directly or indirectly controlled by the authorities (e.g. public buses, taxis, and government fleets). While we hold that bat-

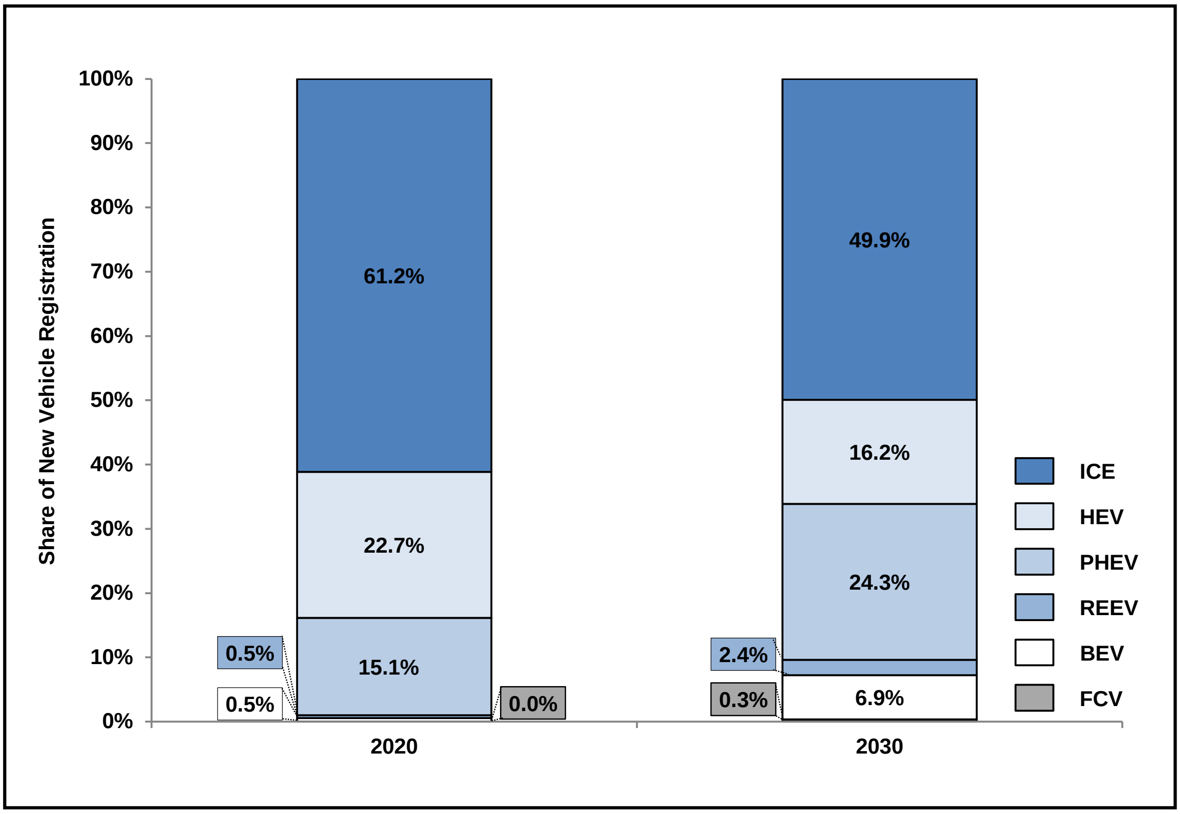
[101] McKinsey (2012)

tery electric drives will be the preferred technology for buses, plug-in hybrids will become most prominent with regard to passenger cars.

In **Japan**, the share of new vehicle registrations with traditional combustion engines will decline until 2030 (with a share of about 61.2 percent in 2020 compared with a share of 50 percent in 2030) while the registrations of electric vehicles will increase (with an approximate 16 percent share in 2020 compared with an approximate 34 percent share in 2030). By 2030, the Japanese electric vehicle market will be dominated by registrations of ICEs and Plug-In Hybrid Electric Vehicles. Presently, we expect that Battery Electrics will have a share of 7 percent in 2030 while Range Extenders will prove to be unpopular in Japan (2 percent).

The Japanese automotive industry is focusing on the development of Hybrids, Plug-in Hybrids and Battery Electric Vehicles instead of Range Extenders. Battery Electric Vehicles will primarily gain importance in metropolitan areas like Tokyo while Hybrid Electric Vehicles (particularly Plug-in Hybrids) will dominate the new vehicle registrations even in the medium term. For the next 10 years, no concrete plans for the market introduction of Fuel Cells by Japanese manufacturers are published. Therefore, it is not expected that a substantial market penetration will take place until 2025/2030.**Altogether, approximately 900,000 of the total new vehicle registrations in Japan will be electric vehicles in 2030**. A quarter of these new electric vehicle registrations will be Plug-In Hybrids. Figure 18 illustrates the continuous increase in the Japanese electric vehicle registrations up to 2030.

Figure 18: Japanese Electric Vehicle Registrations in Percent until 2030(Passenger Cars + LCV)



(Source: Own Calculation)

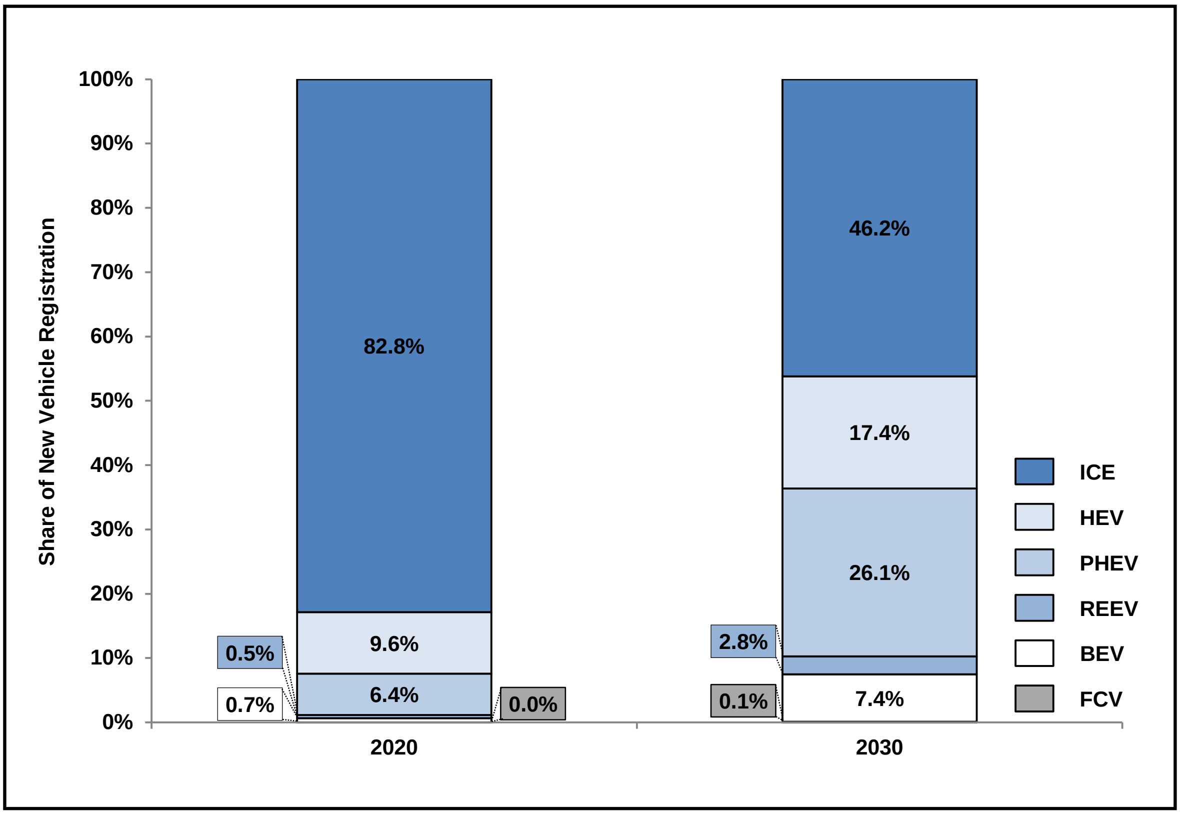
Experts interviewed in Japan consider this development of electric vehicles in Japan as realistic. Most of them believe that the registrations of vehicles with internal combustion technology will be about 50 percent in 2030. This assumption is also reflected by the results of our market model.

In **Korea**, the share of new vehicle registrations with traditional combustion engines are expected to decline until 2030 (with a share of about 83 percent in 2020 compared with a share of 46 percent in 2030) while the registrations of electric vehicles will increase (with an approximate 8 percent share in

2020 compared with an approximate 37 percent share in 2030). Figure 19 illustrates the continuous increase in the Korean electric vehicle registrations up to 2030.

By 2020, the Korean electric vehicle market will be dominated by registrations of ICE. From 2020 Hybrid Electric Vehicles will gain importance. Up until 2030, Plug-In Hybrids will dominate the registrations of electric vehicles. Battery electric vehicles will become more attractive, especially in mega cities like Seoul. Altogether, approximately 550,000 of the Korean new vehicle registrations will be electric vehicles in 2030.

Figure 19: Korean Electric Vehicle Registrations in Percent until 2030(Passenger Cars + LCV)



(Source: Own Calculation)

The majority of experts in Korea believe that the **registrations of vehicles with internal combustion technology will be about 50 percent in 2030**. This assumption is also reflected by the results of our market model. While the Korean government is focusing on the research and development of battery electric vehicles and components, Korean car manufacturers are additionally focusing on the optimisation of ICE technology and research and development in the field of fuel cells. Similar to the Japanese experts, the Koreans believe that the ICE technology will dominate even in the long term due to a high potential of optimisation in terms of fuel efficiency. Some of the surveyed experts pointed out that very few of the Korean customers are "green enthusiasts".

2.3.3 Interim Conclusion

The UDE base case scenario expects a global market development resulting in an annual increase of approximately 86 million new vehicle registrations in 2020 and 99 million in 2030, of which 9 percent in 2020 and 31 percent in 2030 will be electric vehicles. The Asian, US and European markets are expected to be the leading ones in terms of electromobility.

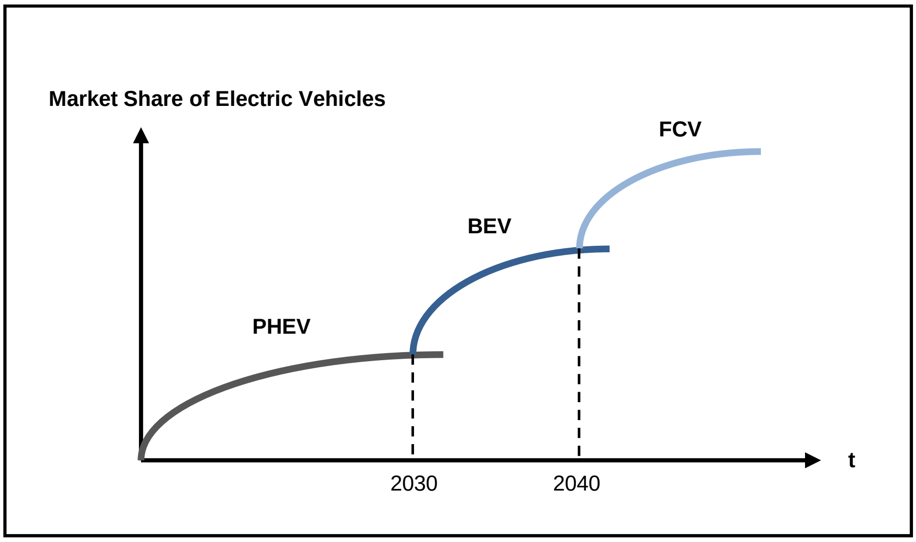
Based on UDE forecasts for 2020 and 2030, it is clear that **the EU market in electric vehicles will increase, but moderately.** Apart from a small number of early adopters, most of the customers are not willing to pay the additional expenses although most of them are open-minded toward environmentally friendly vehicles. The majority of experts interviewed in this study consider **(innovative) fleets as**

the real "Early Adopters" among all customers segments. Although this segment is very small compared to the other customer segments, it is very important in terms of market penetration. In the long term, the utility-cost index will shift from ICE and hybrid technology toward Battery Electric Vehicles. In the future, batteries will be cheaper dependent on mass market penetration. If electric vehicles no longer have a substantial cost disadvantage, private customers will also enter the market. In this context, **different measures of the public policy framework become relevant** in order to support a zero-emission driven technology.

The results of our forecast reflect that primarily full hybrid and plug-in hybrids will enter the EU market by 2020. This market forecast has to be, however, moderated with the fact that on the supply-side mostly BEV will be offered. This is why the high share of PHEV, based on pure market forecast modelling may be in the end not a realistic assumption. It can also be expected that the combination of the internal combustion engine with an electric powertrain will gain importance in the medium term. Both the results of our market model and the survey results underline this assumption.

Altogether, we expect that **about 7 percent of new vehicle registrations in the EU-27 in 2020 will be electric vehicles, representing about 1 million new vehicle sales. By 2030, the share of electric vehicle registrations will increase to approximately 30 percent, representing 4.6 million new vehicle sales.** The EU-27 registrations of Fuel Cell vehicles will be less than one percent. Although a few manufacturers have already developed production-ready vehicles, the majority of experts interviewed assume that the registrations of Fuel Cells will remain below one to two percent through 2030. Several reasons for this have been mentioned: lack of hydrogen infrastructure, cost, and a current paucity of energy-efficient hydrogen production, storage and transportation of hydrogen, as well as the cost and robustness of the Fuel Cell technical components. In 2040, fuel cell vehicles will become more relevant (see Figure 20).

Figure 20: Market Development of Electric Vehicles



(Source: Own Compilation)

The majority of OEM representatives interviewed confirm that due to a high degree of potential in terms of fuel consumption, lower costs in R&D and in the production process, Plug-In Hybrids will gain importance first followed by Battery Electric Vehicles.

At the 3rd Science Forum Mobility in July 2011, which is annually organized by the Chair of Business Administration & International Automotive Management for the Faculty of Engineering in Duisburg, many future developments in mobility were analysed and discussed in three plenary lectures and over 40 papers. Altogether, three major trends of future mobility were identified:

I. Reduction in car size with priority given to functionality in response to changing customer demands and more stringent environmental requirements,
II. Changes in the mobility behaviour in the context of broader concepts of mobility, and

III. Technical appreciation of premium vehicles through mobile communications and technological innovations[102].

According to the these trends and the majority of OEM representatives interviewed, BEV will have a market potential particularly in smaller vehicle segments - but precisely in these segments most of the customers are very price sensitive (see Figure I in Appendix III). **The small and compact vehicle segments currently have the largest market potential in the European new vehicle market**. Roland Berger 2011[103] and Automobilwoche 2012a[104] expect that the market potential of smaller vehicles will increase by 2025. Automobilwoche 2012b expects this trend also for the U.S. market.[105]

Due to both the vehicle properties (i.e. weight/size) and the market potential, we expect that **most of the battery electric vehicles will belong to small and compact vehicle segments or minivans** (e.g. for delivery in urban areas). Studies from the Joint Research Center (JRC) 2010 and A.T. Kearney share this opinion. While **the first generation of battery electric vehicles have already entered the market** (see Chapter 2.1.1), **future generations will benefit from the cost reduction of the powertrain components** (e.g. decreasing battery costs as batteries with lithium-ion technology will not only be used in BEVs). Increasing production units will lead to economies of scale. By 2030, most of the battery electric vehicles will use a “Purpose Design”. Due to the lower weight and compact size, small and compact vehicles with “Purpose Design” will, in particular, benefit from electric powertrains. The lower weight allows the use of a smaller battery and provides greater range.

Figure 21 analyses the suitability of the electric powertrain related to the vehicle segment. Plug-In Hybrids combine high customer benefits (e.g. in terms of range) with lower CO2 emissions especially for larger passenger cars.

102 To I: The car will generally become less important as a status symbol, not only among the younger generation. Together with more stringent environmental regulations, especially in the EU, a trend towards smaller vehicles with standard equipment will evolve. Many young people lack the funds for a new car. The very low proportion of under 30 year-old new car buyers in Germany decreased in the first half of 2011 by 3 percent. This is a clear sign that, for example, brands of smartphone suppliers (e.g. Apple) are more attractive to the majority of the younger population than the brand of a vehicle.

To II: Individual transport will decrease relative to alternative means of transport (e.g. aircraft, long-distance rail, mass transit, and bicycle) or alternative transport concepts (such as car sharing).

To III: Premium vehicles are constantly being upgraded technically, e.g. by integrating mobile communications, route planners, mobile internet and new innovations in automotive engineering (such as emergency braking and evasive systems for long distances in cars, especially the upper middle, upper and luxury class, but also for smaller premium models).

103 Roland Berger (2010)

104 Automobilwoche (2012a)

105 Automobilwoche (2011a)

Figure 21: Suitability of the Electric Powertrain Related to the Vehicle Segment

Segment/ Propulsion Type	Battery Electric Vehicle	Plug-In Hybrid	Market Share EU*
Small	- Suitable due to the vehicle size (e.g. leads to advantages in terms of range) - Most of early models will belong to this category - Optimal fit with „Purpose Design“ - Example: Nissan Leaf, Citroen C-Zero, Peugeot I-On ++	- Hardly no cost advantages (e.g. double powertrain) compared to small BEVs - Customers are very price sensitive (hardly no cost advantages compared to BEV, less effectivity as PHEV are mostly based on „Conversion Design“) O	33.2 %
Compact	- Suitable due to the vehicle size (e.g. leads to advantages in terms of range) - Optimal fit with „Purpose Design“ - Example: Renault Fluence Z.E. +	- Initially: dominant and suitable segment (higher range, promotion effect of existing hybrid cars) - Later: less advantages (e.g. double powertrain, less effectivity as PHEV are mostly based on „Conversion Design“) - Example: Toyota Prius Plug-In +	44.3 %
Large	- Large cars are mostly used for long distances, the range of the battery capacity is an obstacle - Only a very few vehicles are expected in the short and medium term (e.g. small volumes of luxury cars or roadster) O	- Dominant segment due to higher autonomy range, promotion effect of existing hybrid cars - Example: Mercedes Benz S-Class PHEV [Concept Vehicle] ++	22.5 %

- Current market shares of Passenger Cars in EU27, Norway and Switzerland, excluding Luxembourg, Source: IHS 2010 cited by ACEA 2011

Small: Mini (e.g. Ford Ka, Fiat 500 or Opel Cora, Renault Clio)
Compact: incl. Lower Medium (e.g. VW Golf, Mercedes Benz A-Class) and Upper Medium (e.g. Opel Insignia, BMW 3-series), but also small vans and LCVs (e.g. VW Caddy, Renault Kangoo)
Large: Including MPVs (e.g. Ford C-Max, Opel Zafira), SUVs (e.g. VW Touareg), Luxury (Mercedes Benz S-Class) and others

(Source: Own Compilation based on JRC 2010; CE Delft 2011 and A.T. Kearney 2012)

According to experts interviewed **we expect that most of the rechargeable hybrids and range extenders will belong to the compact or large vehicle segments** (e.g. premium sedans, vehicles of the luxury segment, SUVs, roadster, crossover vehicles), while **Battery Electric Vehicles will be mostly small and compact vehicles**[106]**,including passenger cars and light commercial vehicles** (e.g. small vans or LCVs like the Renault Kangoo Z.E., Volkswagen Caddy, Citroen Berlingo) which can be used for delivery and postal services[107].

Box 1: Light Commercial Vehicles using Electric Powertrains – Examples from Germany and France

The Volkswagen Group and German Post DHL cooperated in 2011, using a three-month test fleet of ten Volkswagen Caddy Blue-e-motions in Potsdam. Because 80 percent of the vehicles of the German Post DHL drive less than 50 kilometers a day and use almost the same route, small electric vans are particularly suitable for use as delivery vehicles. Altogether, the fleet of the German Post DHL has over 80,000 vehicles, which is a huge potential for the German market.[108]As the Paris Environment Ministry announced in November 2011, approximately 15,600 electric vans of the type Kangoo Z.E. have been ordered by Renault. About 10,000 vehicles will be used by the French postal service while the rest will be delivered to various public departments. A second contract was awarded to Peugeot Citroen group (PSA), covering 3,000 electric vehicles of type Peugeot Ion. A third tender for nearly 4,000 additional electric cars is still in progress.

[106] See also JRC (2010) and CE Delft (2011)
[107]Postal service delivery vehicles are mostly driven slowly on short and predictable routes. These cars have to cope with up to 200 stop and start processes per day. In this case, the vehicles would benefit from electric motors, because the engines do not have to warm up. Thus, the consumption is not driven unnecessarily high.
[108] Volkswagen (2012c)

2.4 Market for Microcars

Microcars belong to a class of vehicles which is positioned below the A-Segment. The segment of minicars can be divided into Quadricycles (<15KW) and the Sub-A segment (15-40 KW).[109]Presently, microcars are a niche in the European new vehicle registrations. In the transition to electromobility, microcars are expected to become more successful due to the following main market drivers:[110]

- Development of mega cities (e.g. scarce parking space)
- Exemption from city congestion charges
- Vehicle Properties (light weight/size) are very suitable for electric propulsion
- City driving (no drivers license required)
- Growing interest in urban vehicles with low emissions and low fuel consumption.

Nevertheless, microcars are faced with restraints:[111]

- Limited speed and performance
- Little differences in the purchase price compared with the A-segment due to low quantities in manufacturing (niche)
- Safety concerns

The following manufacturers are key players offering or producing **electric microcars** in the EU.

Aixam is a French microcar manufacturer based in Aix-les-Bains. Founded in 1983, Aixam is producing microcars in the factory of the bankrupt manufacturer Arola. Since March 2007, Aixam has been producing the battery electric vehicle MEGA e-City in Aix-les-Bains. Until late 2008, the vehicle was exclusively built for the London market as a right hand drive.

AutomobilesChatenet is a French manufacturer of microcars. The company was founded in 1984 and is based in Pierre-Buffiere, Haute-Vienne. Automobiles Chatenet distributes its vehicles in nearly all main European countries and has sales organisations (importers) in e.g. Austria, Belgium, the Netherlands, Portugal, Italy, Spain, Sweden and Finland. Chatenet plans to launch its type CH26 with battery electric propulsion soon.

In 2008, the two key players of the European market for microcars, Automobiles Ligier and Microcar consolidated to the **“Driveplanet Group”**,with 40 percent market share and 10,265 vehicles in 2010.[112]**Automobiles Ligier** is a French automobile manufacturer. The company has been operating in the automotive industry since 1969 and also in car racing. After initially mainly sports cars were produced, Ligier specialized in microcars with electric and combustion engines as well as quads. Ligier recently launched its microcar concept "Be Sun Proline" for use in urban and metropolitan areas. Presently, about 50 yellow electric microcars have been delivered to the French post.

Microcar is one of the largest European manufacturers in the field of microcars, with about 25 years of experience in developing and producing microcars. In 2000, an over 10,000 m^2 assembly plant was inaugurated in Boufféré near Nantes (France). Micro cars currently offers various types of the Series M.Go with 2 cylinder diesel engines but also a version with battery electric propulsion called "M.Go Electric". Recently the Driveplanet group has been supplemented by a third new brand called Dué. Currently, **Dué** is offering its model “Dué First” with only a two cylinder diesel engine and 505-cm3 capacity which has been developed by the manufacturer Lombardini. Altogether, Driveplanet was the market leader in the European market in 2011.

Grecav is an Italian automotive and agricultural machinery manufacturer from Gonzaga. The company produces different types of its model “Sonique” with 2 cylinder diesel engines. Presently, electric vehicles are not on offer by Grecav.The Tazzari Zero has a 15 KW electric motor with a maximum torque of 150 Nm. The vehicle uses a lithium-ion battery with a battery capacity of 12.3 kWh and thus offers a range of about 140 km, depending on driving style and environmental conditions.

[109]See “DIRECTIVE 2002/24/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 March 2002”, p. 4.
[110] Frost & Sullivan (2011c)
[111] Frost & Sullivan (2011c)
[112] Microcar (n.d.)

Mia was founded in 2010, mainly through the initiative of a pharmaceutical entrepreneur and the car designer Murat Günak, who had worked for the Volkswagen group and Mercedes Benz previously. The French region of Poitou-Charentes also belongs to the co-owners. About 1,000 electric cars were already produced in the first six months since production started in September 2011. The company has a modern assembly plant in Cerizay/France with a production capacity of 12,000 units per year. Currently Mia employs 300 workers including more than 80 specialized engineers and 16 designers.[113]

Newteon is a French company offering several types of electric vehicles (e.g. conversion of Fiat Dobló or Piaggio Porter with electric propulsion) was founded in 2006. The French headquarter is based in Rungis/France. The company also offers a microcar called Newteon Estrima equipped with a 4 KW engine. The vehicle has a range up to 50 km and is able to reach a top speed of 45 km/h.

Renault has been currently entering the market with its new "Twizy" which is built in Valladolid/Spain. In the first six months of 2012, about 6,000 units of the Twizy were sold in the EU. Renault has become the **market leader in the sub-A segment**.

Reva is an Indian manufacturer of electric cars (Mahindra Reva Electric Vehicles Pvt. Ltd.) from Bangalore/India. Reva has already presented its new electric vehicle XNR at the IAA in 2009 that will replace the current model Reva i/L-ion .The XNR will be available in two versions: The "City" version of the NXR will use a lead-acid battery which will suffice for a range of 80 km, reaching a top speed of 80 km/h. The "Inter-City Deluxe" model will be equiped with a lithium-ion battery. Due to its higher capacity, this version of Reva NXR has a range of up to 160km and is able to reach a top speed of 104 km/h. Production of the Reva XNR is expected to begin in 2012.

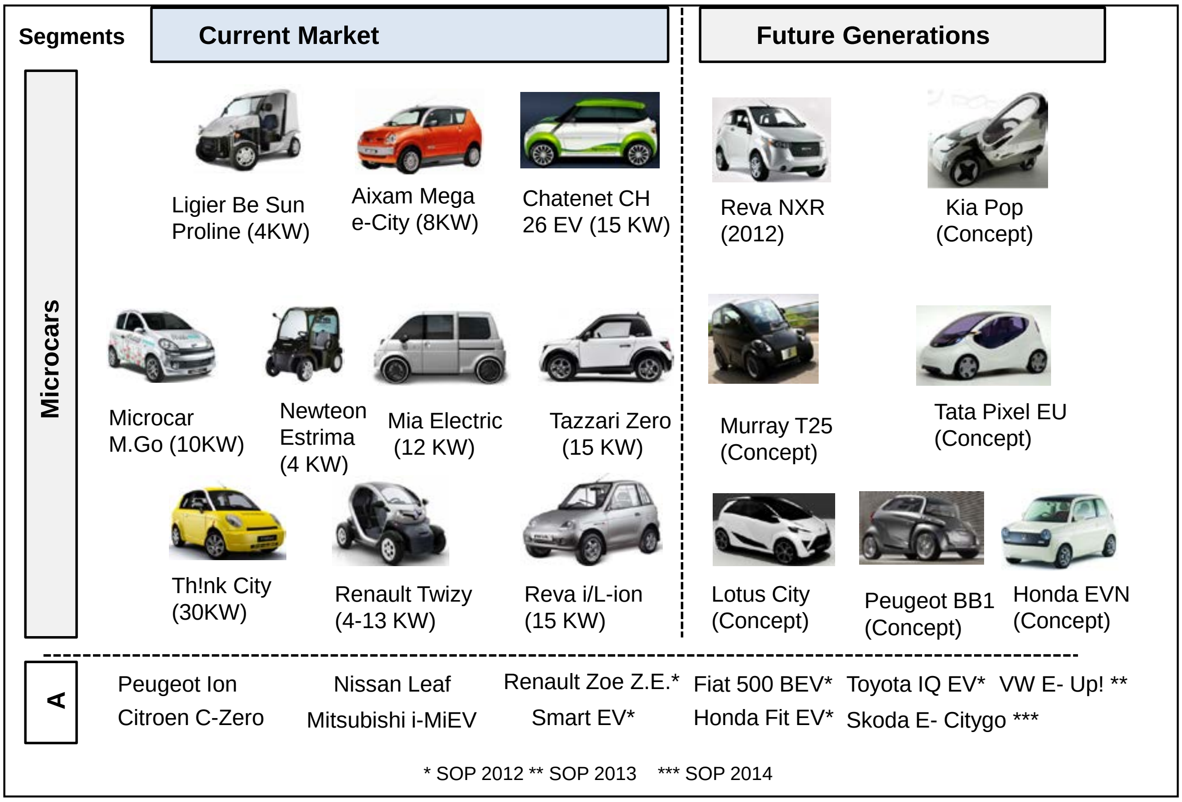
Tata Motorsis India's largest automobile manufacturer and is primarily owned by the Tata Group. The Tata Pixel is a new city car concept for Europe based on the Tata Nano. Data for market introduction and volume production have not yet been published. Tata Motors is planning, however, to price the vehicle below the limit of 5,000 Euro.

The **Think City** is an electric minicar offered by the Norwegian company Think Global. Due to economic reasons, Valmet Automotive stopped the production of the Think City EV in Finland in March 2011. At present it is unclear whether and when production of the vehicle will be resumed.

The following figure provides an overview on both the current market of battery electric microcars and future generations.

[113]CarIT (2012a)

Figure 22: Current Market and Future Generations of Microcars



Source: Own Research based on Frost&Sullivan 2011

Currently plans from manufacturers have not yet been published concerning a future supply of other propulsion types such as the REEV or FCV. In accordance with section 2.3.3, **we do not expect that microcars will be offered as Range Extenders or Fuel Cells**, since their main use as city cars can be easily operated by a fully electric vehicle.

A study by Frost & Sullivan (2011) expects a market potential for microcars in the European megacities like London, Paris, Berlin, Rome, and Madrid. The majority of experts, who have been surveyed in this study, expect market potential in Southern Europe; not only in megacities but also in rural areas. A Spanish expert emphasized that microcars will be very successful in France:

“In France these vehicles are already very popular. A lot of drivers use these cars to move into rural areas (France has a lot of these kind of areas).”

In Paris, the French company Autolib started to offer microcars in December 2011 with a new car sharing program. Parisians who are members can use small electric cars on short trips a small charge.[114] The Bolloré Group, which is a family-owned industrial holding company behind Autolib, plans to have 3,000 battery electric cars, called "Blue Cars," circulating on the streets of Paris and its inner-ring in the short term.[115] In the first six months of 2012, 1,383 units of the battery electric vehicle Blue Car were registered by the Bolloré group.

According to a European expert interviewed, Southern Europe and France already have the “right culture for this kind of vehicle”. The consumer preferences vary a lot between the EU Member States. In Southern Europe, even today’s smaller vehicle segments dominate the new vehicle registrations. Many more motorcycles and scooters are registered per inhabitant in countries like France, Spain and Italy than compared to Germany or the United Kingdom.

[114] Autolib (2012)
[115] IEA (2011a)

In contrast to the European experts, an expert from the United States considers the market potential for microcars as sceptical:

“Microcars still have a cost problem. The high fixed costs of electromobility are linked to a low-price segment. I cannot even imagine that this will work in general. It might work out in countries like Italy or Japan where microcars already play a significant role.”

Accordingly, two Italian experts particularly expect large market potential in small, affordable vehicles with a small and light battery (city car) with the option of wireless charging. By eliminating the cost of energy storage, the vehicle in turn would cost less. The Italian experts maintain that most of the city cars need a limited range (i.e. less than 80 km).

Altogether, the majority of experts interviewed expect a market potential for microcars in large and mega cities particularly in Southern Europe, Japan, and India but are quite sceptical concerning a market potential in Northern and Eastern Europe and the U.S. A French expert emphasized, that German and U.S. customers are intensely concerned about safety (e.g. in terms of accidents). In contrast, Chinese customers have less safety concerns about smaller cars. In China particularly, two market segments will gain importance: low-cost and premium vehicles (e.g. SUVs, sedans). Consumer interest in battery electric vehicles will rise in the lower segments (especially small-town cars, microcars and scooters which are used in mega cities). The sales of electric bikes and electric scooters in China are already illustrating this trend. For Chinese mega cities, microcars might be a real alternative because they offer individual mobility.

Expert opinions vary regarding the question whether consumer behaviour will change in the transition to electromobility (smaller cars, less prestige) or whether most of the consumers rather remain loyal to their current habits. For example, a European public policy-maker interviewed states:

“I don´t expect a significant change in the consumer behaviour of normal citizens - but this would be possible in fleets (e.g. mail services, pharmacy products) - in order to reduce energy cost.”

A Spanish expert emphasised:

“Electric vehicles will lead to a change of the customer behaviour like in terms of charging. I expect a little change of behaviour in terms of vehicle usage but not a change in the likes or tastes concerning power, sizes and general characteristics of the vehicles.”

In the next few years, more global volume manufacturers like Renault will offer cars in this segment. Frost & Sullivan expect that the annual sales of minicars will rise from 37,000 vehicles in 2011 to potential sales of 280,000 vehicles in Europe by 2017. They assume that nearly 85 percent of the sub-A vehicles will be electric. We consider this assumption as too optimistic. According to the results of our market model (see Chapter 2.3.3) about 170,000[116] new Battery Electric Vehicles will be registered in Europe in 2020. Based on discussions with several experts, we expect that about **10-15 percent of the battery electric vehicles will belong to the sub-A segment in 2020** (~ 20,000 vehicles). Presently, **most of the minicars are more expensive compared to vehicles of the A-Segment** (e.g. Volkswagen Up!, Toyota Aygo, Ford Ka)[117], because most of them are manufactured in a low volume production by niche or small manufacturers i.e. leading to less economies of scale. In transition to electromobility, the expensive components of the electric powertrain (e.g. battery cost, see Chapter 2.3.1.2.2) will initially lead to higher purchase prices. With the development of new vehicle generations, which are mostly tailored to the benefits of electrical mobility (“Purpose Design”), the costs are expected to fall. As Figure 22 shows, **even traditional vehicle manufacturers such as Kia, Honda and PSA will enter the market in the sub-A segment**. These manufacturers will benefit from economies of scale (e.g. sharing modules, components with vehicles from A-segment), which lead to less production costs in the segment of small cars. According to Frost & Sullivan, almost all quadricycles will be battery electric vehicles in the long term. That seems to be optimistic as well but should not be underestimated, as the vehicles are technically reduced to the essential and therefore very similar to electric bicycles and scooters which also provide ideal conditions for an electric powertrain.

Altogether, due to the low utility-cost index, battery electric vehicles have compared to vehicles with internal combustion engines in the medium term (see Chapter 2.3.1.2.3). We do not expect rapid mar-

[116]Including all segments, see Chapter 2.3.3
[117] See Frost&Sullivan (2011c), p.9.

ket penetration in the low-cost segments in Europe until 2020. **By 2030, decreasing production costs (e.g. new vehicle concepts) related to an increased utility (e.g. free parking, use of bus lanes, access to zero-emission zones and inner cities), will contribute to the market success of microcars**. Therefore, we expect that microcars will become an attractive alternative in terms of individual mobility particularly in mega cities.

2.5 Second Hand Electric Vehicle Market

Due to rising fuel prices car drivers are affected given the running costs of their vehicle. No wonder why car buyers have recently focused on more economic models. This is commendable also for environmental purposes, but clearly most of the purchase decisions are rather made from an economical than an ecological point of view. **The most important cost factor in the ownership of automobiles is still the loss of the residual value over lifetime**.

Currently **there is very limited knowledge concerning the future development of the residual values of electric vehicles**. The residual values of the various propulsion types depend on government support and regulations (e.g. purchase premiums, entry city zones), but are also influenced by the operating costs (fuel prices at gas stations, vehicle taxes, service charges). Whether or not a customer will include ecological aspects into their purchase decision of a vehicle will continue to remain speculative. In the past, the transition to new emission standards (e.g. from EU4 to EU5) showed that customers were legally pressured to become more aware of ecological aspects when selecting future vehicles. The majority of the customers are assumed to act from economic motives, such as tax breaks. Shortly after the introduction of the diesel particulate filter, used cars which were equipped with such a filter were in higher demand than vehicles without such filters. Regulations (e.g. entry restrictions of city centres) have contributed to this phenomenon.

Furthermore, when focussing on electric vehicles, **the propulsion battery, the complete electric drivetrain and especially the lifetime of these components have a strong impact on the residual value of such vehicles**. The residual value of an electric vehicle depends essentially on the durability of the battery, as it is one of the most expensive components of the vehicle. If the already small range will be reduced further, the utility of the electric vehicle will decrease. Concerning lifetime, the propulsion battery is the most critical component. Battery experts from Johnson Controls state a battery lifetime of approximately 3,500 cycles when using the battery in a full electric vehicle (90 percent DoD "Depth of Discharge")[118], while the experts at Smuel De-Leon Energy LTD state a lifetime of 2,500 cycles[119]. Additionally the results considering the lifetime tests of Lithium-Ion batteries presented by Saft at the ESA Annual Meeting in 2001 show that the capacity of the battery does not decrease after 2,000 cycles.[120]**Currently companies purchasing electric vehicles and PHEV issue a guarantee on the electric propulsion system respective to the battery**. A study by CE Delft 2011[121] assumes an increasing lifetime of lithium-ion batteries, starting at 10 years in 2010 up to 14 years in 2030. We consider this assumption as too optimistic. Instead, estimations should focus on specific factors, such as vehicle mileage and environmental conditions. Nissan, for example, stated that the Leaf battery will need some maintenance after five years of use, but will not require a replacement of the complete battery. The Leaf batteries will still have about 80 percent of its original capacity after 60,000 miles of use. If the battery capacity fell below that level, customers would be able to swap out individual modules of the battery without needing to replace entire battery packs.[122] This would have a positive impact on the price development of used electric vehicles.

A crucial starting point for the life extension is to ensure that the battery is fully charged only when it is needed. For example, almost all users of laptop batteries shorten the lifetime of them given the irrefutable fact that their computers are constantly connected to the power grid. In terms of electric vehicles especially the battery management systems ensure the optimum durability by active cell blancing. The vehicles internal battery charger may additionally include functions like the start of the automatic recharging, so that the battery is fully charged when the vehicle is needed (e.g. in the early morning). During the week, when the same regular routes are chosen every day e.g. to go to work, the battery

[118]Johnson Controls (Ed.) (2011)
[119] Shmuel de-Leon (2010)
[120]An average driving range of 100km would lead to a total driving range of 200,000 km for an electric vehicle, see also Saft (2001)
[121] CE Delft (2011)
[122] Autoblog (2012c)

may be charged less than during the weekend, when the customer needs maximum flexibility. Another important role is the cooling of the battery. Without active cooling, a study by the U.S. Department of Energy emphasized that the battery's capacity falls to 85 percent[123] in Phoenix, U.S. within three years, rather than six years under the same conditions with liquid cooling.

Currently there is limited empirical data reflecting a decrease of the battery performance during intensive use of vehicles after several years. The battery life will contribute significantly to the development of the residual value. Different business models such as battery leasing or battery replacement (e.g. business model of Better Place) will transfer the risk from the consumer to the service provider. In the case of the purchase, the confidence in the manufacturer is essential. Manufacturers offer guarantees in order to influence the risk perceptions of the customers.

Box 2: Battery Warranties of Current EVs

- Opel grants a warranty of 8 years for a maximum driving range of 160,000km for the Opel Ampera.
- Renault grants a warranty of 5 years for a maximum driving range of 100,000km for their ZE vehicles.
- Mitsubishi grants a warranty of 5 years for a maximum driving range of 100,000km for the Mitsubishi i-MiEV.

(Source: Press Releases of OEM)

In our market model hybrid electric vehicles will achieve higher residual values in 2030, compared to vehicles exclusively using an internal combustion engine (ICE). The combination of the effective internal combustion engine, the diesel engine and the electric motor will lead to less fuel consumption. Therefore, Schwacke expects that the residual value of the full-hybrid petrol and full-hybrid diesel models will increase in the next few years.[124] Until 2020, it can be expected that electric vehicles (particularly battery electric vehicles or range extenders) will not be able to play on the same level like vehicles with other types of propulsion, in terms of their residual value. The high depreciation of the residual value of electric vehicles is mainly based on the high additional costs, (especially if there is no, purchase premiums offered), but is also because of their shorter driving range compared to vehicles with ICE-technology.Our market model shows that the utility-cost index of electric vehicles will increase in the long term.

In terms of three year old vehicles, the study from Schwacke assumes significant lower residual values (9,300 Euro, 31 percent)[125] compared to gasoline models (8,600 Euro, 43 percent) in their 2015 forecast. The starting points for this calculation are comprised of the average prices for new electric vehicles (30,000 Euro) and gasoline vehicles (20,000 Euro) in the C segment. Nominally, the value loss of an electric vehicle is expected to be approximately 20,000 Euro, compared to a value loss of about 11,000 Euro of the comparable gasoline model.[126]

The residual value is a critical variable influencing the utility-cost index. Therefore, it has been included in our market model. **In our market model, we believe the value loss of BEV will amount to nearly 70 percent after five years (approximately 60,000 km mileage)[127], while the value loss of vehicles with internal combustion engines will only amount to about 55 percent**. Furthermore, we assume that the value loss of the full hybrid and plug-in hybrids will be higher compared to vehicles with internal combustion technology, particularly due to their higher prices. Nevertheless, due to an improving utility-cost relation, this will change over time.

The majority of experts, who have been surveyed in this study, expect that the **early adopters of electromobility will be commercial customers**, especially Innovative Fleets. Due to different usage patterns, **commercial customers usually have a higher annual mileage** than most of the private customers. The majority of Off-Lease vehicles have an average mileage of 100,000 km after three years. We expect that even the commercial customers of electric vehicles will use their vehicles longer than three years (assuming about four to six years), regardless of the financing model. Otherwise,

[123]Further information on the battery test are provided by Going Electric (see Going Electric 2012)
[124] Schwacke (2010)
[125]Including the battery
[126] Schwacke (2010)
[127] Private customers

procurement of electric vehicles would be even less profitable. The higher cost of electric vehicles will be compensated by lower operating costs. Therefore, the highest possible operating life will be achieved. At the end of the operating life, electric vehicles are likely to have a high mileage.

Basically, the higher purchase price (high additional technical costs) and the uncertainty in terms of durability of battery performance are key drivers influencing the price of used cars. The most significant obstacle for used-car sales is customers' lack of trust in used-car dealers and in the condition of individual cars. This can be remedied by offering transparency and the support of strong brands.[128] Furthermore, the residual value of a used car depends on the type of vehicle. Small and compact cars normally have a higher percentage in terms of the residual value than cars of other vehicle classes. Presently, even small sized electric vehicles have very high purchase prices compared to vehicles with internal combustion engines of the same segment.

Apart from the higher total cost of ownership, consumer concerns about safety and durability counteract the market penetration of electric vehicles. We expect that **guarantees might help the dealer and OEMs´ sales organisation to reduce the high risk (e.g. in terms of battery defects) perceived by the customers when purchasing a used-car**. Without a comprehensive multi-year guarantee, new alternative fuel technologies will continue to be regarded sceptically, leading to low residual values. All-inclusive packages might support the sales of new and used electric vehicles.

Altogether, we do not expect a frictionless working market for used electric vehicles until 2020, especially considering that fleet owners completely depreciate their EVs. Due to innovations and rapid changes in technology, residual values will remain low. The utility-cost index of electric vehicles will rise slightly compared to vehicles with internal combustion engines (see Chapter 2.3.1.2.3). Nevertheless, the technical optimisation of battery technology, increased customer experience, market presence and further regulation will lead to an increasing market potential of used electric vehicles in the long run. We assume that a market for used electric cars will have been established by 2025. Currently, the market potential of used electric vehicles has to be regarded from a different point of view: **We expect a market potential of used electric vehicles, particularly in the field of recycling of certain components (e.g. for the extraction of rare earth materials or lithium).**

2.6 Trade Patterns in electric vehicles EU-Asia

The following chapter describes **existing trade patterns** between the EU and Asia relevant for electric vehicles. Furthermore, **existing non-tariff barriers** of Asian countries for European exporters and Asian imports to the European Union will be analysed, which also apply for the trade of electric vehicles. Finally, future volumes of Asian exports to the EU (conventional and electric vehicles) are estimated. These trade patterns will be analysed country by country, starting with Japan.

2.6.1 Japan

2.6.1.1 Description of Current Trade Patterns between Japan and the EU in the field of Electric Vehicles

In 2010, Japan's eight passenger car manufacturers domestically produced about 8.3 million automobiles of which approximately half (about 4.2 million) were exported. Almost 70 percent of all these Japanese exports were delivered to Europe and the Americas, whereby the share delivered to Europe accounts for about 20 percent or about 942,000 units in absolute terms (2010). Vehicles exported from Europe to Japan amounted to just 145,000 in 2010 but European exports account for more than 60 percent of all imports to Japan.[129] **In terms of (imported) electric vehicles Japanese manufacturers have been gaining importance in the EU because the current market of (imported) electric vehicles is essentially characterized by three Japanese carmakers: Nissan, Mitsubishi and Toyota.**

[128] Carfax (2009)

[129] Appendix XI provides an overview on current trade patterns between Japan and the EU in the automotive industry.

Since its market launch in late 2010, **Nissan** has sold more than 32,000 units of the battery electric vehicle **Nissan Leaf** globally.[130] In 2011, about 3,000 Nissan Leafs were sold in the EU. The manufacturer expects to triple its sales reaching about 9,000 units in Western Europe in 2012. Presently, all vehicles are produced in Oppama (Japan). Nissan plans to start the European production of the Leaf in Sunderland (UK) in February 2013, with an annual capacity of about 50,000 units.

Mitsubishi is the second largest exporter of electric vehicles from Japan to Europe. Since the start of the production of the **i-MiEV** in 2009 and **the Citroen C-Zero and Peugeot iOn** in 2010, Mitsubishi has built 28,000 units of the three models.[131] According to media reports, Mitsubishi stopped the delivery of Peugeot Ion und Citroen C-Zero, which are built on the same assembly line as the Mitshubishi i-MiEV at the Mizushima plant in Japan. In the first six months of 2012, about 900 Peugeot Ion and 1,200 Citroen C-Zero units were sold by the PSA group in Europe.[132] In the same period, about 3,600 units have been produced by Mitsubishi (1,800 each).[133] Spokespersons from PSA and Mitsubishi recently confirmed that the production of iOn and C-Zero has been stopped temporarily, but failed to say when production would resume.

Toyota will launch its **Prius Plug-In Hybrid** in the European markets by the end of 2012 (e.g. in Germany on the 6th of October).[134] The manufacturer anticipates global sales of approximately 50,000 units annually. Currently, Toyota is only producing the Prius Plug-In in its plant in Tsutsumi (Japan). Toyota announced plans to produce the Toyota Prius in the US and China from 2015 onwards.[135] Plans concerning production of the Toyota Prius in Europe have not been published so far. Therefore, the sales volumes of the Toyota Prius are expected to be imported from Japan in the medium term.

Until 2011 major shares of available electric vehicles were produced in Japan. With the start of production of electric vehicles by Renault, the proportion of vehicles which are produced in Europe has been increasing. In 2012, about 6,000 units of the Renault Twizy have been produced in Valladolid (Spain). Furthermore, about 2,600 Kangoo Z.E. have been produced in Maubeuge (France) and about 1,200 Renault Fluence Z.E. have been produced in Bursa (Turkey) up until the end of June. The production of the Renault Zoé in Flins (France) will start soon. Nissanwill be the first Japanese manufacturer who will shift the production of battery electric vehicles from Asia to Europe.

On the other hand, no **electric vehicles have been exported from the EU to Japan so far**. However, with German premium manufacturers like BMW, Audi or Daimler offering electric vehicles in the future (see Table 3 in Chapter 2.1.2), this ratio could be compensated in the medium term, since these brands are sold in Japan as well. Consequently, Japanese market barriers to EU exports are analysed in the next section.

2.6.1.2 Japanese Market Barriers to EU Exports

Whereas Japan imposes no import tariffs on imported cars from Europe, Europe's import tariff is 10 percent. Nonetheless, European exports to Japan remain low. Japan's has a unique regulatory environment in which cost of compliance are high.

The following NTBs can be identified:[136]

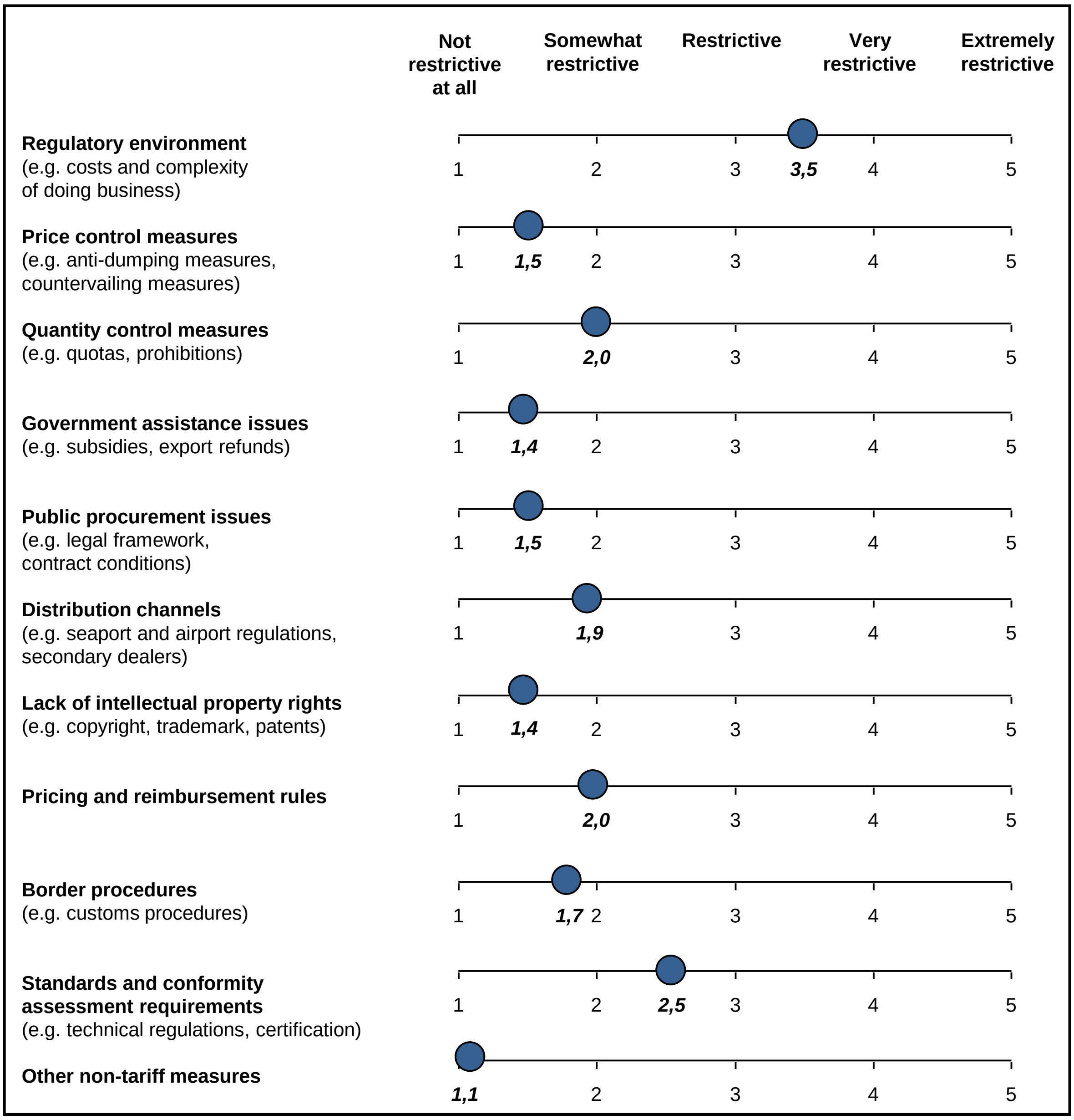
- Acceptance by Japan of cars manufactured and type-approved in the EU without further testing and/or modification
- Introduction by Japan of a new worldwide test cycle (WLTP) in the same time frame as the EU
- Reform of the automobile taxation and regulatory requirements to put 'kei' cars[137] and other motor vehicles on an equal footing

[130]Nissan Europe (2012a)
[131]Autonews (2012k)
[132] PSA (2012)
[133] See Table 2 in Chapter 2.1.1 and PSA (2012)
[134]Gruene Autos (2012)
[135]Hybridcars (2012c)
[136] ACEA (2011b)
[137] Vehicles defined as kei cars do have maximum dimensions of (length/ width/ height in meters): 3,4/ 1,48/ 2; engine displacement: ≤ 660cc.

- Revision of the zoning regime for maintenance workshops
- Harmonisation of requirements for pyrotechnic devices between Japan and the EU
- Flexible application of the High-Pressure Gas Law

Sunesen et al. (2009) conducted a comprehensive study on trade barriers between the EU and Japan, including the automotive sector. The authors analysed non-tariff measures, such as "divergent standards, technical regulations, and conformity assessment procedures."[138] Data was gathered based on a questionnaire completed by managers of the branches of EU firms located in Japan. Selective aspects based on these interviews and relevant to non-tariff barriers are shown in Figure 23. The regulatory environment[139] in general in Japan and in more detailed standards and conformity assessment requirements are perceived as somewhat restrictive (see Figure 23).

Figure 23: Perception on the Importance of Non-Tariff Measures



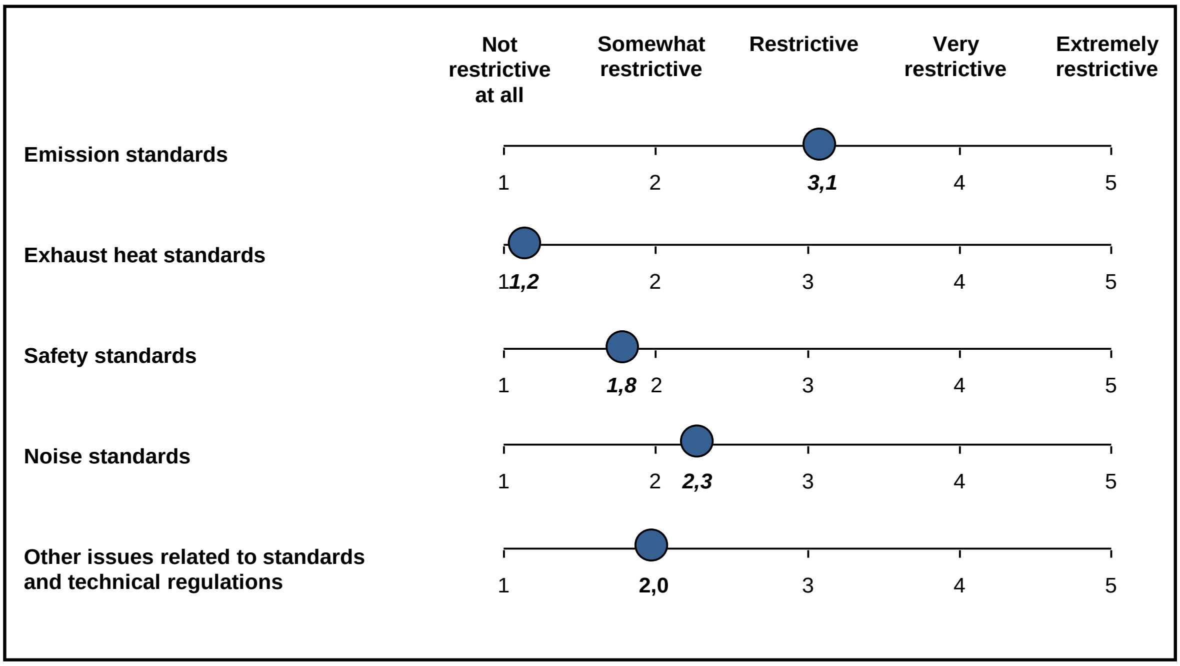
(Source: Sunesen et al. (2009), p. 226)

[138] Sunesen et al. (2009), p. 15. In more detail, the authors define non-tariff measures as "all non-price and non-quantity restrictions on trade in goods and services. This includes border measures (customs procedures etc.) as well as behind-the border measures flowing from domestic laws, regulations, and practices."

[139] Defined by Sunesen et al. (2009, p. 16) as "standards, technical regulations, and conformity assessment procedures"

The highest barrier in relation to standards and conformity assessment requirements is seen in Japan's policy for type approvals that accrue for imported vehicles from the EU before being allowed to be sold on the Japanese market. Two systems exist in parallel: The United Nation Economic Commission for Europe (UN-ECE) international regulations[140] and Japan-specific regulations. In cases where Japanese regulations differ from UN-ECE or EU directives[141], compliance becomes costly of for European makers. This is especially the case for emission, noise, and safety standards (see Figure 24).

Figure 24: Perception on the Barriers Related to Standards and Technical Requirements[142]



(Source: Sunesen et al. (2009), p. 228.)

Only government approved facilities can be used to test emissions. European vehicle makers face additional costs due to differences in the different testing procedures that are unique to Japan, while at the same time norms do not differ compared with UN-ECE norms. Other issues include unique test cycles to measure fuel efficiency and emissions for light duty vehicles. Japan's regulations on noise levels are again unique and not harmonised to UN-ECE standards. Moreover, new safety standards are introduced that are not included in the UN-ECE, namely "pedestrian leg protection for larger vehicles" and "collision mitigation brakes for heavy-duty vehicles". Additionally, safety features using explosives (e.g. pyrotechnic safety devices such as airbags) are not allowed to be generically approved. Each device must be approved separately irrespective of whether a similar device has been approved before.

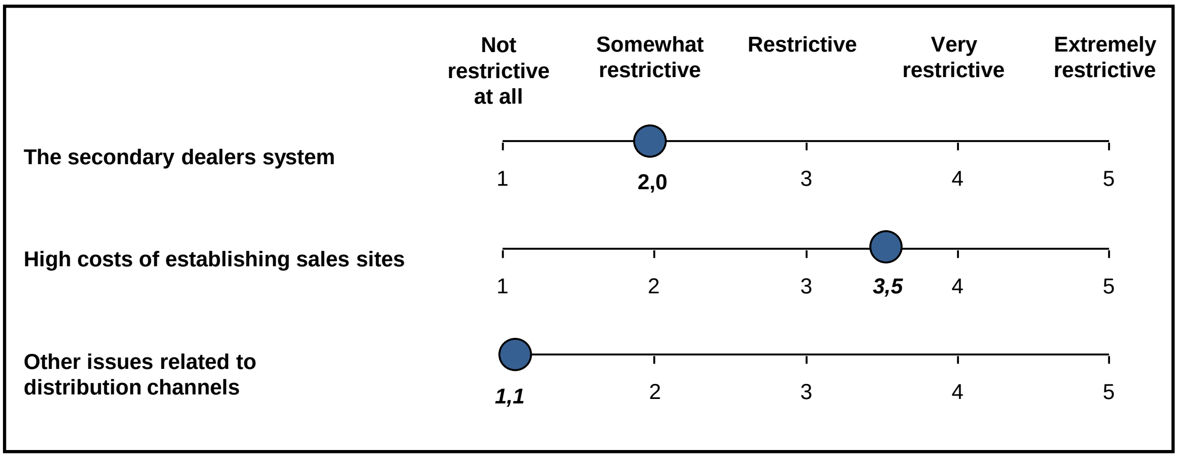
Establishing a distribution network in Japan is connected with high costs. Managers of European automobile manufacturers perceive this situation as quite restrictive (see Figure 25).

[140] The UN Commission strives to harmonise technical standards and certification procedures. The EU and Japan are members of the UN-ECE.

[141] The EU directive allows national type approvals, e.g. if one vehicle is type approved in one EU member state it Is allowed to be sold in any other member state.

[142] Note: The figure shows the average score for each response category.

Figure 25: Perception on the Access to the Japanese Distribution Network



(Source: Sunesen et al. (2009), p. 227.)

The zoning system in Japan is an important element in urban planning, and represents a hurdle to gaining commercial space access. In regions such as the metropolitan area of Tokyo, it is nearly impossible to receive permission to open showrooms or service facilities, whereas Japanese auto makers already have access to these facilities. Based on analysis conducted by Sunesen et al. (2009), the European Automobile Manufacturers Association (2011a) and Millington (2010), the most burdensome non-tariff barriers are:[143]

- Standards and technical requirements unique to Japan, especially regulations relating to emissions, safety (including pyrotechnic devices), and noise
- Amount of taxes relating to vehicles ownership
- Privileges for kei-cars
- Zoning regime for service shops and showrooms

Several of these issues have been addressed to Japan. Progress is apparent, albeit slow; e.g. Japan agreed to adopt the UN-ECE's International Whole Vehicle Type Approval (IWVTA) by 2015. Also, the dialogue on more transparent and harmonised technical guidelines for new automotive safety technologies is ongoing. Contrarily, discussions on kei car privileges and tax reforms seem to be having difficulties or just show limited progress so far (see Appendix XII).

Clearly, standards and technical requirements unique to Japan represent the highest cost burden to European auto makers. Based on the survey results, Sunesen et al. (2009) assume that the non-tariff barriers amount to a total cost increase of 10 percent for European automobile manufacturers exporting to Japan. By reducing barriers related to standards and technical regulations, about nine percent of the cost can be saved. This could support sales of European vehicles, also electric ones in Japan in the future.

2.6.1.3 Future Volume of Japanese Exports to EU – Conventional and Electric Vehicles

In order to estimate the future export volumes of conventional and electric vehicles from Japan to the European Union we use a rather realistic scenario taking the Japanese transplant production strategy into account. Based on assumptions, future volumes of Japanese exports of electric vehicles are estimated.

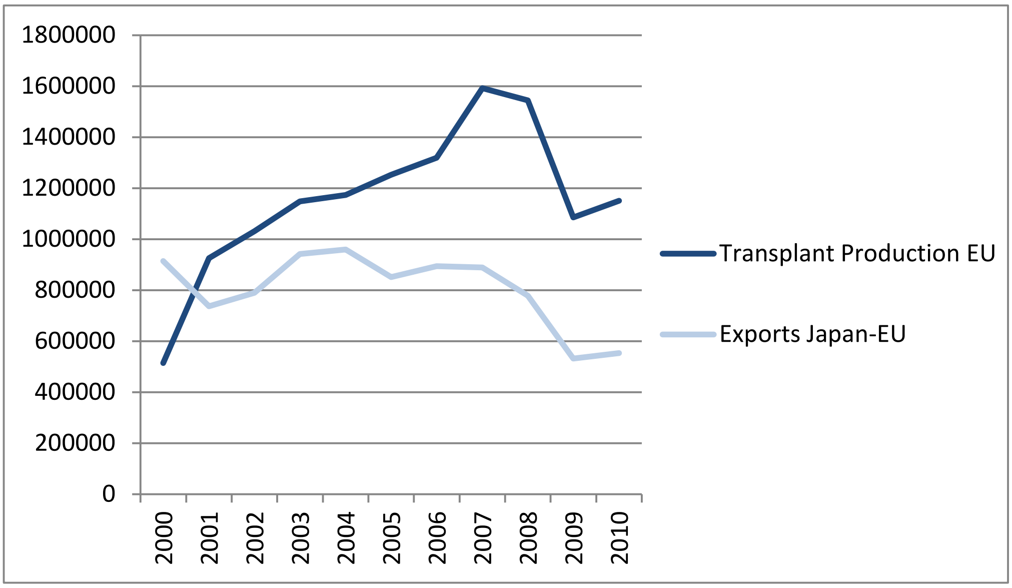
A rather realistic scenario for the future exports of cars from Japan to the European Union would presume stagnation in volumes with a declining tendency. Table 12 shows the export volumes of Japanese passenger cars produced in Japan and exported to the European Union. Between 2000 and 2007 the average volume stagnated at around 900,000 units. The financial crisis from 2008 onwards lead to a sharp decline but volumes gained ground again in 2009. A continuous stagnation of export volume speaks initially of the sharp increase in transplant production volumes of Japanese

[143] Sunesen et al. (2009); ACEA (2011b); Millington (2010)

cars. Or expressed in other words: **Japanese cars are increasingly manufactured in the region where they are sold.**

Within six years, between 2000 and 2007, production volumes of Japanese cars in the European Union increased vastly by almost 1,000,000 units. Japanese makers have expanded production capacities in the European Union. Thus there is less necessity for a more expensive export of vehicles from Japan.

Table 12: Number of Passenger Cars Produced by Japanese OEMs in the EU and Exported from Japan to the EU, 2001-2010



Transplant Production [-]

High: 1,353,402 vehicles
Low: 403,281 vehicles

Japanese Exports to the EU[-]

High: 959,636 vehicles
Low: 553.109 vehicles

Note: Transplant production EU: Based on Toyota, Nissan, Honda, Mitsubishi, Suzuki

T-EU: Passenger cars produced by Japanese automobile manufacturers in the European Union
EX JP-EU: Passenger cars exportedby Japanese automobile manufacturers to the European Union

(Source: OICA 2012)

While the absolute figures of Table 12 appear impressing, it can be stated that Japanese brands play a minor role in European markets. While Japan's premium automobile maker Toyota is successful in China and the United States it has in 2012 a market share in Europe of just 4,5 percent, even after a market presence of several decades.[144] Nissan, another example, announced in 2012 its highest market share ever in Europe: just 4.1 percent.[145]

Electric vehicles produced by Japanese auto makers may be partly exported from Japan in the initial phase of market ramp up in Europe but as price pressure is especially high in this segment (due to high battery costs), Japanese makers may consider shifting production to the European Union soon, as well as source key components in the region.[146]**In the long run it is likely that the majority of Japanese electric vehicles will be produced in the European Union.**

Forecasting how many electric vehicles Japanese OEMs will sell long term in Europe is not easy. However, based on the facts mentioned above it is rather clear that **volumes will not be vast**. As no new customer group will be reached, electric vehicles will not contribute to additional sales volumes. Rather more, as more electric vehicles are sold, more conventional vehicles will phase out.

[144] Reuters (2012a)
[145] Inautonews (2012)
[146] Reuters (2012a)

Historical statistical figures of the European Automobile Manufacturers Association (ACEA) on market shares of new vehicle registrations between 2000 and 2010 show that Japanese OEMs reached a market share of 13 percent in total; corresponding to 1,838,824 newly registered vehicles (see Table 13)[147].

Table 13: Annual Market Shares and New Registration Volumes of all Japanese Passenger Car Manufacturers (EU 15 plus EFTA 3)

	Market Share	Volumes
2000	11%	1,676,311
2001	10%	1,545,465
2002	11%	1,650,985
2003	13%	1,806,369
2004	13%	1,911,486
2005	14%	1,964,070
2006	14%	2,098,168
2007	14%	2,115,310
2008	14%	1,882,564
2009	14%	1,958,155
2010	12%	1,618,181
Average	**13%**	**1,838,824**

(Source: ACEA 2012b)

Given a saturated automotive market in Western Europe these figures may be taken as a reference point for forecasting future exports of electric vehicles from Japan. If Japanese OEMs are able to defend a market share of 13-15% it would correspond to **1,800,000 to 2,200,000** new vehicle registrations annually. Given an export: transplant volume relation of 1:2 (compare Table 13), and assuming that every fifth vehicle (20%) will be electrically powered, **EV exports from Japan** may amount to just **120,000-146,666** units (see Table 14).

Table 14: Forecast on Future EV Export from Japan to the EU

Condition	**Volumes (p.a.)**
20% vehicle electrification in the EU	360,000 - 440,000
Export : transplant ratio = 1:2	
EU transplant production	240,000-293,333
Exports from Japan	**120,000-146,666**

(Basic assumption: Japanese OEMs can keep a market share of 13-15%, i.e. 1.8-2.2 mil. vehicles)

(Source: Own Calculation)

2.6.2 Korea

2.6.2.1 Description of Current Trade Patterns between Korea and the EU in the Field of Electric Vehicles

In 2011 the five Korean automobile manufacturers produced about 4.3 million cars, of which about 70 percent were exported. Korean car makers currently export nearly 3 million passenger cars to overseas markets. In 2010, the largest export market was the U.S. (about 1.1 million units), the Middle

[147] Those figures relate to Western Europe, i.e. EU 15 plus EFTA 3.

East (about 590,000 units) and Europe (EU about 312,000 units, rest of Europe 211,000 units).[148] In 2010, Europe exported 59,000 passenger cars to Korea. However, currently no electric vehicles are exported from Korea to the EU et vice versa. Korean manufacturers will enter the electric vehicles market later (see Chapter 2.1.2).The Korean manufacturer Kia introduced its first Battery Electric Vehicle called Ray in 2012. Kia plans to produce 2,500 units of Kia Ray EV in 2012. All vehicles will, however, belong to the government fleet. Presently, Kia is not yet clear when the vehicle will be sold to retail customers. Plans to export electric vehicles e.g. to European customers have not been published either. According to experts interviewed for this study, the market for electric vehicles in Korea is mainly influenced by government activities. Furthermore, a public interest in vehicles with alternative powertrain is currently rather low. Hyundai is expected to launch an electric car based on the i30 not before 2014/2015. Hyundai has already started developing hybrids and hydrogen fuel-cell vehicles.

2.6.2.2 Korean Market Barriers to EU Exports

Given the low amount of imported passenger cars NTBs are obviously hindering a higher penetration rate. Six main areas of NTBs can be identified:

1. Safety and environmental standards
2. The vehicle taxation system
3. Social or market based issues
4. Currency manipulation
5. Regulation on noise certification and
6. Breadth of vehicles

These fields are summarised in Table 15:[149]

Table 15: Korea – NTBs to European Vehicle Imports

Area	Detail
Safety and environmental standards	• **On-Board Diagnostic (OBO) System** The US OBO systems standard of the US (OBO II) prevails. EU OBO standards are not accepted. Due to relatively low import volumes European car makers face a cost-related disadvantage to comply with US OBO II regulations. In order to comply with EU OBO regulations, Korean car makers are able to depreciate costs for technical changes over the high volume of cars exported to the European Union.
	• **Average Fuel Efficiency (AFE)** The Korean AFE regulation purports that “producers which perform better than the 8.1 litres/ 100km limit for vehicles below 1,500 ccm obtain a credit to compensate for any exceeding of the corresponding limit for vehicles with engine displacements above 1,500 ccm.”[150] Imported vehicles from Europe often exceed 1,500 ccm. Thus there is no compensation potential for European makers.
	• **Korea Ultra-Low Emission Vehicle (KULEV) Regulations** The KULEV regulation is similar to EURO4. It comprises compulsory CO_2 emission reductions. The KULEV is, however, regarded stricter than the EURO4 regulations by European auto makers, resulting in higher costs for modifications in order to comply with KULEV.
	• **Special Act on Capital Region Air Quality Improvement** This regulation relates to the area of Seoul, Incheon and Gyeonggi. Importers are urged to sell vehicles with low emissions, so-called LEVs (Low Emission Vehicles), once their sales level exceeds on average 3,000 vehicles for the past three years.

[148] Appendix XIII provides an overview on current trade patterns between Korea and the EU in the Automotive Industry. Exports of Korean cars to the European Union amounted to 312,406 in 2010 and 414,707 units in 2011.
[149] See more detailed in Decreux et al. (2010), p. 80-85.
[150] Decreux et al. (2010), p. 81.

	• **Self-certification** The regulation for safety standards established in 2003 allowed car makers to test according to EU or US testing requirements in order to comply with Korean regulations. But the situation is more difficult in practice.
Korean vehicle taxation system	Imported vehicles are taxed based on the CIF[151] price which is in consequence higher than for domestically produced cars.. Besides that, a multitude of taxes exist, many based on engine size are especially burdensome for foreign car makers. Taxes imposed include: - purchase tax, - special consumption tax (relating to engine size), - educational tax, - value-added tax (VAT), - registration tax, - acquisition tax, - subway bond (based on engine displacement), - motor vehicle tax (staggered according to engine displacements) Since most cars sold by foreign makers feature large engines, i.e. engine displacements above 2,000 ccm, imported cars cause a higher cost burden for owners.
Social or market related issues	During the 1980s and 1990s authors reported that the Korean government had actively promoted "anti-import perception policies and tax investigations in order to discourage the purchase of foreign brands."[152] Still today anti-import attitudes can be detected among Korean consumers which may in part explain low market share of foreign cars in Korea.
Currency manipulation	It has been claimed that the Korean government manipulates the value of the Korean won (KRW) to the U.S. dollar in order to promote exports.
Breadth of vehicles	Different to international standards.
Regulation on noise certification	In line with international standards, but vehicle tests and the number of tests to be performed, as well as the selection standards are stricter compared to international standards.

(Source: Decreux et al. 2010; CEPS/KIEP 2007)

Presently, safety and environmental standards and taxation policies represent the most significant Korean market barriers to European car manufacturers. In the past, the high import tax applied to European cars made them too expensive to compete with domestic auto makers, especially in the small- and mid-sized car segment.

2.6.2.3 Future Volume of Korean Exports to EU – Conventional and Electric Vehicles

The domestic Korean automobile production, exports and imports included, have experienced continued growth since the 1980s. Hyundai and Kia are predominantly successful in large markets such as China, the U.S., and Europe. Since the late 1990s, Korean car makers, particularly Hyundai and Kia have started to internationalize by setting up manufacturing facilities in important automobile markets such as the U.S. and Europe.

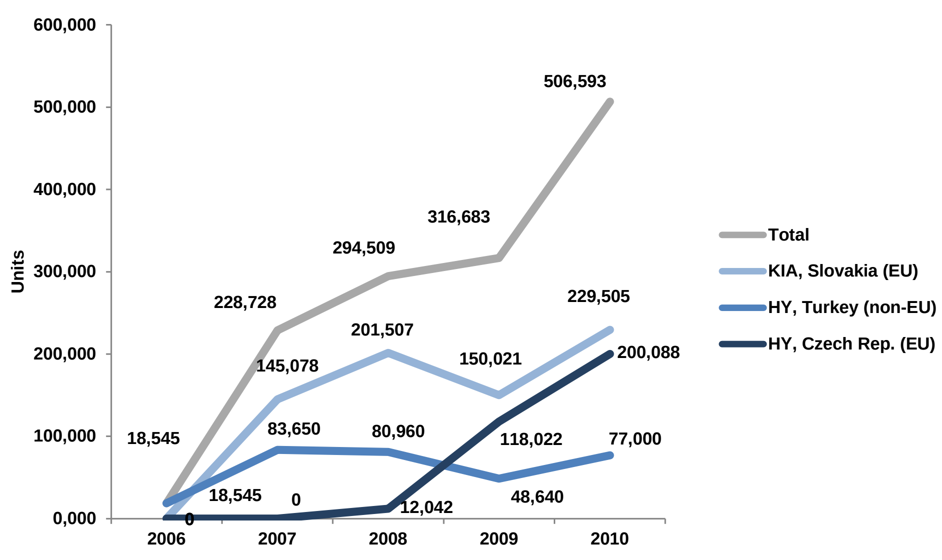
In order to forecast the development for 2020 and 2030, the realistic view (see Scenario 1 in Appendix XIV) assumes a continuous development based on the last decades' growth rate. This scenario would result in production volumes (domestic) of about 4,071,000 units (2020) and about 4,287,000 units in 2030. Exports to the European Union would increase to approximately 339,000 units (2020) and about 368,000 units by 2030.

This scenario, however, does not take the recent development in transplant production capacity extension of Hyundai and Kia into account. Since the production ramp up in mid-2000 of Hyundai's plant in the Czech Republic and Kia's plant in Slovakia, vehicles produced within the European Union by both makers have significantly increased since 2006. In 2010 Hyundai and Kia produced ca. 430,000

[151] Cost, insurance and freight.
[152] Decreux et al. (2010), p. 85.

passenger cars in the European Union (see Table 16). This number does not include volumes produced by Hyundai in Turkey (in 2010: 77,000 units), since Turkey is not a member of the Union.

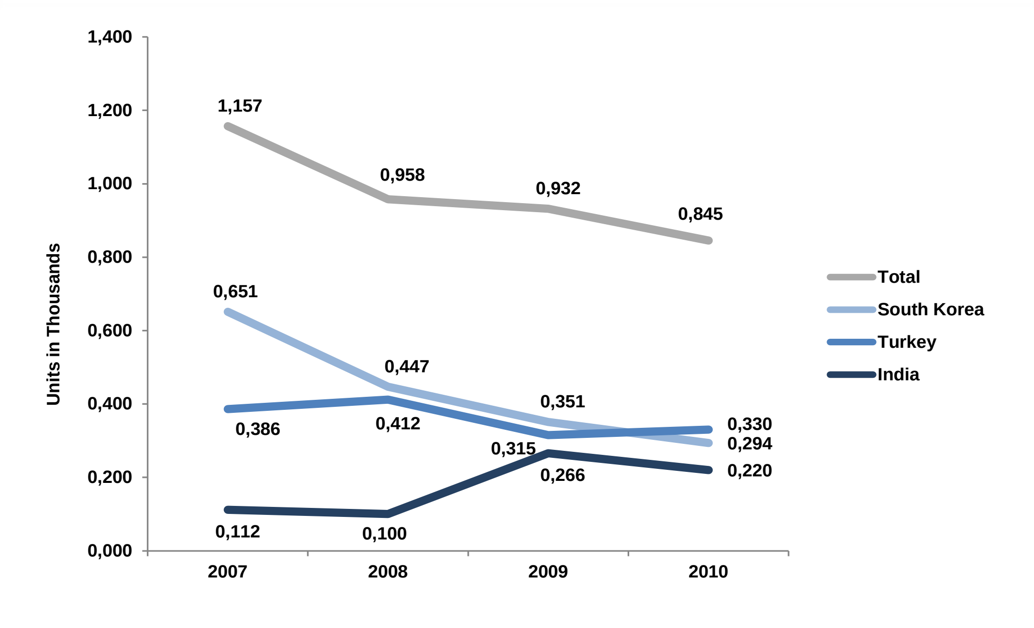
Table 16: Hyundai and Kia European Transplant Production, 2006-2010



(Source: OICA 2012)

In accordance with the volume increase of vehicles produced within the European Union, exports from Korea declined during the same period of time. In 2007 ca. 650,000 passenger cars were imported to the EU from South Korea, within 3 years, whereas in 2010, exports decreased to ca. 300,000 units (see Table 17), reflecting a trend from a former rather export driven strategy towards a preference for local production (localization).

Table 17: EU Passenger Car Imports from South Korea, Turkey, India, 2007-2010



Note: The figure above includes EU imports from Turkey and India in order to indicate the volume level of imports of non-South Korean countries. Substantial volumes of Korean OEMs are not always imported from South Korea. E.g. Hyundai exports from Turkey and recently decided to shift the production of the model i20, popular among European consumers, from India to Europe. With this move, Hyundai can try to avoid the 6.5 percent import duty applied by the EU for vehicles imported from India, as well as to save logistical costs (see Hyundai-Blog 2012).

(Source: ACEA 2011a; Hyundai Blog 2012)

With a production volume of 430,000 vehicles (2010) within the European Union alone, Hyundai and Kia would be theoretically able to supply the majority of its vehicles sold in Europe out of the European plants. The market share of both Korean makers of 3-4 percent corresponds to approximately 500,000 units (new registrations) in Western-Europe (see Table 18).

Table 18: Market share of Hyundai and Kia in Western-Europe, 2006-2010

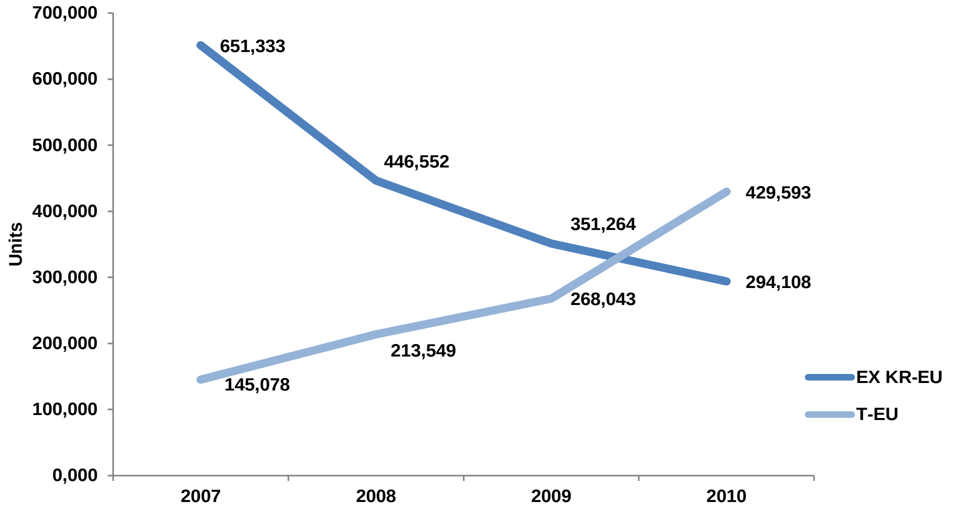
Year	Volumes (combined)*	Market share (combined)
2006	520,647	3.53%
2007	492,331	3.33%
2008	423,214	3.12%
2009	520,301	3.81%
2010	539,602	4.16%

Note: * New registrations

(Source: ACEA 2012b)

The trend of decreasing exports and increasingly locally produced vehicles is shown in Table 19. In 2009 transplant volumes exceeded volumes imported from South Korea. The volume of the latter has drastically declined since 2007.

Table 19: Number of passenger cars produced by Hyundai and Kia in the EU and exported from Korea, 2007-2010



Note:
T-EU: Passenger cars produced by Hyundai and Kia in the European Union
EX KR-EU: Passenger cars exported by Hyundai and Kia to the European Union

(Source: ACEA 2011a)

The figures provided above clearly indicate that Korean automobile manufacturers (just like their Japanese competitors) are increasingly changing from an export driven strategy to one of local production. Estimating the long term volume of EVs exported from Korea to the EU is not an easy task due to difficulties estimating future developments of production cost, a firm's business policy and, foremost, no experience with the market response for Korean EVs. Additionally, Hyundai and Kia aren't fully established international automotive brands yet (contrary to Japanese OEMs) but rather fast growing newcomers. Whether both can continue growing fast will partly depend whether consumers will be attracted by their EV models. The production of Korean EVs has just started (September, 2012), it is still too early to judge whether automotive markets will respond positively or not to their line-up.

More certain is that the export volumes of Korean EVs from Korea to Europe will be comparatively low, taking the localization strategy of Korean OEMs into account. **Assuming a 20%[153] vehicle elec-**

[153] Based on assumptions by Roland Berger (2009c); Rosebro (2007); Lundgreen (2010) and Seiwert (2012)

trification share in the EU, (translated to the Hyundai and Kia market share in Europe), would mean an approximate portion of 120,000 Hyundai and Kia EVs and an EV volume of 100,000 units produced within the European Union. The gap of 20,000 units may be filled by exports. From which location, e.g. South Korea, Turkey or India, remains open. Assuming today's production capacity of Hyundai and Kia in Europe of about 500,000 units, the EV demand in Europe may theoretically completely covered by the European production plants, meaning exports may become unnecessary in the long run (see Table 20).

Table 20: Forecast on Future EV Exports from Hyundai and Kia to the EU

Condition	**Volumes (p.a.)**
20% vehicle electrification in the EU	120,000
EU transplant production	100,000
EV export from Korea	20,000 (-0)

Note:
Basic assumption: Hyundai and Kia can keep a market share of 4-5 percent (ca. 600,000 vehicles), EU-transplant production volume is assumed to reach 500,000 units p.a.,

(Source: Own Calculation)

2.6.3 China

2.6.3.1 Description of Current Trade Patterns between the EU and China in the field of Electric Vehicles

In 2011, China's automobile manufacturers produced about 18.6 million vehicles (+2.2%) of which approximately 824,000 were exported (+52.2%). Conversely, exports to the EU dropped to roughly 32,000 units (-8.4%) accounting for only 3.9% of total shipments (2011: 5.5%). The number of vehicles imported from Europe increased by 37% to 481,000 units, holding a share of 46% of total Chinese imports.[154]

In light of the small EV production volumes on the part of Chinese OEMs, overseas shipments for 2011 are estimated to include no more than a few dozen units. Official statistics for 2011 state that Chinese EV output totalled 8,368 units (of which 5,655 were BEVs and 2,713 hybrids of all types) while sales amounted to only 8,159 units (of which 5,579 were BEVs and 2,580 hybrids). In the absence of foreign trade data, the difference between production and sales – 76 BEVs and 133 hybrids – cannot simply be assumed to constitute exports. **The figures indicate, however, the minuscule scale of both output and sales, suggesting that trade flows were negligible when compared to China's overall exports and imports of automobiles.**

Among Chinese car manufacturers, **BYD appears to command the largest EV export business**, as the company reported cumulative sales revenues in excess of $100 million by July 2010. As BYD's BEV and PHEV models were the most successful in China until July 2012, this chapter will largely focus on the company's efforts to open international markets – be it through trade or FDI.

[154] Appendix XV and XVI provide an overview on Chinese Electric Vehicles in International Markets and Non-European Exports to China.

Box 3: BYD – an example from China

In cooperation with German Daimler AG, **BYD has successfully developed the Denza, a compact car based on the Mercedes B-Class.** With the platform and vehicle technology provided by the German counterpart and BYD adding its expertise in battery and electric powertrain design, the Denza is **scheduled to be introduced in the Chinese market in early 2013**. Both sides have repeatedly made themselves clear, that this car is exclusively designed and produced for the Chinese market and will not serve to generate exports.[155]

BYD has shown great interest in exporting its electric vehicles, particularly focussing on European and North American markets. At the 2011 Geneva Motor Show, Wang Chuanfu, BYD's founder and Chairman, announced his intention to sell electric vehicles in Europe starting from late 2012.[156] The market launch would centre around the all-electric e6 MPV and the new PHEV SUV model S6DM (DM stands for dual mode). BYD suffered a major setback when its cooperation agreement with German utility company RWE fell apart. In September 2010, the two firms had announced high flying plans to offer European customers package deals, comprising of EVs and their rapid charging infrastructure manufactured by BYD as well as green energy provided by RWE.[157] The German counterpart withdrew from the deal in early 2011 after it had become apparent that BYD's e6 and F3DM models could not obtain approvals for operation on European roads.[158]

Although it is not immediately clear if or when the missing road approval may have been granted, BYD successfully concluded an agreement with the city of Rotterdam in the Netherlands to supply an undisclosed number of e6's for use as taxis. This move is part of the city's campaign to introduce 75 electric taxis in order to raise public awareness and create favourable attitudes towards this new technology.[159]

Little information is available about the international activities of the other Chinese OEMs. While Chery Motors has no immediate plans to export EVs[160], Harbin HF Automobile Industry Group (Hafei) has already shipped 100 units of its Saibao[161] to the US.[162] Geely Motors, another independent Chinese OEM, has announced plans in early 2010 to develop an electric version of its Panda car for the European and U.S. market. According to a press release, the project in cooperation with the Danish company Lynx was supposed to produce a car with a 200 km electric driving range and a top speed of 130 km/h. The European market launch of the "Lynx Nanoq" took place in spring 2010[163] but according to the experts surveyed for this study, few units have been sold.

Concerning exports of electric vehicles to the European markets, Chinese manufacturers are currently irrelevant. The Chinese side did not identify any major obstacles to trade and displayed a general satisfaction with the present situation; however, stringent EU regulations for the protection of intellectual property complicated the exports of various components made by Chinese companies. Furthermore, the Chinese side remarked that problems have arisen due to vehicle safety standards being higher in the EU than in China. Since Chinese companies are primarily orienting safety designs along the lines of their more lax regulations, they often encounter certification problems when exporting to Europe.

Exports of European manufacturers are currently limited to the supply of vehicles with internal combustion engines, mainly in the premium segment. European exports of electric vehicles to China are faced with trade barriers, which are presented in the following chapter (see also Appendix XVII).

[155] Frankfurter Allgemeine Zeitung (2012)
[156] Financial Times (2011)
[157] RWE (2010)
[158] Heise (2012a)
[159] The Independent (2011)
[160] Hexun (2011)
[161] The Saibao is a BEV with a Lithium Iron Phosphate battery. The car can drive up to 200 km on a single charge and reach a speed of 130 km/h.
[162] D1EV (2012)
[163] Autoblog (2010)

2.6.3.2 Chinese Market Barriers to EU Exports

During two fact finding missions to China in spring 2012 (in the framework of the study), the question of Chinese trade barriers for EU exports of automobiles and parts thereof has been discussed with Chinese and international industry experts. Based on our own research and drawing on information obtained through expert interviews, several barriers to trade have been identified that complicate European import business in China. Issues relevant for electric vehicles are mentioned in this chapter. Further general issues are discussed in Appendix XVII.

1. **Discouragement of foreign investments into the automobile industry.** As the Chinese car market has maintained strong growth momentum throughout the global economic crisis and beyond, expanding sales there has become top priority for all international OEMs. However, in light of stagnating market growth and mounting overcapacities in its automobile industry, Chinese authorities have become increasingly critical of new investments by foreign companies. In a departure from past practice, the recent revision of the Catalogue of Industries for Guiding Foreign Investment eliminated automobile manufacturing per se as an encouraged investment target. Several experts consulted for this study have also suggested that the overwhelming competitiveness of foreign OEMs hurts the development prospects of local companies. Indeed, the low and continuously declining market share of domestic brands in their home market may have alarmed Chinese authorities. Even where foreign companies have already secured a cooperation agreement with a Chinese counterpart, as in the case of Subaru and Chery, negotiations with supervising authorities remain difficult. It was reported that the Chinese government did not recognize any potential learning opportunities for Chery from entering a joint venture with the Japanese counterpart. It therefore rejected the proposed affiliation unless the jointly produced cars were marketed exclusively under the Chery brand and sold through Chery's distribution network.[164]

2. **Mandatory focus on the development and/or production of EVs**. The revised catalogue, publicised in January 2012 introduced key components for electric vehicles and related infrastructure as encouraged investment targets. It also raised the environmental performance requirements of encouraged products and technologies. Consequently, the investment climate for international OEMs focussing on luxury, premium or sports-utility vehicles, that typically have larger engine displacements and relatively worse green credentials, has become much more challenging. According to several experts consulted, all foreign carmakers seeking the creation of new capacities or the expansion of existing ones have to demonstrate their commitment to improving the environmental performance of their cars and devote themselves to the development and/or production of electric powertrain technology. In this context, it was underlined by the experts that every project proposal has to contain an investment component relating to low or new energy vehicles as a mandatory requirement.

3. **Imported electric vehicles are excluded from purchasing subsidies**. The Chinese government has made it clear that only EVs developed and produced in China through joint ventures with local partners are eligible for buying incentives.[165] International OEMs are free to import their vehicles but face significant challenges to compete against local companies which can benefit from financial incentives and thus offer lower sticker prices. In September 2011, it was reported that the Chinese government refused to provide subsidies for sales of the Chevrolet Volt, which is manufactured in the U.S. and shipped to China.[166] The Volt would be the first mass produced pure electric vehicle imported to China but the denial of financial incentives led to a very high price of RMB 498,000.[167] BYD's e6 BEV has a list price of RMB 369,800 but actually sells in Shenzhen for RMB 249,800 – half the Volt's price - as a result of government subsidies. A similar picture emerges in regards to PHEVs. The F3DM, BYD's first PHEV, has its price tag cut to RMB 69,800 from RMB 169,800 thanks to financial support.[168]

4. **Market access is traded for technology transfer** in the case of foreign automakers willing to engage in the Chinese EV sector. By way of joint ventures with Chinese auto makers is the only way for overseas companies to produce electric vehicles in China; to do this, international players

[164] Fourin (2012a)
[165] China Automobile Industry News Network (2011a)
[166] New York Times (2011c)
[167] China Automobile Industry News Network (2011b)
[168] Fourin (2012c)

are required to share core technologies with their local counterparts. In an effort to force the transfer of key technologies from foreign automakers, the Chinese government insisted that General Motors, which operates several joint ventures with Chinese partners, share three core technologies as a precondition to receive subsidies for the new Chevrolet Volt worth USD 19,300 per vehicle. GM eventually yielded to demands for technology transfers and announced it would jointly develop electric vehicles with its Chinese joint venture partner.[169]

5. **Electric vehicles produced in China cannot be sold under international brand names.** Instead, the joint venture needs to create entirely new brands. Volkswagen has announced to separately develop electric vehicles with both its joint venture partners, First Auto Works and Shanghai Automotive Industry. Overall, the German company plans to kick off its EV plans in 2014 and reach an annual production of 100,000 units by 2018.[170] While FAW-VW will build the "Kaili", Shanghai-VW is set to establish the "Tantus" - both entirely new brands intended for EV sales.[171] According to several experts consulted for this study, the Chinese government has chosen this approach to raise the profile of electric cars which suffer from weak brands. Other than the technical problems, such as limited range and speed, it is the poor image of EVs which are often regarded as immature and even dangerous technology that discourages customers. Clearly, they have yet to gain sufficient attractiveness and aspirational value to project the social status, economic prowess or professional success of their owner and serve as a status symbol. With only a small fraction of potential car buyers willing to pay a significant price premium for electric cars, the establishment of strong brands is seen as a vital tool to kick start sales and promote popularization. At the same time, the forced creation of powerful EV brands is expected to provide a learning opportunity for domestic OEMs, which suffer from low brand recognition, by transferring marketing and branding expertise.

2.6.3.3 Future Volume of Trade and Foreign Direct Investments with China – Conventional and Electric Vehicles

Considering that the **Chinese EV market is still locked in the initial development stages and that local OEMs have yet to enter volume production in the field of EVs**, it is naturally difficult to forecast future trade patterns. This situation is further complicated by the fact that the General Administration of Customs has not yet compiled statistics on the trade of EVs or key components thereof. Because Chinese OEMs have fought an uphill battle in all previous attempts to enter the European market with their conventional models, their future EV products are unable to benefit from positive experiences and attitudes among European consumers. However, **no indication was found in the literature or during interviews with industry experts that Chinese OEMs are in fact aiming to promote their EVs in Europe in the near to medium term**. An analysis of the international expansion of Chinese automobile manufacturers over the past decade indicates that developing countries and emerging markets consistently remain at the heart of both trade and investment strategies. While the importance of the EU as an export destination has slipped in the past years, Latin American markets, particularly Brazil, have gained prominence. Chinese OEMs have also made a strong entrance into Southeast Asian, Central Asian, Middle Eastern and African markets. However, the potential for EVs is expected to be low there due to a lack of support infrastructure, such as charging stations.

Based on past and present strategies of Chinese OEMs, EV exports will likely be directed towards the more developed, affluent and urbanized emerging markets which may provide favourable operating environments for electric cars. **Chinese EV exports to the EU are not expected to exceed a few hundred units per year before 2020**.

2.7 Market Situation for Electric Vehicles - Conclusion

Currently, registrations of new electric vehicles are very low. However, all experts, who have been surveyed in this study, believe that the shift to electric mobility is irreversible. In 2020, the European Union (EU-27) will reach a total of 14.8 million new vehicle registrations (including passenger cars and light commercial vehicles) with a 7 percent market share in electric vehicles. Up until

[169] The New York Times (2011c)
[170] China Car Times (2012)
[171] China Car Times (2012)

2030, European's new vehicle registrations will remain stable with approximately 15 million vehicles. In 2030, about 31 percent of the EU-27 new vehicle registrations will be electric vehicles.

In 2020, the base case scenario expects a global market share of 9 percent electric vehicles. Up until 2030 the global market for electric vehicles will increase to 31 percent. **The difference between the different regions is huge**. Japan's share of electric vehicles, with its declining market, is estimated at about 16 percent in 2020 with an increase to 34 percent in 2030. The strong growth potential in the Chinese market will allow for an approximate 9 percent share of electric vehicles in 2020 with a rapid increase to 40 percent in 2030. In the U.S., the market share of electric vehicles will be less than 10 percent in 2020 and about 35 percent in 2030. The global registrations of Fuel Cells will remain less than one percent in 2030. This rather pessimistic assessment of the market development of fuel cells has been confirmed by the experts interviewed.

A major factor that will be responsible for market penetration is the change of the utility-cost index. The utility-cost index of Battery Electric Vehicles will change from 44 today to 65 in 2020 and 131 in 2030 compared to vehicles with internal combustion engines (100). Furthermore, the utility-cost index of Range Extenders will increase from 55 today to 78 in 2020 and 119 in 2030 compared to vehicles with internal combustion engines (100). The utility-cost index of Plug-In Hybrids will change from 67 today to 83 in 2020 and 128 in 2030 (100). Furthermore, the utility-cost index of Fuel Cell Electric Vehicles will change from 1 today to 8 in 2020 and 54 in 2030 compared to vehicles with internal combustion engines (100).

The market will only develop if the utility-cost index of electric vehicles improves significantly compared to vehicles with an internal combustion engine. In this case, private consumers will also acquire electric vehicles. The majority of experts interviewed assume that the early adopters of electric mobility will be particularly (innovative) fleets in the medium term. The development of the additional technological costs of electric vehicles has a strong influence on the utility-cost index. These additional costs of Battery Electric Vehicles are expected to decrease by 50 percent until 2020 and 70 percent by 2030, mostly due to cost reductions of the main components of electric vehicles (such as battery, electric motors, and power electronics) which are mainly based on scale production, rising competition, and efficiency of the manufacturing process (e.g. in terms of battery technology: efficiency of cell manufacturing and battery assembly). In terms of electric vehicle assembly, the survey results show two main differences; while one group of respondents - manufacturers and suppliers - will offer electric vehicles based on new vehicle architecture (**"Purpose Design"**), a second group is focusing on integration of the electric powertrain in the conventional vehicle architecture **("Conversion Design"**). From an economical perspective, a huge potential of cost reduction can be expected by focusing on the production of new vehicle concepts, particularly due to standardisation and modularisation. Furthermore, new vehicle architectures allow new opportunities in terms of space usage, handling, and weight. In contrast, vehicles with internal combustion engines will have a heightened potential of fuel efficiency. The experts interviewed expect a 25 percent reduction of consumption of fuel up until 2030. In the long term, the better utility-cost index will shift emphasis from ICE and hybrid technology towards electric vehicles.

In 2020 and 2030, the EU automotive industry will maintain the position of a net exporter of combustion engine vehicles but will export electric vehicles as well. EU exports to Japan and South Korea will remain low in 2020 and 2030. This is a result of the consumption behaviours and partly in reaction to the existing regulations of these countries. Chinese foreign trade in automobiles has expanded rapidly and will continue to grow at a quick pace. OEMs from the EU continue to capture more than 60 percent of the market for imported vehicles with luxury and executive cars as well as SUVs. They are well positioned to benefit from the recent trend of affluent consumers to purchase higher grade cars in an increasing number. Chinese exports to the EU are small but may rise in the future as modern production facilities established by Sino-foreign auto joint ventures may want to escape an escalating industry glut and capitalise on their superior costs and quality positions to serve Western markets. Chinese export barriers pertain mainly to differences between Chinese and international standards. The China Compulsory Certification system has become more onerous for foreign automotive companies and obstructs the adoption of international standards.

Altogether, the definition of policy recommendations for the EU (in Chapter 6.3) must take into account that an accelerated development of the electromobility will not take place before 2020 until e.g. increasing markets like China will become important players in electromobility. Together with a need for realistic assumptions to assess electromobility, these findings explain risks that have to be addressed.

3 Situation of the Electric Vehicle Industry in Europe

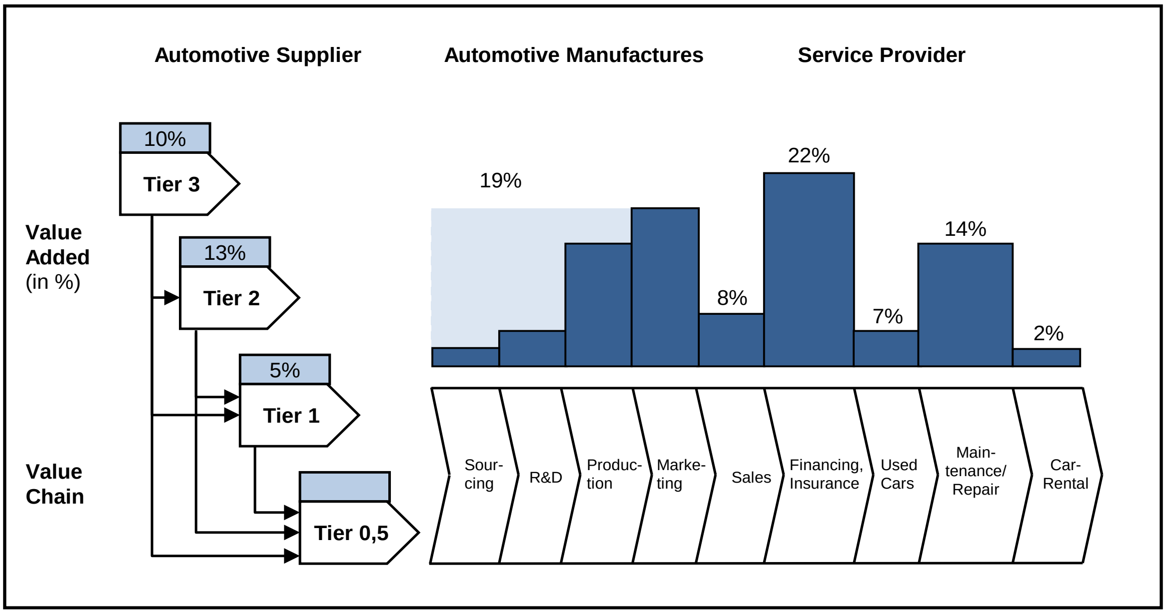
In this chapter, an overview on the automotive value chain and the impact of electrification will be provided (Chapter 3.1). Apart from that, the current competitive position of European automotive OEMs and suppliers (Chapter 3.2.1) will be analysed. Furthermore, the competitive position of the European automotive industry will be discussed in terms of patent applications (Chapter 3.2.2). Additionally, current joint ventures and alliances in the field of electric mobility will be presented (Chapter 3.2.3). Chapter 3.2.4 analyses the role of national platforms. In Chapter 3.2.5 drivers of the industrial situation will be analysed. Finally, in Chapter 3.2.6 First Mover Advantages will be discussed while Chapter 3.2.7 summarises certain challenges of the electric vehicle industry in Europe.

The second part of this chapter focuses on the evolution of the industrial situation of the European electric vehicle industry (Chapter 3.3). In Chapter 3.3.1 industrial plans of the key players will be presented while the development of value added in the EU automotive industry will be estimated in Chapter 3.3.2.

3.1 Overview: The Automotive Value Chain and the Impact of Electrification

The automotive value chain comprises the activities by original equipment manufacturers (OEM), automotive suppliers and possibly independent service providers (see Figure 26). Suppliers can be divided is several tiers.

Figure 26: The Automotive Supply Chain



(Source: Own Compilation)

Tier 1 - Automotive suppliers are suppliers of modules and/or systems[172].

Module suppliers operate in the field of development, integration and/or production of complex assemblies in accordance with delivery. They are responsible for the geometric integration of different parts to a local place in the vehicle, have access to primary data of the individual parts and deliver a reduced version (module). Module suppliers produce e.g. cockpits or seating.

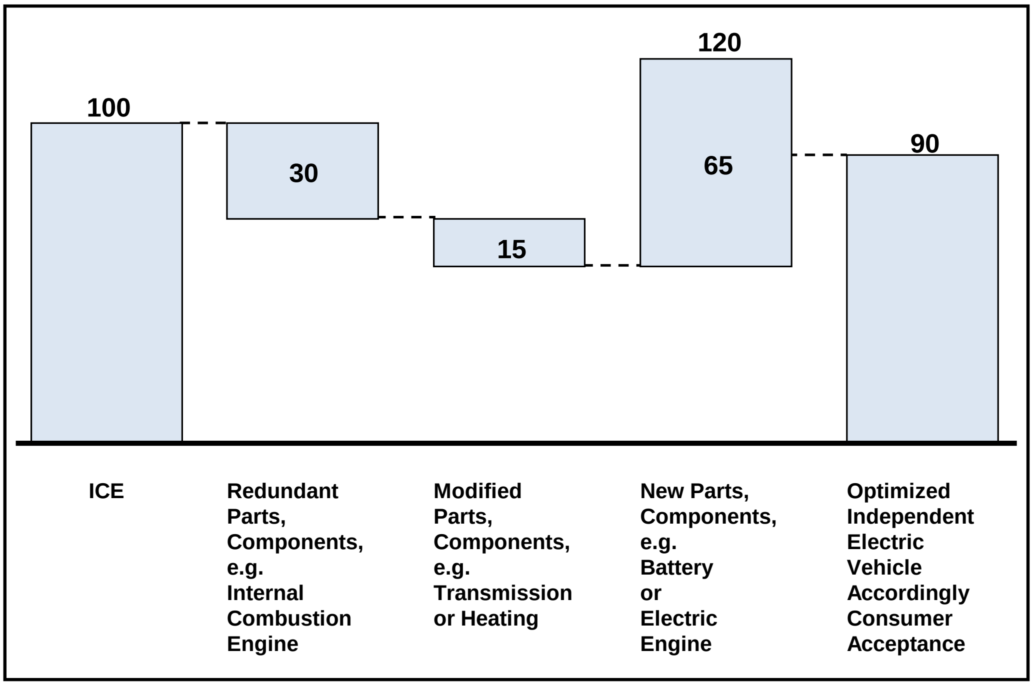
System suppliers operate in the field of development and/or production of functionally related system components for the client; they are responsible for the functional integration of different parts a common purpose used in different locations in the vehicle (e.g. fuel injection, steering and axle system, audio system including radio, antenna, speaker).

[172] VDA (2001)

Tier-0.5 automotive suppliers are general contractors (also known as system integrators).[173] General contractors are responsible for the complete development and/or production (e.g. Development and/or production of complete vehicle models such as Magna Steyer or Valmet Automotive).

The transition to electromobility will lead to fundamental changes in the automotive value chain: On the one hand a **lot of new services** such as the provision of electricity for the recharge process and the development of charging infrastructure can be expected. On the other hand, **the vehicle itself will change**. Electric vehicles are less complex because of the smaller number of parts and modules used, especially for the powertrain. Components like the combustion engine and exhaust system are no longer necessary, while components like the transmission or drive shafts will be modified (pure electric vehicles normally have a gearbox with a fixed transmission ratio). Additionally the main components of the electric drive train like the propulsion battery, the electric engine and the power electronic components have to be further developed and implemented into the vehicle (see Figure 27).

Figure 27: Changing Cost Structure of Electric Vehicles (in Percent)



(Source: Own Compilation based on McKinsey 2009, 2011 and PWC 2010)

Figure 27 shows that the **cost structure of electric vehicles will change significantly in the transition to electromobility**. Redundant modules and components of the internal combustion powertrain have to be replaced, which could lead to a cost decrease by 30 percent, because internal combustion engines, turbochargers, transmissions and exhaust systems are not required in a battery electric vehicle. **This will have an additional impact on the supplier industry in the future**. Especially when focussing on companies mainly producing components for the traditional propulsion system. Assuming a further progression in the electrification of transport and individual traffic, these companies will have to adapt and restructure their product portfolio.

Altogether, **new body concepts, lighter anchored seats, and new electrified auxiliaries**, such as new air conditioning systems have to be developed, which could lead to a cost reduction of 15 percent (reduction of the vehicle to essential functions). Nevertheless, **new components such as batteries, power electronics, and electric motors also have to be integrated into the vehicle which will lead to additional costs**. Offering new services such as financing, insurance, and leasing services, manufacturers and their sales organisations are particularly faced with imponderable risks. Repair centres have to deal with new types of repair due to the exchange of the propulsion system, which results in a reduction of repair costs. Additionally the **service personnel have to be appropriately**

[173] VDA (2001); Heigl/Rennhak (2008)

trained due to the new risk potential of the electric propulsion system. Altogether, these (additional) costs will simultaneously rise by 65 percent.

In sum, electric vehicles will not be permanently more expensive than vehicles with internal combustion engines. If they are developed as independent vehicles or mobility concepts tailored to the benefits of electromobility (see Chapter 2.1, benefits of “Purpose Design”), also taking into account new (mobility) needs of the customers, **optimised electric vehicles could lead to a decrease of costs of 10 percent compared to today´s vehicles with internal combustion engines**.

The expert interviews conducted for this study show that while the majority of the automotive manufacturers consider battery technology as a core competence of electromobility, which should be integrated to OEM´s R&D or production (e.g. battery packaging), other experts assume **a shift of value added towards the supplier industry concerning electric powertrains**. Presently, many co-operations and alliances are made in order to prevent the degradation of skills. Manufacturers such as Volkswagen Group and General Motors have decided to produce battery systems themselves (battery assembly). Therefore, they are purchasing cells from suppliers, e.g. GM from the Korean supplier LG Chem (see Chapter 3.2.1.1). Many key suppliers (e.g. Continental or Johnson Controls), focus on the R&D and production of complete battery systems (see Chapter 3.2.1.1). Suppliers will aim to offer complete modules (e.g. electric engines or battery systems) to the OEM in order to secure a strong market position but to also generate economies of scale by offering complete modules and/or systems to OEMs.

Recently a study by KPMG (2012) concluded that the supplier industry will gain particular significance in the value chain (e.g. in the field of cell production, lightweight materials).Today it is unclear whether and when the value added of the redundant parts and components (e.g. exhaust systems, parts and components for internal combustion engines) can be compensated or even overcompensated (e.g. leading to even more value added in EV production) by this new range of activities. **It is clear, however, that suppliers which are specialized in the production of internal combustion engines must adapt their portfolio in the future, so as not to be driven out of the market.** Since the development of the market is slow, there is enough time to restructure.

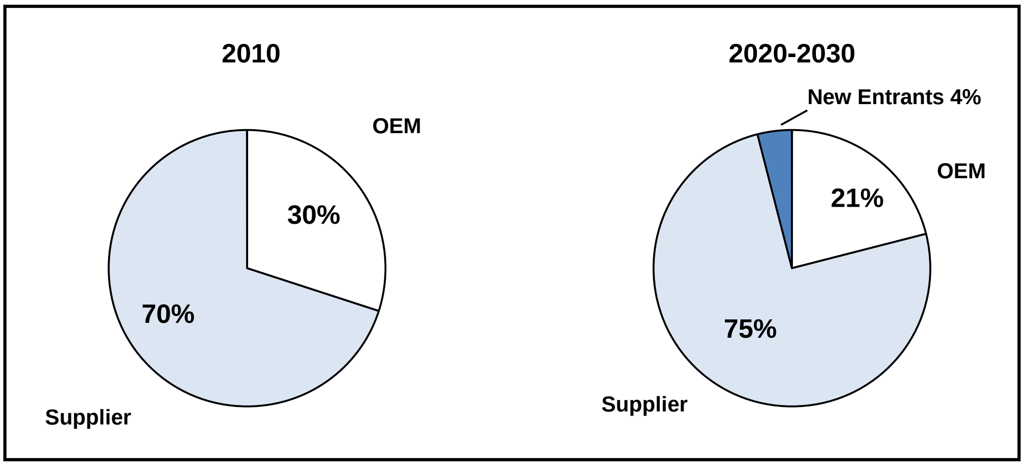
Nevertheless, OEMs will remain the traditional leader in the value chain. They are expected to be the dominant force in electric and traditional powertrain technologies. **Manufacturers will focus on the R&D of new vehicle concepts or technical innovations** (e.g. connectivity: vehicle to grid or vehicle to vehicle).[174]Companies such as BMW, VW and Daimler are already investing in cooperation in the field of lightweight materials, especially carbon (e.g. BMW with SGL Carbon). According to KPMG (2012), Tier 1 suppliers are expected to operate in the field of R&D and production of electronic components and lightweight materials, while OEMs will remain traditionally responsible for R&D, brand management and overall assembly.

Based on discussions with experts we were able to confirm this trend. Within the last 20 years, the value added in the automotive industry has been characterised by a shift from manufacturers to their suppliers. Currently, approximately 70 percent of the total value added in automotive industry is covered by the automotive supplier, while only 30 percent is provided by the manufacturers. The majority of experts, who have been surveyed in this study, expect **a further shift of value added from manufacturer towards supplier.**

In the transition to electric vehicles, the share of value added from the OEMs will decrease in the long run (up until 2020 or 2030) from 30 to 21 percent, while the value added of suppliers will increase to 75 percent. New entrants (e.g. services linked to electromobility such as charging, car sharing, recycling, or companies working in the field of smart grids) will cover 4 percent of the value added (see Figure 28).

[174] KPMG (2012), p. 2.

Figure 28: Segmentation of Value Added in between the Player in the Value Chain



(Source: Own Estimation based on Expert Interviews)

Presently, it is unclear whether the future production of electric vehicles will be located in the plants of traditional car manufacturers, automotive suppliers, or new entrants. However, if the market for electric vehicles develops quickly, traditional car manufacturers will expand their activities in the market. It remains to be seen whether the small companies can catch up with their investments, technological development, market position and the development of cost (e.g. due to economies of scale). If the market stagnates or grows very slowly, new entrants in particular, will enter the market (e.g. offering niche products).

3.2 Current Competitive Position of Electric Vehicle Manufacturing in Europe

3.2.1 Competitive Position of Automotive OEMs and Suppliers in Electric Vehicles

3.2.1.1 Battery Production

Presently, Japanese, Korean, and U.S. companies are market leaders in terms of global battery production. A current Pike Research report has evaluated **10 of the leading electric vehicle battery manufacturers** and rated them on different criteria, e.g. strategy and execution, partners, geographic reach, market share sales and marketing or product portfolio. Pike Research results (see Table 21) demonstrate rankings which display the varying abilities battery manufacturers possess to take advantage of shifts in the market. The data seems to be plausible, but should be further reviewed.[175]

Table 21: Evaluation of Global Battery Production

Battery Manufacturer	Country	Ranking (Pike Research)
LG Chem	South Korea	1
Johnson Controls	United States	2
GS Yuasa	Japan	3
AESC	Japan	4
A123 Systems	United States	5
Panasonic Group	Japan	6
SB Limotive	Germany/ Korea	7
Hitachi Vehicle Energy	Japan	8
BYD	China	9
Electrovaya	Canada	10

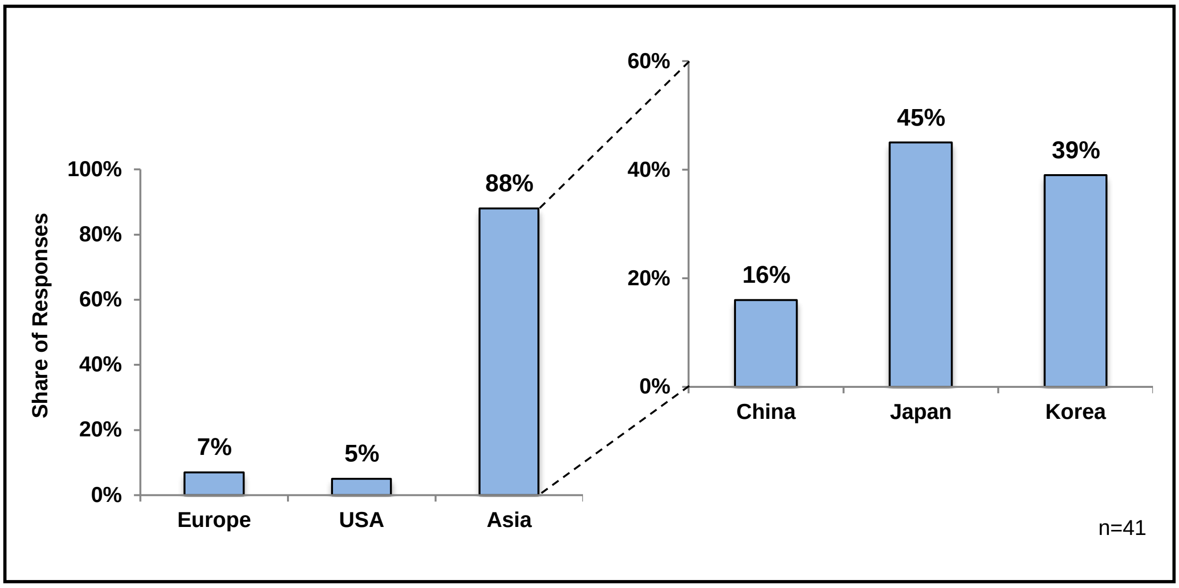
(Source: Pike Research 2012)

[175] Pike Research (2012)

Pike Research (2012) concludes that the manufacturers which are best positioned to take advantage of shifts in the market are LG Chem and Johnson Controls. In the Appendix XVIII, certain key players will be introduced.

Today, Japanese and Korean companies, producing cells for consumer electronics, **are the market leaders in the automotive industry**. But competition is increasing with Chinese and North American companies entering the market. Presently, the Li-Ion automotive market is entering a phase in which smaller companies could fail or be acquired due to an inability to reach volume production. Asia is attributed with strong expertise in battery technology. The majority of the experts surveyed in this study believe that, in the medium-term, the core sizes of battery technology will be developed and produced in Asia. **The majority of the surveyed experts believe that Japan will remain the leader in battery technology while Korea continues to catch up. China is not regarded as a competitor in the upcoming 10 years** (see Figure 29).

Figure 29: Future Capabilities in Battery Technology in terms of R&D and Production



(Source: Own Compilation based on Expert Interviews)

The majority of the Japanese and Korean key players consider China as a competitive player in terms of mass production, particularly in low-cost solutions. Battery technology, however, requires in particular a high degree of cooperation between manufacturers and suppliers (systems expertise). **In this area the Japanese and Koreans benefit from their technological leadership, their experience in the field of consumer goods and their know-how in related industries.**

The majority of the Korean experts interviewed consider the Korean battery supplier as a key player in battery technology (R&D and Production), followed by the Japanese companies. Nearly all experts who have been interviewed within this study stress the importance of Korean public policies in the transition to electric vehicles. Nevertheless, while Korean companies also focus on Fuel Cell technology; the government particularly promotes Electric Vehicles and Hybrids instead of promoting different technologies.

Meanwhile, Chinese companies benefit from their access to raw materials, extensive government incentives and expected rapid market growth for electric vehicles (market proximity). Due to the current trade patterns, it will be very difficult for foreign companies to enter the Chinese market (see Chapter 2.6.3). Presently, middle and long-term partnerships between suppliers and customers can be observed (e.g. alliances of European OEM and battery manufacturers). It remains to be seen whether the Chinese will develop and produce high quality products within a few years.

The global market for Lithium-Ion batteries for electric vehicles is clearly on the rise. According to Roland Berger, the growth will be accompanied by massive overcapacity. In the coming years, the production potential for Lithium-Ion batteries will exceed actual demand by more than 100 percent. This assumption can be confirmed on the basis of the results of our market forecasts in comparison to capacities which have been currently built up in Asia and the U.S. (see the following sections). In the medium term, a consolidation is likely to happen. Roland Berger estimates that even **in 2015, five competitors such as AESC, LG Chem, Panasonic/Sanyo, A123 and SB LiMotive will cover nearly 80 percent of the market.**[176] High market entry barriers exist for new entrants especially concerning anode and separator material.[177]

The following chapters provide an overview on the global battery production in a country specific context, focusing on capacities and investments in Europe, the U.S., and Asia (Chapters 3.2.1.1.1 to 3.2.1.1.4).

3.2.1.1.1 European Battery Production

Presently, the EU does not have any competitive advantages in the production of battery cells as nearly the complete production of Lithium-Ion cells, which have been used in the past particularly for mobile applications, is currently located in Asia. This is due to this fact the Asian countries have significant experience in producing components and battery cells for mobile applications and electric vehicles. In order to be competitive in the field of battery technology in the long term future, a know-how in electrochemistry, battery technology and production technology will have to be developed by the EU automotive industry in cooperation with the chemical industry and the machinery and plant industry sector**. In this case a "European Platform for Battery Technology" could be suitable to support the key players willing to invest and develop the know-how (see the Policy Recommendations in Chapter 6.3).**

Currently, most of the major key players are located overseas.[178]**There are only a few have production sites within the European Union** (see Appendix XIX and XX), such as the Japanese alliance of NEC, Nissan and Renault called AESC (in the UK and Spain), Saft S.A. (France) or the German joint venture LiTec of Daimler AG and Evonik.

The joint venture of Saft with Johnson Controls was disbanded in September 2011. Under the terms of the signed contract, Johnson Controls acquired the shares of Saft amounting to $145 million. The contract also provided a royalty payment from Johnson Controls to Saft. In return, Johnson Controls is allowed to use an extended license for certain Lithium-Ion technologies from Saft in all markets. The fixed assets of the joint venture will remain at Johnson Controls - with the exception of one plant in Nersac (France).[179]In France, Renault, the CEA (French Atomic Energy and Alternative Energies Commission) and Nissan built a factory in Flins close to Paris in order to produce batteries. Within the EU, France is currently playing a leading role in terms of battery production.

Presently, it is not anticipated that the European supplier industry will be able to catch up with the Asian key player's industry expertise or synergies, which Asian companies have by offering batteries to the consumer goods and telecommunication industry as well, and cost savings in the short term (thanks to economies of scale because of mass production, since most of them have been supplying their components to the consumer-goods and electronics industry for several years).

A large scale battery production in the **EU will be only possible if it is based on cooperation, because economies of scale cannot be expected in battery production in the near term** (see our Market Forecast). Appendix XIX and XX provide an overview on current EU-key players in battery production. **Exports or direct investment of European battery manufacturers is likely to be impeded by trade restrictions and existing supplier networks in Asia (especially in Japan). However, foreign direct investment of global players in the EU can be expected. Both the market proximity and rising transportation costs will tend to encourage local production of battery systems in the EU.**

The results of our interviews with experts demonstrate a **clear tendency towards local manufacturing of batteries**. Due to capital commitment, long transport distances, and safety considerations, battery production will take place close to the assembly line of the manufacturers. A component supplier, who has been surveyed in this study, emphasised:

[176] Roland Berger (2011a)
[177] Roland Berger (2011a)
[178] CGGC (2010)
[179] Presseportal (2011b); Saft (2012c)

> "Why do all people think, that battery production will be mostly located in Asia? Due to a high degree of automation they will not have any advantages in terms of labour cost in battery assembly. Manufacturing facilities will be created close to the market! Once economies of scale are expected in manufacturing, modern factories can be built in the EU. Whether the battery systems, cells and components will be produced by Asian or European companies - will remain a crucial question!"

Regarding battery production, different production steps can be distinguished. While raw material research and mining (e.g. of lithium and rare earth materials) will comprise local activities, the production of components, cells or the entire system (packaging) can be located, in principle, anywhere. In the area of components for Li-Ion cells, electronics used in the battery packs and cell production, the EU currently has little expertise. Characteristic of the battery technology is the involvement of manufacturers in the design and production of Li-Ion batteries. Therefore, purchase decisions for a battery system are long-term decisions. Perhaps it includes the whole lifecycle of the vehicle, as various battery designs unique for each different vehicle type will not be feasible. **Battery manufacturers benefit from long-term arrangements with their OEM by permitting large volume production**. Nevertheless, these arrangements also tie them to the success of the vehicle manufacturer.[180]

3.2.1.1.2 U.S. Battery Production

In the 1980s, U.S. companies decided to withdraw from the Lithium-Ion battery industry, leaving it to better established electronic enterprises in Asia.[181] Therefore, the U.S. industry did not have any competitors in the 1990s. With Toyota launching the first hybrid vehicles at the end of the 1990s, U.S. car manufacturers belatedly built up relevant capabilities in terms of battery manufacturing.[182] A study by CGGC analysing the U.S. supply chain of Lithium-Ion batteries for electric vehicles yielded the following key findings:[183]

- In 2010, about 50 U.S.-based companies were manufacturing and conducting research and development at 119 locations in 27 states in the field of battery technology. California (28) and Michigan (13) had the most of activities. By 2010, at least 18 start-up companies were entering the market.
- U.S. activity is concentrated in Tier1 operations (cell/battery pack assembly). About 21 lithium battery pack players were operating in the automotive industry in 2010. Most of these enterprises purchase their cells from non-U.S. companies except EnerDel operating its own cell manufacturing. With the support of the Department of Energy, certain companies such as A123, CPI, EnerDel and JCI Saft are trying to establish vertically integrated cell-to-package capacities.
- U.S. companies are working to increase their know-how in cell production which represents the highest amount of value with approximately 45 percent of total input cost. The United States is a major player in two components (out of four) namely electrolyte and separators but is a minor player in cathodes and anodes. In 2010 about 30 companies were operating in the field of cell components and electronics.
- U.S. companies are moving aggressively to catch up to their advanced Asian competitors. U.S. companies rely on mergers and acquisition. Ener1, for example, acquired Enertech (a large Korean battery manufacturer) and the battery division of the automotive supplier Delphi, while EnerDel hired several Asian battery engineers to expand their R&D division.

The CGGC study (2010) emphasises the major role of joint ventures in the evolving value chain. We also assume that alliances and joint ventures will gain importance in order to spread costs/risks and to share knowledge (see Chapter 3.2.3).

Currently, the increasing demand for plug-in and hybrid electric vehicles combined with federal and state level incentives is leading to extensive investments in U.S. battery production. On-

[180] Canis (2011)
[181] DOC (2011); CGGC (2010)
[182] CGGC (2010)
[183] CGGC (2010)

ekey player in the U.S., A123, received a $249 million grant from the U.S. Department of Energy (DOE) plus a further incentive from the state of Michigan in order to build up its new plant in Livona (Michigan). In addition, foreign companies such as the Korean LG Chem have been investing and adding production capacities inside the U.S.[184]. Appendix XXI to XXII provide an overview on U.S. key players in battery production.

In 2009, the United States had only two factories producing advanced vehicle batteries encompassing less than 2 percent of the world´s advanced vehicle batteries. By 2012, the U.S. Department of Energy (DOE) had assumed that 30 battery factories will enter the U.S. market. They expect a capacity to produce 20 percent of the world´s advanced vehicle batteries by 2012 and even 40 percent by 2015.In order to promote the establishment of manufacturing facilities in the United States, the U.S. government has adopted the "Recovery Act" which includes $2.4 billion in order to establish 30 electric vehicle battery and component manufacturing plants.[185]

Presently, only EnerDel, located in Indiana, has been operating a domestic high-anode and cathode volume and cell manufacturing facility in the U.S. A123 Systems does it's R&D and engineering in the United States, while producing most of it cells in Korean or Chinese plants. A123 Systems has built up two U.S. facilities in Michigan conducting cell assembly as well as anode and cathode coating production.[186] Recently, even the South Korean company LG Chem has been duplicating its Korean facilities at a new production plant in Michigan in order to build up local production.[187] Currently, the U.S. American battery production has a slight advantage compared to the battery production of the EU. This is mainly due to state funding (ARRA). This assumption can be supported by the results of our expert interviews. The question is, whether the rapid expansion of capacity can be used in the medium term (market penetration) or whether some players will quickly disappear from the market. Ener1 was one of the first battery manufacturers that went into bankruptcy. Major obstacles in the success of battery technology suppliers are both the high development costs and customer reluctance. Furthermore, A123 recently stated, that it will only have liquidity for the next five months. Analysts consider a partnership with a South Korean player to be possible, e.g. Samsung.[188] In August 2012, Wanxiang, who is China's largest automotive components supplier and one of China's largest non-government-owned companies, announced an investment of up to $465 million in A123.

The majority of our surveyed experts believe that the U.S.at present has no significant advantage compared to the EU, neither in R&D, nor in the production of battery systems. Even in the U.S., pack manufacturers usually import cells. Automotive manufacturers such as GM operate in the field of battery packaging, but they have to purchase the battery cells (e.g. from LG Chem for the GM Volt). A characteristic of the battery-supply chain is close cooperation between players, e.g. between manufacturers and battery suppliers. This is also reflected in the opinions of experts surveyed.

Furthermore, a European expert working at a global supplier believes that the U.S. will have a problem of excess capacity in the medium term. Many capacities have been built up in the recent years in the U.S. Some experts believe that excess capacity in particular will lead to lower prices, because competition is increasing.

3.2.1.1.3 Asian Battery Production

The largest share of battery production belongs to Asia; particularly Japan, South Korea, and China. Appendix XXIII and XXIV provide an overview on Asian key players in the battery sector.

Japan'searly move to hybrid electric vehicle market through the Toyota Prius led to extensive knowledge in integrating the entire energy system in vehicles. Sony and Sanyo (taken over by Panasonic) belong to the largest cell producers based in Japan.[189] This shows that nearly all of Japan's main technology companies concentrate on the production of batteries. A high share of their development force is focused on battery technology. It can be expected that the Japanese battery

[184] DOC (2011)
[185] DOE (2010)
[186] Canis (2011)
[187] Canis (2011)
[188]Autonews (2012d); Autonews (2012e)
[189] BMBF (2010)

manufacturers will continue to play an important role in the market due to their very strong investment (see Appendix XXII and XXIV).

Japanese manufacturers of battery components such as Mitsubishi Chemical occupy a dominant position in the world market. Apart from that, traditional manufacturers and suppliers such as Toyota Industries and its subsidiary DENSO have become major suppliers of battery components. Due to Toyota's early move towards the development of electric vehicles the Japanese automotive industry felt the need for battery improvement in terms of cost and performance early, in order to maintain the leadership position in this type of vehicle segment. In the initial phase the main driver for further development of battery technology were private companies. Meanwhile the government was becoming more involved by funding research activities and facilitating collaboration activities of stakeholders, such as private firms, ministries, universities and research institutes. The battery development roadmap proposed by the Ministry of Economy, Trade and Industry (METI) targets a performance increase of 150 percent of Lithium-Ion batteries compared to batteries in current use while reaching a cost level of 1/7 of the current battery cost by 2015 (see Figure 30).

Figure 30: Battery Technology Development Roadmap of the Ministry of Economy, Trade andIndustry (METI)

	2006	**2010**	**2015**	**2030**
	Conventional Batteries	Improved Batteries	Advanced Batteries	Innovative Batteries
	Lithium-Ion Technology			**Post Lithium-Ion Technology**
Performance	1	1	150%	700%
Cost	1	1/2	1/7	1/40
Main Driver	Private Initiative	Private Initiative	Industry-Government-Academia- Collaboration	University and Institutes

(Source: Adapted from Miura 2011)

By 2030 post-Lithium-Ion batteries are planned to be developed that last 700 percent longer than current batteries while cost only 1/40 compared to contemporary batteries. The targets for 2015 and 2030 (see Figure 30) shall be reached by collaboration between private firms, government universities, and research institutes.

The Japanese government acts as a facilitator for progress in the development of post-Lithium-Ion batteries. In this role funds of 330 million Euros are provided until 2015 in order to realise set targets. However, the Japanese government assures funds only for a limited and rather short period of time. According to the expert interviews conducted in Japan, the industry is therefore facing insecurity in long term planning.

Korea: Although Korean firms occupy a leading market position in battery technologies, several important battery components are imported from Japan. Know-how related to capacitor technology and other components such as the motor and inverter is relatively low except for its application to battery knowledge. **Most Korean companies active in this field are small and medium enterprises which lack in innovation but work hard in development**.[190]Korea's strengths can be seen from past experiences in cell- and battery production for mobile phones and notebooks.[191]

There are five key players in Korea's rechargeable battery industry: LG Chem, Samsung SDI, SK Energy, SK Energy, and SB LiMotive (see Appendix XXIII).The market development of Korean battery manufacturer's, even of South Korean companies, is characterised by significant investments and capacities exhibited by companies such as LG Chem, Dow Kokam, or SK Energy. SK Innovation for

[190] Virtanen/Lee (2010)
[191] BMBF (2010)

example, is investing $1 billion in order to produce Lithium-Ion batteries for its new joint venture with Continental.[192] It can be expected that Korean manufacturers will gain more in competitiveness.

Since Japans battery manufacturers can look back on long research and development experience in NiMH battery technologies and production compared to Korean firms, the latter decided to **extend and focus on Li-Ion battery technology competencies (a so-called "leap frogging" approach).** Today Korea possesses world class lithium-Ion battery manufacturing technologies in order to compete against Japanese firms. Korean firms were slightly ahead in the market share in 2011. Japan occupies a market share of 38.4 percent while Koreas share accounts for 38.5 percent.[193] Japan was able to reach its leading position in NiMH battery technology from early experiences in electronic home device applications and early research and development investments in hybrid vehicle technologies. Korea, on the other hand, benefited from its experience in smart phone applications and other mobile IT devices useful for battery technologies which can later be applied to electric hybrid vehicles.

The **Chinese battery industry has its roots in the 1990s when the electronics industry created a large demand for rechargeable batteries used in mobile phones, laptops, and other cordless devices**. Production capabilities improved over time as companies mastered subsequent generations of battery technology. Manufacturing capacities expanded dramatically as global electronics (and battery) demand skyrocketed. After Nickel Metal Hydride Batteries entered large scale industrial production in the mid 2000s, Chinese companies invested heavily in the next evolutionary step, Lithium-Ion technology (see Appendix XXIII).[194] Due to their superior performance compared to previous battery generations, e. g. in terms of energy density, Lithium-Ion batteries have opened a path to electric vehicle manufacturing.[195]

BYD, located in Shenzhen, has followed this path. Founded in 1995, the company subsequently mastered the technologies to make Nickel Cadmium and Nickel Metal Hydride batteries before focussing on large scale production of Lithium-Ion batteries for which it has become one of the leading manufacturers worldwide.[196] Drawing on years of experience and strong expertise in making cell phone batteries, the company eventually ventured into the automobile industry.[197] In 2003, it obtained one of the rare automobile production licenses through the acquisition of Qinchuan Auto, a small failing carmaker. In 2008, only five years later BYD presented the F3DM, China's first mass-produced PHEV at the international auto show in Detroit. Shortly after the F3DM became available in 2010, BYD released the e6 BEV, a micro van which is used by taxi fleets in Shenzhen, BYD's home base, and other major cities.[198]

Several studies have pointed out that Chinese battery manufacturers can benefit from significant cost advantages due to favourable access to locally sourced raw materials and low cost production patterns.[199]The availability of domestically mined and processed lithium, which is required in significant quantities for the production of traction batteries, has often been considered a major competitive advantage.[200] In regards to production technology, **Chinese players have adjusted their manufacturing operations to substitute highly automated production equipment with manual labour wherever possible. BYD, one of the leading battery and electric vehicle makers, is a case in point.** The company has introduced a labour intensive production pattern which allows it to take advantage of low wages and minimise the use of expensive machinery.[201]Furthermore, Chinese battery companies have gradually come to utilise domestically produced manufacturing equipment which is significantly cheaper than imported plant equipment. Assuming that economies of scale exist in the field of traction batteries, it can be assumed that they are **well positioned to drive down costs as they expand volumes, thanks to production patterns tailored to prevailing factor conditions and the availability of relatively low priced machinery and inputs.**[202] The fact that large investments have sparked a rapid capacity build up and led to important product and process innovations, reinforces the impression that China will inevitably become the world's prime production base for

[192]Automotive World (2012)
[193] Chosun Ilbo (2011b)
[194] Wang/Kimble(2010)
[195]The Climate Group (2008)
[196] Id.
[197] Id.
[198] Kasperk (2010)
[199] Roland Berger (2009b)
[200] GreenWheel EV (2012)
[201] Wang/Kimble (2010)
[202] Roland Berger (2009a)

traction batteries. Indeed, one industry expert consulted for this study confirmed that among the three core technologies related to electric vehicles (batteries, power electronics, and electric engines), competitive advantages are particularly strong in battery production.

This view, however, has oftentimes been disputed by **Chinese industry experts who argue that both in terms of R&D and production**, Chinese companies lag behind international competition. Particularly in regards to the prevailing quality and precision levels as well as standards and equipment, the development gap between them and their international peers is particularly large.[203] Four major problems have been identified as negatively affecting Lithium-Ion batteries. Firstly, Chinese Lithium-Ion battery makers struggle to come to grips with large performance variations of individual cells. The combination of large numbers of cells, necessary for making traction batteries, is thus greatly complicated. This shortcoming is attributed to immature production technology and substandard manufacturing equipment.[204] Secondly, despite their advantages in obtaining vital raw materials, Chinese companies have not yet developed necessary capabilities to make all major battery components such as separators and anodes. In these key areas, Chinese companies have to rely on imports for 80 percent of their inputs.[205] Thirdly, although Chinese battery makers have achieved breakthroughs in the development of several battery chemistries, the application of these capabilities is hampered by the fact that overseas companies have already registered patents in these fields. Fourthly, the use of domestic raw materials is complicated as they have to pass international certification standards as a prerequisite for the finished battery to pass certification. Deficits in this area have also negatively affected Chinese battery makers. [206]

One industry expert interviewed in China has remarked that the differences in dimensions and technical specifications of batteries used by various OEMs are a major reason why costs remain high. The lack of compatibility and exchangeability of batteries between electric vehicles from different manufacturers requires the development of customised solutions which consumes unreasonable amounts of resources. Furthermore, size and technical specifications could be a part of a business model which would enable the companies to differentiate.

In the same vein, the government endorses the standardization and modularization of batteries to ensure their applicability across the product line ups of all manufacturers. A unification of battery design is considered crucial to ramp up volume production and drive down costs.[207] However, this step would not only make electric cars more affordable but also improve the convenience for EV users in terms of buying, using, maintaining, and recycling batteries. As pointed out by several experts, **auto companies strongly oppose this concept as they fear a loss of influence and control over the automotive value chain**. They refuse to accept the idea to design a vehicle around a standardised core component and much rather prefer to have batteries customised to cater to the individual requirements of different vehicle models.

3.2.1.1.4 Global Battery Production in Comparison

It can be stated that European companies currently are weak in terms of battery production. Presently, the Lithium-Ion battery market is dominated by consumer electronic applications. **Panasonic (Japan) und Samsung (Korea) are the major players, both supply nearly half of the total production.[208]**Almost all battery suppliers have established joint ventures and partnerships with either an automotive OEM or a Tier1 supplier (see Chapter 3.2.1.1 and 3.2.3). The market for battery material and components is so highly concentrated that the top-3 suppliers cover 60-80% of the market.[209] Roland Berger (2011b) identified the following main market barriers for the production of cell components (see Figure 31):

[203] ESCN (2012)
[204] Id.
[205] China Commodity Net (n.d.).
[206] Id.
[207] Ministry of Science and Technology (2012
[208] Electrification Coalition (2009)
[209]According to Roland Berger (2011b): in terms of Anodes: BTR Energy and Nippon Carbon, Hitachi Chemicals; in terms of Cathodes: Umicore, Nichia and Toda Kogyo; in terms of separators: Celgard, Tonen/Toray and Asai Kasei and in terms of electrolytes: Mitsubishi Chem., Ube and Chail.

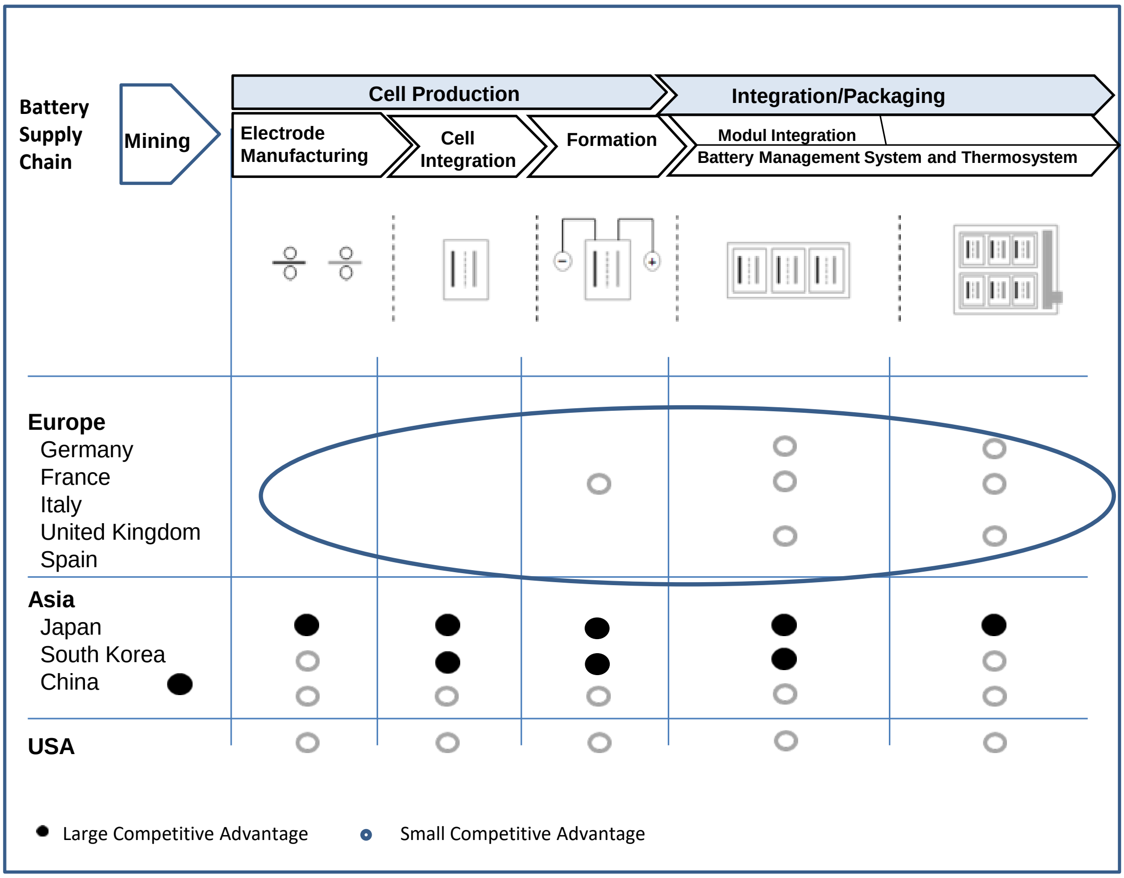
Figure 31: Market Entry Barriers for Battery Materials

Material	Market Barrier	New Entrants
Anode:	Investment, Production Know-how	Timcal (Switzerland)
Cathode:	Access to Raw Materials (especially Ni, Co, Mn)	BASF (Germany), Sumitomo Chem. (Japan)
Electrolyte:	Product Know-how	Idemitsu Kosan (Japan)
Separator:	Product Know-how, Production Know-how	Mitsubishi Cem. (Japan) Idemitsu Kosan (Japan) Mitsui Mining (Japan)

(Source: Own Compilation according to Roland Berger 2011b)

At present, European key players are hardly involved in the initial steps of the lithium-ion battery value chain, e.g. in terms of mining and trade of raw materials, cell production or component production (see Chapter 3.2.5.1 and Figure 31 and Figure 32).

Figure 32: Competitive Position of EU Automotive Industry in Battery Technology



(Source: Own Compilation)

However, since the European key players were able to build up capabilities in terms of battery assembly and packaging (e.g. AESC in Flins/France, Saft S.A. in Nersac/France, Deutsche Accumotive in Kamenz/Germany, Volkswagen Group in Braunschweig/Germany or Continental in Nürnberg/Germany), **starting points for successful backward integration exist.**

Due to the already existing shortage of engineers and natural scientists (e.g. in chemistry and material science) a successful build-up of a battery technology needs training initiatives (see also the policy recommendations in Chapter 6.3).

3.2.1.2 Production of Electric Engines

Electric mobility brings new driver concepts into the car, including different types of motors; in addition to simple asynchronous e-motors, permanent magnet synchronous motors and separately excited synchronous motors become relevant.

Characteristic features of the electric motor compared to an internal combustion engine are less complex and have a greater potential for standardization (roughly 200 parts versus 2,500). Electric motors for Battery Electric Vehicles only require gears with a fixed transmission ratio (except for parallel hybrid technology). **Unlike in the field of battery technology, engines for electric vehicle are based on technology which has been developed and produced in the EU for several decades.**Electric motors have already been used for decades in the area of mass transit such as the railway system. The majority of experts consider electric motors as a commodity:

> "Electric motors are less critical for success. There will be incremental cost reductions but no revolutionary breakthroughs!"[210]
>
> "In terms of electric motors, there will be only minor improvements, because the technology is already very mature!"[211]
>
> "The technology for electric motors is easy to handle, there will be hardly new impulses!"[212]

In the area of R&D, electric engines definitely still have potential for optimisation, e.g. in terms of:

- Use of know-how from industrial engines
- Wheel drives that enable new vehicle concepts (engine bay is not needed)
- Power density and weight
- Changes in design(reduction of the electrical resistance and thus the energy loss through heat in the engine with a modified design; thicker cables and lines mean lower losses but higher weight)
- Use of a speed control so that the engine consumes only as much energy as is actually required

3.2.1.2.1 European Electric Engine Production

In international comparison, Germany is in very good competitive position sharing its top position with Japan, followed by the U.S. Germany has a very high share of patents in electric motors (Germany 26%, Japan 26%, U.S. 18%, France 6%, UK 4%, China 1%, miscellaneous 19%).[213] According to a recent study by Plötz/Eichhammer (2011), **Germany is one of the most important exporters of electric motors in the world** and dominates particularly in multi-phase AC motors[214]. For several years, the international trade was dominated by China (about $7 Billion) and Germany (about $6 Billion).[215] The exported production value of both countries is at least two to three times higher than from American and other Asian competitors.[216]

The automotive supplier Continental can be regarded as a pioneer in terms of electric vehicles due to its current market share in the manufacture of electric motors and the associated volume of power electronics, batteries and electronic control of the powertrain division. Continental supplies e.g. electronics and the electric motor for the Renault Fluence Z.E. and Kangoo Z.E. models.[217]

Appendix XXV provides an overview on EU key players in electric engine production. Furthermore, its portfolio includes batteries, software, and power electronics. **In addition to Continental, global German suppliers like Bosch and Siemens are developing and producing electric motors in the EU as well.** Bosch produces systems and components for several types of electric vehicles and hybrid electric vehicles, including e.g. electric engines, software, chargers, and inverters. The French key player Valeo is developing a second generation of electric motors at affordable prices together with its

[210] Quote from a Chinese expert working at a Chinese Manufacturer
[211] Quote from a German expert working at a German manufacturer
[212] Quote from a Chinese expert working at a Chinese manufacturer
[213] Plötz/Eichhammer (2011)
[214] AC: Three-phase motors
[215] Includes different uses, but mainly engines for industrial purposes.
[216] See Plötz/Eichhammer (2011), p. 19.
[217] Autohaus (2012a)

partners Leroy Somer and GKN. **They focus on cost reduction of the complete electric motor, including the inverter, charger, voltage converter, and reduction gears, to become reduced to equal of half the cost of a gasoline driven powertrain (engine, gearbox and differential).** Therefore, Valeo collaborates with different partners such as Leroy-Somer, Saft, GKN, Michelin, and Leoni.[218] Furthermore, Portugal has a very strong and varied automotive supplier industry in terms of the production of electric and electronic components. According to IEA five of the six main global component suppliers have production facilities in Portugal, i.e. Delphi, Faurecia, Bosch, Lear and Johnson Controls. From a geographical point of view, about 22.2 percent of the automotive component industry sales (including electric and electronic components for all vehicle types) belong to Germany, followed by Portugal (21 percent), Spain (18.3 percent) and France (16.2 percent), while the rest includes other countries like the United Kingdom, Belgium, Austria or Italy.[219]

Unlike in the field of battery technology, engines for electric vehicles are based on a technology which has been developed and produced in the EU for many decades. Electric engines have high potential for standardization especially when focussing on production technology. **The experts interviewed for this study confirm that the European automotive industry currently has a strong competitive position in R&D and production of electric engines**. **However, due to the high potential of standardization that can be expected, the value added regarding the production of electric engines will shift from the EU to low-wage countries like China in the future**. The majority of experts emphasise, that the production of electric motors does not require specific skills.

Nevertheless, it has to be stated, that in the EU suppliers like Bosch and Continental engage in the production of electric engines in cooperation with carmakers to provide a better implementation of the powertrain components into the vehicle. While most OEM purchase electrical components (especially electric motors for their electric vehicles) from suppliers, the Volkswagen Group for example, decided to engage in the production of electric engines in its plant Baunatal/Kassel for its own needs. Apart from that, Daimler has founded a joint venture with Bosch in order to produce electric engines (see Chapter 3.2.3). Presently, the EU manufacturers produce electric motors for their own requirements. Industrial plans concerning exports to foreign competitors have not been published yet.

3.2.1.2.2 U.S. and Asian Electric Engine Production in Comparison

In the U.S., electric engines particularly for the automotive industry are manufactured by three key players: General Electric, GM Powertrain, and Ohio Electric Motors (see Appendix XXVI).

Appendix XXVII provides an overview on Asian key players in electric engine production. In Korea, for example, a division of Hyundai (Hyundai Motors Electric) produces electric engines for electric vehicles. In Japan, electric engines are manufactured by Yamaha, Kokusan Denki, and Jeco Ko. The Chinese companies Shanghai Edrive, Sichuan Dongfeng Electric Machinery Works and Zhejiang Unite Motor also operate in the production of electric engines for electric vehicles. Zhejiang Unite Motor is one of the key players, with an annual capacity of about 5 Million various engines and a total investment of about $50 million.[220]

Compared to Europe both the U.S. and the main Asian countries do not presently have a competitive advantage in R&D and production of electric engines. In summary, the European key players are well positioned in terms of R&D and production of electric engines compared to their competitors from the U.S. and Asia. The Chinese industry currently has a less innovative potential. The Japanese economy has indeed a good position, but is lacking in the international trade of electric motors, especially with three-phase motors. Since electric engines have been considered a "commodity" by most experts, they are expected to be purchased from global suppliers with the best quality-price ratio in the future.

[218] IEA (2011a)
[219] IEA (2011a)
[220] See more detailed information in Appendix XXVII.

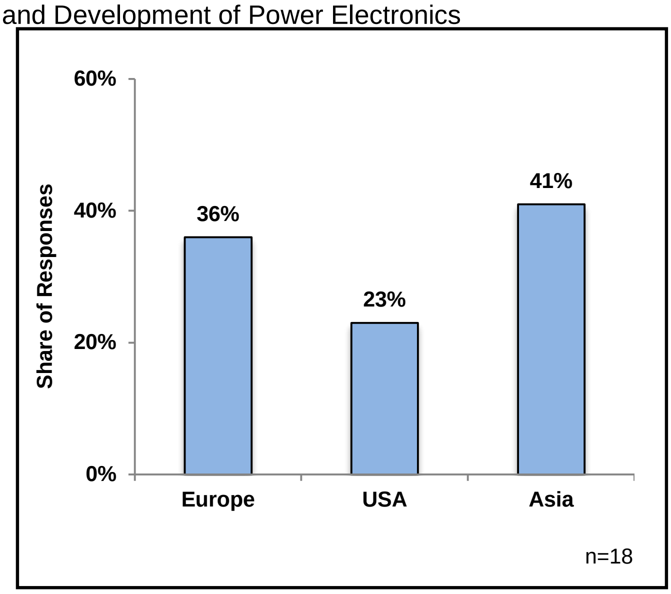
3.2.1.3 Production of Power Electronic Components

The electric drivetrain in an electric vehicle requires three main power electronic components:

- **the drive inverter** converting the DC battery voltage to a three phase voltage to supply the electric machine,
- the A(?)C-DC converter connecting the high voltage wiring system with the 12V wiring harness and
- the battery charger converting the AC voltage supplied by the grid to a DC voltage to recharge the battery, respectively.[221]

Most of the experts, who have been surveyed in this study, consider competitiveness of the EU automotive industry in terms of power electronics as substantial. "Power electronics is the core of electric vehicles," has been emphasised by a German manufacturer. Therefore, car manufacturers are focusing on partnerships with capable and experienced suppliers, especially with Tier1 suppliers (e.g. Bosch or Continental). **Nevertheless, according to the majority of experts interviewed, power electronics are currently even more developed and produced in Asia than in Europe** (see Figure 33).

Figure 33: Assessment of the Experts on the Future Production and Development of Power Electronics



(Source: Own Compilation based on Expert Interviews)

The Chinese experts in particular expect a market opportunity in the field of power electronics. However, a Germany based global manufacturer emphasised that power electronics are especially important. Therefore, they will be developed and produced by OEMs in cooperation with certain capable Tier1 suppliers. **In terms of power electronics, quality and performance are expected to outweigh low cost in terms of importance**.

3.2.1.3.1 European Power Electronic Production

In the area of power electronics, European companies currently have a strong competitive position. The majority of experts interviewed in this study consider German companies as being particularly competitive, due to a high competence in the field of power electronics. Unlike electric motors, power electronic components are technically complex and difficult to imitate. In terms of power electronics, Bosch, Continental, Siemens, and Infineon can be considered key players in the EU.

Furthermore, many small-and medium-sized enterprises operate in the area of power electronics (see Appendix XXVIII). The majority of European experts, who have been surveyed in this study, consider

[221] For further information refer to Appendix IV.

the German automotive industry especially as a pioneer in terms of development and production of power electronics in the EU.

3.2.1.3.2 U.S. and Asian Power Electronic Production in Comparison

Appendix XXIX provides an overview on current key players in the U.S., which are for example AC Propulsion, Azure Dynamics, Delphi and GM Powertrain. In Asia many more companies are operating in the business of power electronics, especially in Japan and Korea (see Appendix XXX). The Japanese Key players include Aisin Seiki, Denso, Hitachi, Kokusan Denki and the powertrain divisions of the main Japanese manufacturers Mitsubishi, Nissan, and Toyota. The key players in Korea are Deasung Electric, Korea Electric Terminal, and the powertrain division of Hyundai. In China BYD and the Delphi Group China are esteemed key players in terms of power electronics.

The majority of experts assume that Asian companies will occupy leading positions in terms of R&D and production of power electronics in the future, followed by Europe. Due to low weight and no special logistical requirements, power electronics do not require a location close to the assembly facilities of the manufacturers. Concerning the future competitive position of the EU automotive industry in terms of power electronics, the majority of experts interviewed distinguish between the R&D and production of these components. **While the development of power electronics in the future is expected to take place in the EU, cost aspects will be especially crucial, regardless of whether or not the production of power electronics will be located in the EU.**

In summary, the European automotive industry currently has a good competitive position concerning the R&D and production of power electronics in comparison with their competitors, especially from Asia.

A German expert from the electric component area confirms that particular power electronics will be very important concerning the system effectiveness and driving quality of the electric vehicle.

Compared with Asia and the U.S., the competitive position of the EU automotive industry in terms of power electronics is valued much higher by the majority of experts interviewed than for example in battery technology. Based on experience and technical know-how, the EU automotive industry has a good foundation to maintain its competitive position and to develop this position, both in terms of R&D as well as in production.

3.2.1.4 Final Assembly

Final assembly in industrial production means a systematic assembly of components (e.g. electric engine) and modules (e.g. instrument panel, front-end) into complete products (e.g. electric vehicle) or into components/modules of higher product levels(e.g. headlights, heat exchangers and bumper are assembled to one front-end module).

From the perspective of electromobility the question arises whether OEM or suppliers will operate in the field of final assembly of electric vehicles in future. **Several alternatives in terms of final assembly are conceivable:**

- **(traditional) OEM (e.g. Production of Renault Twizy in Valladolid/Spain)**
- **Tier- 0.5 suppliers (e.g. contract manufacturers like Magna Steyer)**
- **New Entrants (e.g. Electricity Provider, Practical example: RWTH Aachen)**

The development and production of electric vehicles require large investments (which can be encouraged by Public Policy with special depreciations – see chapter 6.3). For new players the economic risk of an insecure development in electromobility is probably very high. **The leading OEM will benefit from their access to the customers. Furthermore, they can grant after-sales services.**[222]

In the field of EV components, manufacturers are currently pursuing different strategies. While some manufacturers such as BMW and Volkswagen have decided to develop **in-house production of the**

[222] Enevate (2012)

main components of the electric powertrain (e.g. electric engines, battery assembly), other manufacturers have decided to **purchase these components**. Renault, for example, recently reported that the batteries for the Zoé will be purchased from LG Chem, instead of producing them in Flins near Paris. There are still talks about a battery factory in France, with shared ownership by Renault and LG, but it could also be possible that Renault will expand deliveries from Korea.[223]

Box 4: BMW - Homemade Technology

BMW decided to overtake even simple tasks of the value chain of electric vehicles, instead of outsourcing activities to suppliers. The manufacturer is investing 125 million Euro into its plants in Landshut and Dingolfing. The BMW plant in Dingolfing (Germany) will manufacture the battery (packaging), the electric engine and the aluminium structure of the chassis of its i-brand family. The cells will be purchased from SB LiMotive (Bosch & Samsung).[224] About 30 kilometers away in the Landshut plant CFRP body panels and electric motors, range extender components, high-voltage batteries and engine-transmission units will be produced. Thus, the Lower Bavarian locations Dingolfing and Landshut will be the main “suppliers” of the BMW plant in Leipzig, assembling the new electric vehicles i3 and i8.[225]

According to a survey by KPMG (2012), **Tier 0.5 suppliers will play a major role in terms of the final assembly of (electric) vehicles(e.g. suppliers like Magna Steyer or Valmet).** These suppliers **operate as contract manufacturers**; they are responsible for the complete car design and the development of capabilities including the vehicle production. Infiniti will produce its new compact hybrid Etherea at Magna Steyr in Austria by 2014. This will be the first time that a complete car of an Asian manufacturer has been developed and produced by a European Tier-0.5 supplier. The final assembly will probably take place in Graz.[226]

Furthermore, 8 percent of the respondents of the KPMG survey believe that new entrants will gain significance in the value chain.[227] Immature e-technologies and relatively low complexity will allow newcomers to compete with established manufacturers. According to the European Network of Electric Vehicles and Transferring Expertise (ENEVATE), about 30 percent of the total value added per vehicle is generated in the powertrain sector of vehicles with an internal combustion engine. About 44 percent of the effort is generated by the OEM with focus on the basic motor.[228]In terms of electric vehicles, the area of electronic components is dominated by the supplier industry. OEMs have to claim their part in the value chain.[229]

In contrast, the **majority of experts interviewed in this study expect that electric vehicles will be produced and offered by traditional OEMs**. While the European experts expect that the development and assembly of future electric vehicles will be located in the EU, the experts from other regions (e.g. Japan, Korea, China and the U.S.) believe that their domestic OEM will stabilise and extend the value added, even abroad.

Nissan for example is creating capacity to produce 250,000 Leafs a year, with annual production plans of 25,000 units in Sunderland (UK); 150,000 in Smyrna, Tennessee (U.S.) and 50,000 in Japan.Local production will reduce capital commitment (shipping time) and will mitigate currency fluctuations. Instead, the Citroen C-Zero and the Peugeot Ion are manufactured at Mitsubishi plant in Okazaki (Japan). The joint production with Mitsubishi i-MiEV leads to synergies and economies of scales. Furthermore, Opel produces its Ampera Range Extender which is identical to the Chevrolet Volt in Hamtramck (Michigan).The Fiat-Chrysler group plans to manufacture the electric version of the Fiat 500 in Toluca (Mexico).

In contrast, Renault produces its electric vehicles in Europe. The Kangoo Z.E. is a light commercial vehicle with battery electric propulsion produced on the same assembly line as the Kangoo, with an internal combustion engine, in the production plant in Maubeurge (France). In 2012 Renault launched

[223] Motornature (2012b)
[224] Handelsblatt (2012a)
[225] Automobilindustrie Vogel (2012)
[226] Kleinezeitung AT (2012)
[227] KPMG (2012)
[228] Enevate (2012)
[229] Enevate (2012)

its new Twizy Z.E., produced in Valladolid (Spain), and the Fluence Z.E. sedan, which is manufactured in Bursa (Turkey). Apart from that, Renault will build its battery electric vehicle Zoé in Flins, near Paris.The Zoe is expected to be for sale in Europe in autumn 2012/spring 2013. The batteries will be built in Flins, corresponding to Renaults' strategy of producing electric vehicles and components close to the market. BMW and Volkswagen are also building up production capacity in the EU (see "Industrial Plans", Chapter 3.3.1)

In terms of R&D and the production of electric vehicles, both competitive position and market proximity will play significant roles. Presently, EU automotive manufacturers have a well based competitive position in comparison to competitors from the U.S. and Asia. Due to **high investments and experience (e.g. in terms of electrochemistry and electronics) among the EU automotive key players, new joint ventures and alliances (of different key players) will gain importance** in order to strengthen the competitive position – even in terms of manufacturing (e.g. production of Peugeot Ion and Citroen C-Zero at Mitsubishi's assembly line in Japan).

Based on their overall strengths (e.g. diversity of vehicle types, multi-brand differentiation or mixed strategies like minimal cost differentiation), the EU manufacturers benefit from their leadership in diesel technology and export intensity. **During the transition to electromobility EU manufacturers will benefit from several strengths:**

- **Economies of scale** (modularization, diversified product mix) - due to operation in almost all vehicle segments and classes
- **Know-how in lower vehicle segments**, which have been determined to be very appropriate for the BEV segment because of their low weight and size.
- **Efficient and lean manufacturing processes** from platform and module strategies (e.g. model kit of Volkswagen) with simultaneous differentiation between vehicle types and models will lead to further advantages, particularly in electromobility. In the transition to electromobility an increasing amount of modularization can be expected.

In contrast, the European manufacturers are faced with various weaknesses such as:

- The **saturation of the domestic market**.
- The fact that **additional assembly capacities are not expected** (focus is currently on utilization of existing capacity). In fact, most of the experts await a shift to third countries and BRIC markets in the field of assembly (e.g. Eastern Europe, North Africa or Turkey).

Based on the discussions with several experts we anticipate that the final assembly of electric vehicles will be located in markets with the largest market opportunity. In the next few years in particular, a trend for hybrid- and plug-in electric vehicle sales will emerge (see the results of our market model in Chapter 2.3.2). **Due to the possibility of manufacturing plug-in hybrid and electric vehicles (e.g. Ford Focus BEV, Smart BEV) with other vehicle types on a shared assembly line, we do not expect a shift of value added in vehicle assembly outside the EU in the medium term.**

In the long term, the vehicle concept (i.e. "Purpose Design") of the electric vehicle will be crucial, whether the integration of electric vehicles in an existing production line will be possible, or whether the production of electric vehicles will be consolidated, especially in the markets with the highest market growth.

3.2.2 Patent Applications in EV-Technology

The leading position of the European automotive industry in powertrain technology is based on the traditional ICE technology. **In transition to alternative propulsion technologies the European automotive industry faces the challenge of how to compensate for the existing technological gap between them and the Asian OEMs and suppliers in the field of electric mobility** as quickly as possible. While Asian OEMs have pushed the hybridization of the powertrain intensively since the early 1990s, the development of know-how and the preparation for mass-production has only been part of the European automobile industry in recent years. The number of patent publications can be used as an indication for innovation and thus also for the technological leadership of individual companies, countries, or regions.

Although the sheer number of patents still does not allow for conclusions about the quality of the inventions described herein, the scope of the patent portfolio turns out to be one of the key factors in licensing and/or collaborating agreements – the higher the number of patents a company owns, the more it is considered a suitable partner for e.g. joint ventures.[230] In this context, **it has to be noted that only a part of the innovations and inventions of companies are registered as patents –a significant amount of them are handled as trade secrets and are not disseminated to the public**. Since this part of the innovations and inventions amount to deprivations within the systematic collection and because there is no reliable data on the patent rate of individual companies, trade secrets are not taken into consideration.

For the keyword search on EV technology in the database ESPACENET of the European Patent Office the search terms "electric vehicle", "hybrid vehicle", "Elektrofahrzeug", "Hybridfahrzeug", "traction battery" and "fuel cell" were connected by a Boolean “OR”-operator. For detailed information on the research strategy and for the companies included in the study, please refer to appendix XXXI. In addition the appendix XXXII contains a detailed table of the number of patents per firm over time. For this reason in the following sections the citation of absolute numbers is waived to improve clarity.

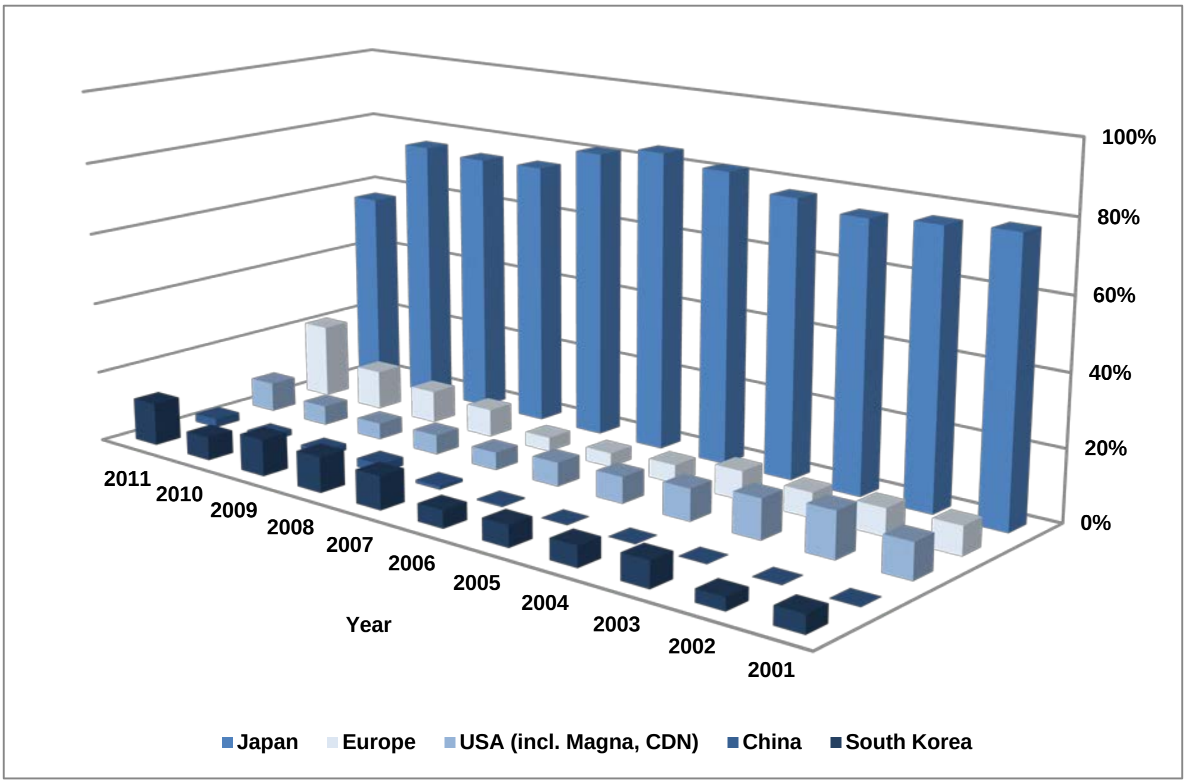
Initially, the following chapter will analyse the distribution of patents in EV technology by region (Chapter 3.2.2.1), by groups of companies (Chapter 3.2.2.2) and by OEMs (Chapter 3.2.2.3) respectively for the years 2001 to 2011. Furthermore, the relation of patents in EV technology to all other patents (i.e. 2001 to 2011) will be considered (Chapter 3.2.2.4).[231]

3.2.2.1 Patents in EV Technology by Region (2001 to 2011)

To perform an analysis of the global distribution of patent applications in EV technology covering a total of 50 companies**,** the companies were clustered by regions (OEMs´ headquarters): Japan, Europe, the U.S.(including Magna, Canada), China, and South Korea. A subdivision in OEM, suppliers and service providers did not take place in this chapter. Figure 34 shows the regional distribution of patent applications in EV technology for the period from 2001 to 2011.

[230] Koch/Meisinger (2011), p. 4.
[231] Appendix XXXI provides an overview on patents in EV Technology 2001 to 2011

Figure 34: Patents in EV Technology by Region in Percent (2001-2011)



(Source: Own Compilation)

The overwhelming dominance of Japanese companies is shown here very clearly of which have continuously logged almost 75 percent of the total patents in respect to EV technology in the period from 2001 to 2007.

At the beginning of the millennium, U.S. companies (including Magna, Canada) were in second place, while European OEMs and suppliers were in third place. It should be pointed out that there are two independent countries capturing the first and second places while third is a grouped "Europe", consisting of the four countries, Germany, France, United Kingdom, and Italy.

Starting in 2008, a positive trend – especially among the European countries – was recorded. By 2011 about 20 percent of worldwide patent applications in EV technology were filed by the countries Germany, France, the United Kingdom, and Italy. The relative decline of Japanese companies, which submitted about 20 percent fewer applications in 2011, is notable as well. The main reason for this shift is likely two pronged; thanks to the increased attention on alternative drives in Europe since about 2006 on the one hand, and the economic crisis of 2008/2009on the other, which has adversely affected Japanese companies. In the aftermath of the world financial crisis, many organizations cut back their development budgets, leading to a lower number of patent applications with a time lag of about 18 to 20 months. Both the United States (including Magna, Canada) and South Korea have been on an almost constant level over the last decade. Asimilar picture is shown in the study by Koch and Meisinger (2011).[232] **In summary, the European companies have shown a positive development in patent applications in EV technology in the last few years,** which is also reflected in the increase of public reporting and perception. However, although this is a sufficient noticeable upward trend in Europe, it is doubtful that European companies will catch up with the Asian companies within a few years.

[232] Koch/Meisinger (2011), p. 13.

3.2.2.2 Patents in EV Technology by Group (2001 to 2011)

If in addition to the regional allocation of patent applications from the field of electric vehicles, the split between different groups of companies is also taken into account, a more complex picture materialises. For this purpose, the 50 analysed companies are split into the groups "OEM" and "supplier" and "service provider" (see Table 22).

Table 22: Companies included in Patent Research

OEM		Supplier	
Country	**Company / Applicant**	**Country**	**Company / Applicant**
Germany	Bayerische Motoren	USA	3M
China	BYD	USA	A123
China	Chery	Japan	Aisin Seiki
USA	Chrysler	Germany	BASF
Germany	Daimler*	Germany	Benteler
Italy	Fiat	Germany	Continental
USA	Fisker	USA	Delphi
USA	Ford	Japan	Denso Corp
China	Geely	France	Faurecia
USA	General Motors	United Kingdom	GKN Driveline
Japan	Honda Motor	Japan	Hitachi Automotive
South Korea	Hyundai	South Korea	Hyundai Mobis
Japan	Mazda Motor	USA	Johnson Controls
Japan	Mitsubishi	USA	Lear
Japan	Nissan Motor	South Korea	LG Chem
France	Peugeot Citroen	Canada	Magna
Japan	Suzuki Motor	Italy	Magneti Marelli
USA	Tesla	Germany	Robert Bosch
Japan	Toyota Motor	France	Saft
Germany	Volkswagen**	Germany	SB LiMotive
*incl. DaimlerChrysler / ** incl. Audi		Japan	Sumitomo Electric
Service provider		Japan	Toyota Boshoku
USA	Better Place	USA	TRW
France	Electricité de France	France	Valeo
USA	General Electric	Japan	Yazaki
Germany	RWE	Germany	ZF

(Source: Own Compilation)

Furthermore, a subdivision into "TOP 10 OEM"[233] and "other OEM" and "TOP 10 supplier" and "other supplier" was conducted. The assignment to the subgroups is based on the sum of patents in EV technology from 2001 to 2011. The "TOP 10 OEM" and "TOP 10 Supplier" include the following companies (see Table 23):

[233] Own compilation based on the sum of patents in EV technology.

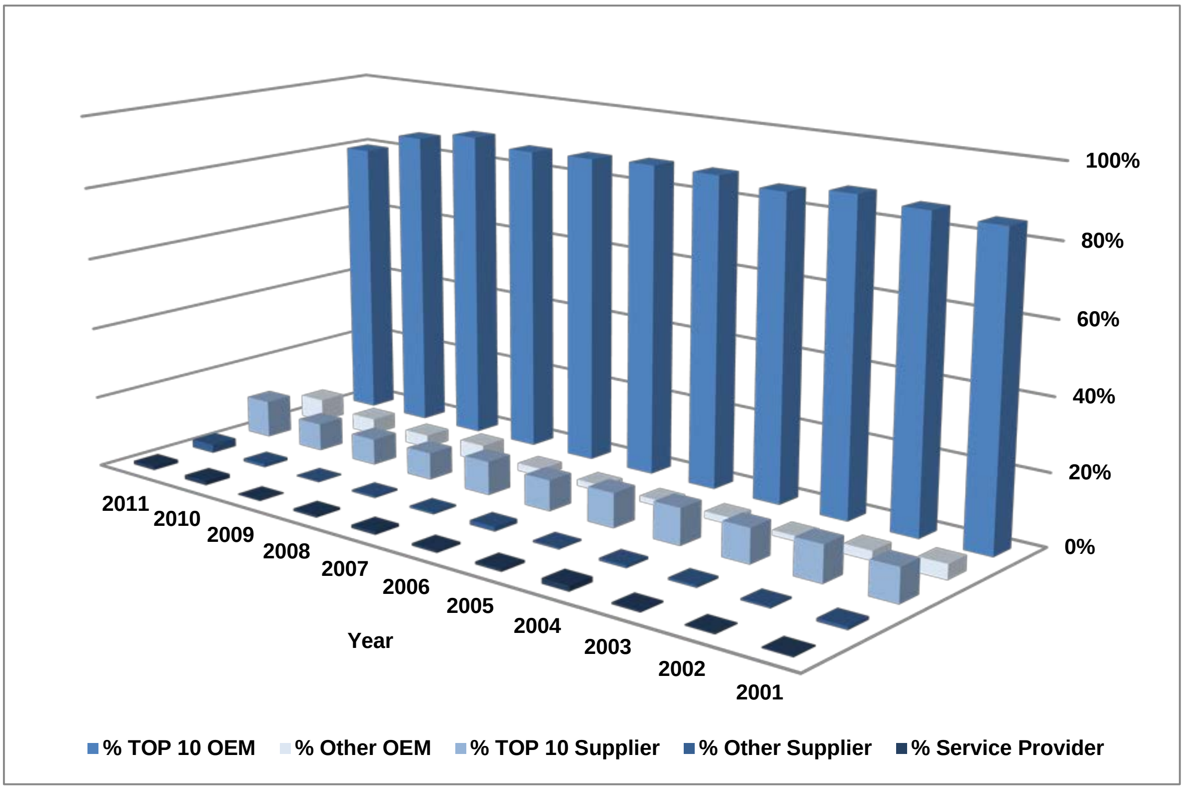
Table 23: Patents in EV Technology by "TOP 10 OEM" and "TOP 10 Suppliers"

OEM		Supplier	
Country	**Company / Applicant**	**Country**	**Company / Applicant**
Japan	Toyota Motor	Japan	Denso Corp
Japan	Nissan Motor	Germany	Robert Bosch
Japan	Honda Motor	Japan	Aisin Seiki
USA	Ford	Germany	Continental
Japan	Mitsubishi	Canada	Magna
South Korea	Hyundai	South Korea	LG Chem
Germany	Daimler*	France	Faurecia
USA	General Motors	USA	Johnson Controls
France	Peugeot Citroen	USA	Delphi
Germany	Volkswagen**	Germany	ZF
	*incl. DaimlerChrysler / ** incl. Audi		

(Source: Own Compilation)

All of the OEM and suppliers not listed are assigned to the subgroups "Other OEM" and "Other Suppliers". Following this assignment, the Figure 35 provides an overview on patents by group in percent.

Figure 35: Patents in EV Technology by Group in Percent (2001-2011)



(Source: Own Compilation)

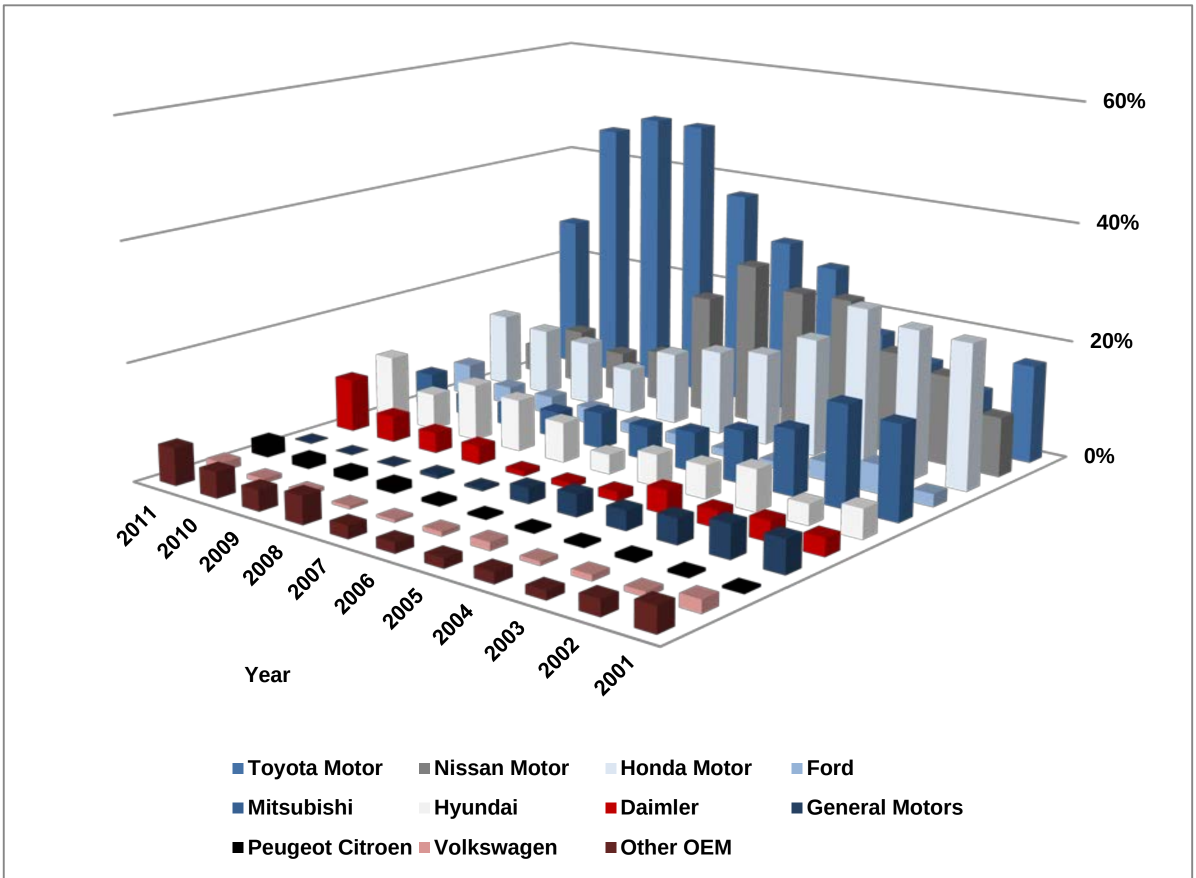
Quite surprisingly depicted, the proportion of the "TOP 10 OEM" in patent applications related to EV Technology has remained almost unchanged at about 80 percent during the past decade (see Figure 35). Only in the last two years a slightly decreasing trend is visible. The proportion of suppliers in total – "TOP 10 Suppliers" plus "Other Suppliers" – has also changed little over the past decade and is about 8 to 12 percent. Only a slight increase in the "Other OEM" and the "Other Supplier" applications can be recognised, which remains in the lower single digits. **Background for this increase is most**

likely the intensified dedication of external suppliers in the automotive industry, particularly of companies from the chemical and electronics industry. A low but growing, primary involvement of the "Other OEM" – these are the new Chinese car manufacturers – in the field of innovation and patent application related to EV technology can already be recognised**. In summary, around 4/5 of all innovations and patent applications in the field of electric vehicles are performed by only 10 OEM**. Only three suppliers (Robert Bosch (381), Aisin Seiki (741), Denso Corp. (486)) can match major OEM (General Motors (494), Peugeot Citroen (308), Volkswagen incl. Audi (245)) in number of patents in EV technology filed in the period 2001 to 2011. It remains to be seen, whether suppliers from the field of chemical and electrical engineering can become established in the automotive industry given to the increasing shifts in the supply chain, not only in the field of production, but also in R&D and the build- up of core competencies. These obstacles could pose additional threats to European companies, as the particular suppliers for lithium-ion cells and electric motors are currently located in Asian countries.

3.2.2.3 Patents in EV Technology by OEM (2001 to 2011)

As stated in the previous chapter, about 80 percent of all patent applications worldwide in EV technology are filed by the "TOP 10 OEM". Figure 36 shows the detailed distribution of the patent applications in EV technology in the period 2001 to 2011 by the OEMs.

Figure 36: Patents in EV Technology by OEM in Percent (2011-2011)



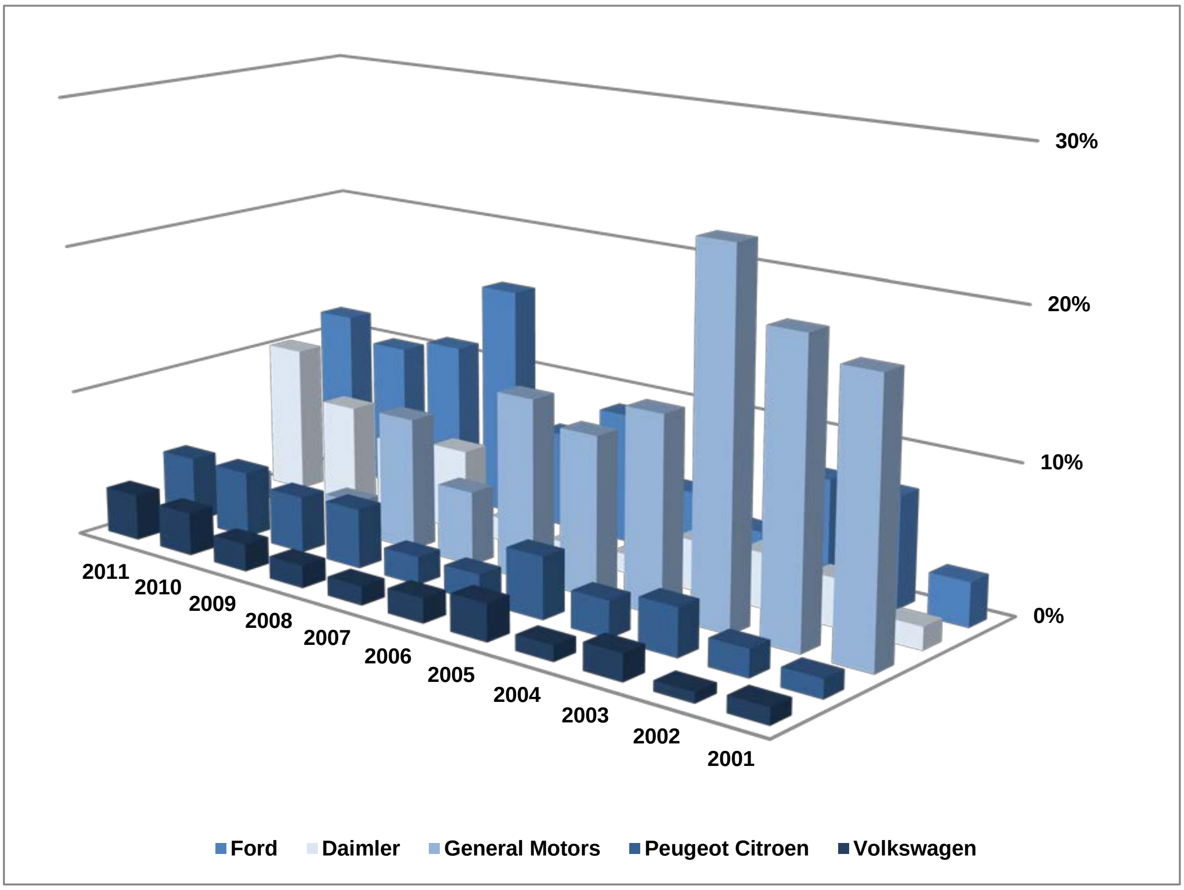
(Source: Own Compilation)

As clearly shown, **the Asian OEMs own by far the largest share of patents in EV technology. During the period 2001 to 2005**, Toyota Motor, Nissan Motor, and Honda were moving at an almost similar level. **Between 2007 and 2010, however, almost 40 percent of all patents worldwide by OEMs in EV technology were owned by Toyota Motor**. Since 2010 a slightly opposite trend can be observed, to which the manufacturers Hyundai, Daimler and – to a lesser extent – Peugeot Citroen have contributed to. In summary, only three Japanese manufacturers, Toyota Motor, Nissan Motor, and Honda account for the bulk of new patents in EV technology in 2004/2005.**2011 saw filings from a much wider pool of companies**. In this context it is quite interesting that the patent application numbers from the major OEMs, i.e. General Motors, Ford, and Volkswagen which are among the TOP 5 worldwide in annual turnover, are very small. While General Motors held a considerable share of patents in EV technology at the beginning of the last decade, it has currently almost sunk to zero. Both Ford and Volkswagen have stagnated at low levels; though arguably in the years from 2009 to 2011 a slight positive trend can be observed.

3.2.2.4 Relation Patents in EV Technology to all Patents (2001 to 2011)

As outlined above, in addition to the ability to protect intellectual property by means of a patent, there is the option to treat innovations or inventions as trade secrets. It appears that Asian companies prefer the protection of a patent application, while European and American companies rely more on internal measures to preserve trade secrets and reject the filing of patents. To investigate this possibility, all (conventional &EV technology) patents filed in the period 2001 to 2011 by the American and European OEMs Ford, DaimlerChrysler, General Motors, Peugeot Citroen, and Volkswagen were identified. Whether or not the above mentioned OEMs have reinforced their R&D efforts in the field of electric vehicles can only be deducted from the ratio between conventional patents and electric vehicle patents. **Figure 37 shows the proportion of patents in EV technology in relation to the grand total of filed patents in the period 2001 to 2011 by the aforementioned OEMs**.

Figure 37: Patents in EV Technology/All Patents in Percent (2001-2011)



(Source: Own Compilation)

As shown in Figure 37, Ford has maintained a level of EV technology related patent applications of about 8 to 10 percent for several years. By contrast, from 2001 to 2003 General Motors' share ranged from 10 to 15 percent but has since greatly declined to the lower single digits from 2009 to 2011. A positive trend is reflected in Daimler, which in the past few years has expanded its share to almost 10 percent in 2011. The two OEMs Peugeot-Citroen and Volkswagen including Audi have remained below five percent throughout the past ten years. In a nutshell, while Ford and Daimler have actively engaged in patent applications in EV technology in recent years, Peugeot Citroen and Volkswagen have stagnated at the same low level. General Motors has heavily waived submission on patent applications in EV technology in recent years.

3.2.3 Joint Ventures and Alliances in the field of Electromobility

To accelerate the transition to electromobility there is a need for cooperation between automotive manufacturers and suppliers, but new entrants can also play a role. In times of a rapid technological change, particularly from the perspective of the European key players vis-à-vis their Asian competitors (see Sections 3.2.1 and 3.2.2) cooperation is used as a strategy to assist rapid catching-up (e.g. leapfrogging).**Therefore, current joint ventures and alliances have been analysed in the countries and regions under review**(see Tables 24 to 26).

Table 24: Joint Ventures and Alliances by Country in the EU

Location of Cooperation	Companies	Origin of Cooperating Companies	Targets	Type	
Belgium	PSA and General Electric (Brussels)	FR (Paris) Connecticut (Fairfield)	Development of an electric mobility offer for corporate clients in Europe	R&D	Int
France	PSA and Bosch	FR (Paris) DE (Gerlingen)	Strategic partnership: Bosch supplies electric powertrains for Peugeot 3008 Hybrid4	Pr	Int
	Renault and Continental	FR (Boulogne-Billancourt) DE (Hanover)	Continental provides drive motors, power electronics and EV controllers for Renault's electric passenger cars	Pr	Int
	PSA and BMW, 50:50 Joint Venture	FR (Paris) DE (Munich)	Cooperation for hybrid components: High-voltage batteries, E-engines, generators, power electronics, battery chargers, software for hybrid-systems	R&D	Int
	Renault and Daimler	FR (Boulogne-Billancourt) DE (Stuttgart)	1. Strategic partnership: Joint platform for compact cars (Twingo, Smart) 2. Option for an alliance on EVs and batteries	R&D/ Pr	Int
	Renault, CEA Institute and LG Chem	FR (Boulogne-Billancourt) KR (Seoul)	Development and Industrial Production of next generation batteries. Installation of European battery factory in France	R&D	Int
	Renault-Nissan, NEC (AESC)	FR (Boulogne-Billancourt), JP(Tokyo)	See Table "Asian Joint Ventures and Alliances by country", AESC Japan		
Germany	Opel and Eco-Electricity-Suppliers	DE (Rüsselsheim)	Opel cooperates with 18 German eco-electricity-suppliers in order to guarantee CO2-free driving to "Ampera"-drivers	Pr	Nat
	Audiand Voith	DE (Ingolstadt) DE (Heidenheim)	Cooperation on fiber-reinforced materials (Voith holds a 9.14 percent share in SGL Carbon)	R&D (I)	Nat
	BMW and SGL Group	DE (Munich) DE (Wiesbaden)	BMW holds a 26.87 percent share in SGL Carbon via SKion Joint Venture "SGL Carbon Fibers" with a carbon-fiber-reinforced- plastic-plant in Moses Lake (U.S.)	Pr (I)	Nat
	VW and SGL Carbon	DE (Wolfsburg) DE (Wiesbaden)	VW holds a 8.18 percent share on SGL Carbon SE (lightweight components)	R&D (I)	Nat
	Bosch and VW, Porsche	DE (Gerlingen) DE (Wolfsburg) DE (Stuttgart)	Cooperation for the development of a parallel-hybrid drivetrain	R&D	Nat
	Brose and SEW Eurodrive	DE (Coburg) DE (Bruchsal)	50:50 Joint Venture "Brose-SEW Elektromobilitäts GmbH & Co. KG", Development and production of electronic drive and charging systems	R&D	Nat
	Audi and E.ON, TU Munich, Stad-twerke Munich	DE (Ingolstadt)	Field trial on the Audi A1 e-tron	R&D	Nat
	BMW and Siemens	DE (Munich) DE (Munich)	Cooperation on the development of the technique for inductive (contact-less) charging	R&D	Nat
	BMW and Vattenfall Europe	DE (Munich) DE (Berlin)	Field trial in Berlin with a Mini E by BMW and a charging infrastructure by Vattenfall	R&D	Nat
	BMW, Siemens, Stadtwerke Munich	DE (Munich)	Field trial in Munich with a Mini E by BMW and a charging infrastructure by Siemens	R&D	Nat
	Continental and Akasol Engineering	DE (Hanover)	Cooperation on the development of high-voltage Li-Ion-battery systems	R&D	Int

	Schaeffler and TU Munich	DE (Herzogen-aurach)	Development of an active electronic differential	R&D	Nat
	Daimler and RWE, EnBW	DE (Stuttgart) DE (Essen)	Filed trial “e-molbility Baden-Württemberg” Damiler provides 200 EVs and fuel cell vehicles EnBW builds up the charging infrastructure	R&D	Nat
	Daimler and RWE	DE (Stuttgart) DE (Essen)	Field trial “e-mobility Berlin” with EVs and fuel cell vehicles by Mercedes-Benz and a charging infrastructure by RWE	R&D	Nat
	Siemens and Ruf	DE (Munich) DE (Pfaffen-hausen)	Cooperation for building up a trial fleet of 10 Porsche 911 with different electronic powertrain concepts	R&D	Nat
	VW and Varta Microbattery	DE (Wolfsburg) DE (Hannover)	R&D-Cooperation for EV-batteries	R&D	Nat
	Daimler and Toray Industries Inc (Jap)	DE (Stuttgart) JAP (Tokyo)	Joint Venture (Daimler 44.9 percent, Toray 50.1 percent, Others 5 percent) located in Esslingen for the production and marketing of carbon-fiber-reinforced- plastic vehicle parts	Pr	Int
	Bosch and BASF (materials), Thyssen-Krupp (System engineering)	DE (Gerlingen, Ludwigshafen, Essen)	Partnership for building up a pilot plant for the development of materials and manufacturing processes of lithium-ion-cells	R&D/ Pr	Nat
	Daimler and Bosch	DE (Stuttgart) DE (Gerlingen)	50:50 Joint Venture: “EM-motive” for the development, production and sales/distribution of electronic engines for vehicles	R&D/ Pr	Nat
	Daimler and Linde	DE (Stuttgart) DE (Munich)	Cooperation for the enforcement of building-up 20 hydrogen filling stations	R&D/ Pr	Nat
	Daimler and Evonik	DE (Stuttgart)	1. Joint Venture: “Li-Tec” (Daimler 49.9 percent, Evonik 50.1 percent) 2. Joint Venture: “Deutsche Accumotive” (Daimler 90%, Evonik 10 percent) Both: Battery systems for electronic mobility	R&D/ Pr	Nat
	ZF and Continental	DE (Friedrichs-hafen) DE (Hanover)	Cooperation for the development and production of hybrid-powertrains in commercial vehicles	R&D/ Pr	Nat
	RWE and BYD	DE (Essen) CN	Joint field trial in Germany in 2011, RWE provides fast-charging technology	R&D	Int
	Continental and SK Innovation	DE (Berlin/Hanover) KR (Seosan)	Joint Venture in Lithium-Ion battery technology	R&D	Int
	Wolfsburg AG und TU Clausthal	DE (Wolfsburg) DE (Clausthal)	R&D projects in the field of electromobility	R&D	Nat
United Kingdom	GKN driveline and Evo Electric Ltd.	GB (Redditch)	Joint Venture: “GKN Evo eDrive Systems” for electric motors and drive systems	R&D/ Pr	Nat
Italy	Enel and Daimler	IT (Rome) DE (Stuttgart)	Field trail: “e-mobility Italy” in Rome, Pisa and Milan, Daimler provides 100 EVs (Smart and Mercedes-Benz)Enel provides the charging infrastructure	R&D	Int
Spain	Opel and Ibil	ES (Bilbao) DE	Opel and the electricity supplier Ibil promote EVs and accelerate the build-up of a charging infrastructure	Pr	Int
	PSA and Ibil	ES (Bilbao) FR (Paris)	Peugeot and Ibil jointly offer EVs and home-charging stations	Pr	Int
	Renault and Ibil	ES (Bilbao) FR (Boulogne-Billancourt)	Market development: Renault and Ibil accelerate the build-up of a charging infrastructure	Pr	Int
Sweden	Vattenfall AB and Volvo Car	SE (Stockholm) SE (Goteborg)	Joint Venture: “ V2 Plug-in-Hybrid-Vehicle-Partnership” for the development of the plug-in-technology	R&D	Nat
	Siemens and Volvo	SE (Goteborg) DE (Munich)	Cooperation for the development of electronic drive technology	R&D	Int

Note: Int= International Cooperation, Nat= National Cooperation, R&D = Research and Development, Pr =Production

(Source: Own Compilation based on Automobilwoche 2011b)[234]

Table 25: Joint Ventures and Alliances in North America (Canada and U.S.)

Location of Cooperation	Companies	Origin of Cooperating Companies	Targets	Type	
Canada	Daimler and Ford, Ballard	DE/Michigan	50.1:30:19.9 percent Joint Venture "Fuel Cell Cooperation". Daimler builds up their own production of fuel cell stacks in Vancouver	Pr	Int
California	Daimler and VW	DE/DE	"California fuel cell partnership"	R&D/ Pr	Int
	Toyota and Tesla Motors	California/JAP	Toyota holds 50 million Tesla shares, cooperation for the development of electronic pre-version of Toyotas RAV4	R&D	Int
North Carolina	GM and ABB Group	Michigan (Detroit)/CH	Development-Cooperation for the re-usage of the Chevrolet volt-battery	R&D	Nat
New York	BMW and My City Way	NY/DE (Munich)	Participation of BMWi in Ventures on My City Way (Mobile App, Information for public vehicles and parking spaces)	Pr	Int
Connecticut	GM and General Electric	Michigan (Detroit)/ Connecticut (Fairfield)	Acceleration of a charging infrastructure in China	R&D/ Pr	Nat
	Nissan and General Electric	Connecticut/JAP	Cooperation for the development of intelligent charging technology (Smart Grid, Smart Charging)	R&D	Int
Massachusetts	WiTricity and Toyota	MA (Boston)/ Jap (Kodama)	Cooperation for the development of inductive (contact-less) charging technology	R&D	Int
	WiTricity and Thoratec	MA (Boston)/ California (Pleasanton)	Technology development agreement relating to proprietary wireless resonant energy transfer technology for application in the field of mechanical circulatory support	R&D	Int
	WiTricity and Mitsubishi Motor Company	MA (Boston)/Jap	Develop easily deployable wireless charging systems for electric vehicles	R&D	Int
Michigan	ZF and ISE	Michigan (Nothville)/DE (Friedrichshafen)	Cooperation for the development of hybrid drive systems and components for commercial vehicles in North America	R&D	Int
	Chrysler, Ford,GM	Michigan	USABC,R&D of Chrysler, Ford and GM	R&D	Nat

Note: Int= International Cooperation, Nat= National Cooperation, R&D = Research and Development, Pr =Production

(Source: Own Compilation based on Automobilwoche 2011b)[235]

[234] This list is not intended to be exhaustive since smaller and less known market participants can also collaborate.

[235] This list is not intended to be exhaustive since smaller and less known market participants can also collaborate.

Table 26: Joint Ventures and Alliances by Country in Asia

Location of co-operation	Companies	Origin of Cooperating Companies	Targets	Type	
India	GM and Reva Electric Car Company	IN (Bangalore) /Michigan	Development ofelectric vehicles for the Indian market	R&D	Int
China	BYD and Daimler	CN (Shenzhen) /DE (Stuttgart)	50:50 Joint Venture “Shenzhen BYD Daimler New Technology Co” for the development and production of an EV	R&D/ Pr	Nat
	SAIC and GM	CN (Shanghai)/ Michigan (Detroit)	R&D of a new EVfor China	R&D	Int
	SAIC and A123	CN (Shanghai) / Massachusetts (Watertown)	Development and manufacturing of com-plete vehicle traction battery systems for use in hybrid electric and BEVs	R&D/ Pr	Int
	BMW, StateGrid, Southern Grid, China autom. Technology and R&D Corp.	DE (Munich)/ CN (Peking)	Fleet trial with Mini and BMW Active E in Peking and Shenzhen	R&D	Int
	Brilliance and BMW	DE (Munich) / CN (Shenyang)	Development of an EV that is intented to be produced in 2013	R&D/ Pr	Int
	Wanxiangand Ener1	CN (Hangzhou)/ NY	Joint venture for the production of EV batteries	Pr	Int
	Lishen Battery Comp. and Coda (LA)	CN (Tianjin) / CA (Santa Mon-ica)	Joint venture for the production of Lithi-um-Ion batteries	R&D/ Pr	Int
	BYD and Volkswagen	CN (Shenzhen) DE (Wolfsburg)	Development of Lithium-Ion batteries for electric vehicles	R&D	Int
South Ko-rea	Hyundai-Kia and Kep-co	KR (Seoul)	Partnership on EVs and the development of charging infrastructure	R&D/ Pr	Nat
	Hyundai Mobis and LG Chem	KR (Seoul)	51:49 Joint Venture “HL Green Power Co”, Production of Li-Ion-Batteries for passenger cars	Pr	Nat
	LG Chem and Ford	KR (Seoul)/ Michigan	LG Chem’s subsidiary “Compact power” supplies Li-Ion battery systems for the electric version of the Ford Focus in the U.S.	Pr	Int
	Samsung and Bosch	KR (Giheung)/ DE (Gerlingen)	50:50 Joint Venture “SB LiMotive” Development and production of Li-Ion-Batteries, Dissolution announced in 09/2012	R&D	Int
	Kia Motors and SK Innovation	KR (Seoul)	Research and development, promotional activities	R&D	Nat
Japan	Hitachi Maxell and Shin-Kobe Electric Machinery	JP (Hitachinaka)	Joint Venture “Hitachi Vehicle Energy Ltd.”, Development and production of Li-Ion-Batteries for EVs	R&D/ Pr	Nat
	Enax and Continental	JP (Tokyo)/ DE (Hannover)	Continental holds a 16 percent share in Enax, a Japanese expert for Li-Ion-Batteries	R&D/ Pr	Int
	NEC (Japan), Nissan and Renault	JP (Tokyo) / FR	“AESC” – Lithium-Ion batteries for EVs &PHEVs	R&D/ Pr	Int
	Johnson Controls and Hitachi	Wisconsin (Mil-waukee) /JP (To-kyo)	Strategic partnership on storing electric energy including Li-Ion-Batteries	R&D/ Pr	Int
	Honda Motor and GS Yuasa	JP (Tokyo)	Joint Venture “Blue Energy Co. Ltd.”, Development and production of Li-Ion-Batteries for hybrid EVs	R&D/ Pr	Nat

	GS Yuasa and Mitsubishi Motor Comp.	JP (Tokyo)	"Lithium Energy Japan"- Development and production of Lithium-ion batteries for EVs	R&D/ Pr	Nat
	Toshiba and Volkswagen	JP (Tokyo)/ DE (Wolfsburg)	Cooperation on the development of electric powertrains, power electronics and battery systems	R&D	Int
	Renault-Nissan and NEC Tokin (AESC)	JP (Tokyo)	50:50 Joint Venture "Automotive Energy Supply Corporation" for Lithium-Ion-Batteries for passenger vehicles	R&D/ Pr	Nat
	Nissan and Sumitomo	JP (Tokyo)	51:49 Joint Venture "4R Energy Corporation" for recycling of Li-Ion-Batteries	R&D	Nat
	Toyota, Panasonic and Matsushima	JP (Osaka)	Joint Venture "Panasonic EV Energy (PEVE)": Production and recycling of Li-Ion-Batteries	Pr	Nat
	Sanyo Electric and Volkswagen	JP (Osaka)	Cooperation for the development of Li-Ion-Batteries	R&D	Int
	Panasonic and Tesla Motors	JP (Osaka)	Panasonic holds 1.42 million Tesla shares	R&D	Int
	Toyota and BMW	JP (Osaka) and DE (Munich)	Cooperation in the development of fuel cells, electric powertrain and lightweight components,Supply of BMW diesel engines to Toyota (2014)	R&D/ Pr	Int
	Japan New Chisso and H.C. Starck	JP (Minamata) DE (Goslar)	Joint Venture called "CS Energy Materials", production of cathode material for high performance Lithium-Ion batteries in Minamata (Japan), while the technology is being developed in Goslar (Germany)	R&D/ Pr	Int.

Note: Int= International Cooperation, Nat= National Cooperation, R&D = Research and Development, Pr =Production

(Source: Own Compilation based on Automobilwoche 2011b)[236]

[236] This list is not intended to be exhaustive since small and unknown market participants can also collaborate.

The following figure illustrates that the majority of joint ventures and alliances of EU key players in the field of electromobility are attributable to German companies.

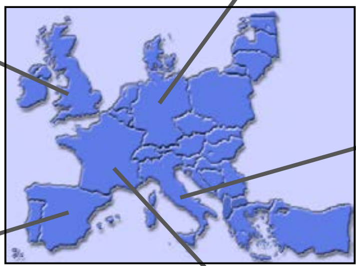
Figure 38: Overview on Joint Ventures and Alliances of EU Key Player in the Field of Electromobility[237]

Joint Ventures/Alliances of German Key Players

∑ 45	R&D	Production	R&D/ Production
EU	16	6	6
Non EU	7	3	7

Joint Ventures/Alliances of UK Key Players

∑ 1	R&D	R&D/ Production
EU		1
Non EU		



Joint Ventures/Alliances of Italian Key Players

∑ 1	R&D	Production
EU	1	
Non EU		

Joint Ventures/Alliances of Spanish Key Players

∑ 3	R&D	Production
EU		3
Non EU		

Joint Ventures/Alliances of French Key Players

∑ 10	R&D	Production	R&D/ Production
EU	1	4	1
Non EU	2		2

(Source: Own Compilation based on Automobilwoche 2011b)

After consulting Figure 38 it becomes evident that the key players from Germany, England, France, Italy, and Spain cover more than 95percent of all collaboration efforts related to R&D and manufacturing. **The majority of these joint ventures and alliances belong to German companies.** Germany covers 80 percent of the co-operations of European key players in the field of R&D, followed by France with 7 percent.[238] About 77 percent of the EU co-operations concerning both R&D and production are attributable to Germany, followed by France with 15 percent and the United Kingdom with 8 percent. Furthermore, German companies account for 46 percent of the EU co-operations in the field of production, followed by France with 31 percent and Spain with 23 percent.

While 65 percent of the German co-operations involve European partners (e.g. Renault and Continental), the remaining 35 percent include non-European counterparts, predominantly Asian companies. In March 2012 for example, the BMW Group and Toyota Motor Company signed a binding agreement on collaborative R&D concerning the next-generation of Lithium-Ion battery cells. Previously, both entered into a contract in December 2011, under which the BMW Group will supply 1.6 litre and 2.0 litre diesel engines to Toyota Motor Europe starting in 2014.[239]

Altogether, **the majority of the German collaboration efforts have been established between OEMs and large suppliers**, e.g. Daimler and Bosch (electric engines), Daimler and Evonik, BMW and

[237] This figure is not intended to be exhaustive since small and unknown market participants also collaborate
[238] Remaining shares belong to other Member States like Italy or Sweden (see appendix XXVI)
[239] Electric Drive (2012)

BYD, Volkswagen and BYD or Volkswagen and Toshiba, or between major suppliers, as ZF and Continental, Bosch and Samsung (SB LiMotive[240]). Recently, Continental and the Korean SK Innovation moved forward on an automotive Li-Ion battery joint venture.SK Innovation is providing its know-how in the development of battery cells as well as separators, while Continental is providing its substantial experience in the development and production of battery electronics and entire battery systems, as well as the integration of them into electric vehicles.SK Innovation has an annual capacity of 800 MWh which is equivalent to 40,000 units of full electric vehicles at its Korean plant in Seosan.SK Innovation will hold a 51% stake in the new company, Continental 49%. The business strategies of SK Innovation and of Continental will remain unaffected by the joint management of the joint venture, which will be managed operationally from Berlin. Initially, about 200 workers will be employed worldwide, with both partner companies providing equal portions of employees.[241]

One of the most important co-operations in France is the collaboration between Renault-Nissan and CEA (French Atomic Energy and Alternative Energies Commission) which focuses on the production of Lithium-Ion batteries in Flins near Paris. Renault has already been producing Lithium-Ion batteries with Automotive Energy Supply Corp, which is a joint venture between Nissan Motor Co. Ltd. and NEC Tokin Group. Furthermore, the joint venture Renault Samsung Motors Inc. is working with SK Energy Co. Ltd. and SB Li Motive Co. Ltd. in order to develop batteries in South Korea.

The alliance of the French battery manufacturer Saft and the U.S. partner Johnson Controls was dissolved in the middle of 2011. In Spain, the electricity provider Ibil and the Renault-Nissan Alliance promote electric cars. Furthermore, Ibil co-operates with Opel and PSA in the development/expansion of charging infrastructure. Remarkably, The Italian electricity provider ENEL has developed more than 400 charging points in three Italian cities (Milan, Pisa, and Rome) with its partner Daimler, providing 100 EV Smart cars for rental services.[242]

Several major electronic companies in Japan such as Panasonic, NEC or Hitachi formed Joint Ventures (JV) or alliances with automakers in order to engage in battery production for electric vehicles. The most important JVs are Panasonic EV Energy (PEVE), which is a JV between Toyota and Panasonic, Automotive Energy Supply Corporation (AESC), which is a JV between Nissan and NEC and the joint ventures of GS Yuasa with Mitsubishi Motors (Lithium Energy Japan) and with Honda (Blue Energy). In both cases the automaker holds the majority share of the newly founded firm in order to maintain control. Japanese manufacturers of battery components, such as Mitsubishi Chemical, have a dominant position in the world market (see Chapter 3.2.1.1.3). Apart from that, traditional manufacturers and suppliers such as Toyota Industries and its subsidiary DENSO have become major suppliers of battery components.

The co-operation of the small U.S. car manufacturer Tesla with the global manufacturers Daimler (Germany) and Toyota (Japan) is one of the most well-known co-operations in terms of electromobility. Additionally, Tesla has launched a partnership with Panasonic in order to promote the development of special Lithium-Ion batteries for the automotive industry.

Recently, the co-operation of global OEMs and Chinese players has developed considerably, such as e.g. BYD and Daimler, SAIC and GM, BMW and Brilliance or BYD and VW. From a strategic point of view these collaborations are very important in order for the major global manufacturers to break into the Chinese market.

The Korean LG Chem's subsidiary "Compact Power" supplies Li-Ion battery systems for the electric version of the Ford Focus in U.S. The joint venture "SB LiMotive" of the German supplier Bosch and the Korean electronics maker Samsung focuses on the development and production of Li-Ion batteries.

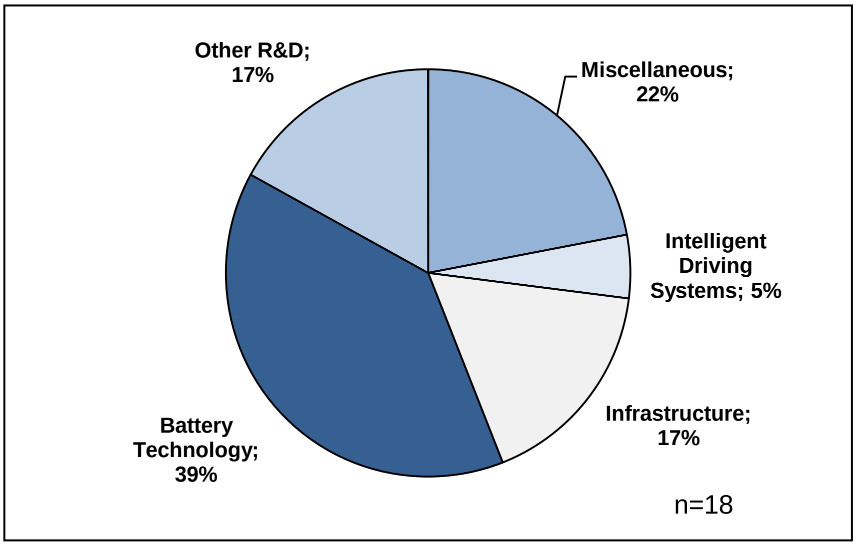
A majority of experts expect that more joint ventures and alliances will emerge in the field of electric mobility. According to the experts surveyed in this study, **cooperation among large companies will be significantly more important than co-operations between the large and small, e.g. specialised suppliers or inventors**. In the race for skills, time, and cost reduction (economies of scale) companies will continue to co-operate. Small inventors will be much less involved in joint ven-

240 Recently, Bosch announced to split up with Samsung. Therefore, no data on the continuation of investments and capacities are available.
241 Green Car Congress (2012d)
242 IEA (2011b)

tures and alliances than major key players. Nevertheless, in the past even small inventors or new entrants were able to co-operate with global key players (e.g. Tesla with Toyota, Daimler and Panasonic).

According to the experts interviewed, electric vehicle technology (R&D and production of components) will be the most important field of activity (battery technology 39 percent, other R&D 17 percent and infrastructure 17 percent). Furthermore, companies will co-operate in the field of Intelligent Driving Systems e.g. vehicle-to-vehicle communication, smart grids (e.g. Figure 39).

Figure 39: Expected Areas of Activities of Joint Ventures and Alliances



(Source: Own Calculation)

Compared to the U.S. and Asia, we expect that high development costs, risks, and the European companies' lack of skills will facilitate further cooperation in the two areas of R&D and production. Our overview on the international cooperation in terms of electromobility shows that in all three regions suppliers and manufacturers have been already acting internationally. This trend will continue. The market power of individual competitors (e.g. in terms of purchasing, technological leadership, synergies, mass production, supplier networks) will lead to consolidation in the near future. Therefore, further collaborations can be expected.

3.2.4 National Platforms in the field of Electromobility

To ensure the global forefront in innovative technologies for national industries, national platforms seem to be a suitable measure of public policy in order to support national companies in the development and market penetration of new technologies. **National platforms are national networks between industry, scientists, policy makers, utilities, transport associations and social groups which join forces to promote** specific technologies or industries. For the purpose of this study, national platforms promoting electric mobility are reviewed.

The emergence of platforms can be initiated either by the state (e.g. Nationale Plattform Elektromobilität NPE in Germany) or by a coalition of key stakeholders (e.g. Electrified Mobility Platform in Italy, founded by Italian industries, research organisations and scientists).

The formation of national electromobility platforms, aims to connect all relevant key players of the new EV value chain (see Chapter 3.1), in order to strengthen their competitive position (see Chapter 3.2.1 and 3.2.2) and initiate co-operations (see Chapter 3.2.3). Table 27 provides an overview on the main national platforms in the EU.

Table 27: Overview on Certain National Platforms in the EU

	Denmark	**Germany**	**Italy**	**Portugal**	**UK**
Name	"Centre for Green Transport"	"Nationale Plattform Elektromobilität" (NPE)	"Italian Electrified Mobility Technological Platform"	"MOBI.E"	"Low Carbon Vehicles Innovation Platform"
Foundation and Scope	Government-founded in April 2009, providing a budget of 39 (38.1)mio. EUR until 2013	Launched in 2010 Governmental fundings of about 4 bn. EUR (3,8), private investments of up to 17 bn. EUR	Launched in 2010 by Key Players	51% under state control	Founded in 2007 by the Technology Strategy Board, a public body aiming to stimulate UK-based businesses
Participants	Danish Transport Authority, private and public stakeholders	Federal agencies (e.g.Bundesnetzagentur), Industry (e.g. Volkswagen AG, Daimler AG, RWE AG), Universities (e.g. RWTH Aachen), Scientific organisations (e.g. Fraunhofer Institut), unions (e.g. IG Metall)	100 stakeholders (industry, scientific organisations, universities)	Portuguese state and industry (e.g. EDP, Siemens AG)	Public bodies, industry, universities
Area of Interest	focus on environmentally beneficial initiatives: reduction of carbon dioxide emission	Aims to develop proposals in order to achieve the "Nationale Entwicklungsplan Elektromobilität's (NEPE)"	Research & Development	Development of infrastructure	Acceleration of the adoption of electromobility
Level of Ambition and Objectives	– Create a framework in the field of sustainable transport – Conduct test and demonstration projects – Create synergies between existing initiatives	– Promote R&D, the preparation for commercialisation and the market launch of BEVs in Germany – Germany must become a lead market, the automobile industry has to maintain its leading role – One million EVs (BEV+PHEV) on German roads until 2020 – Exertion of influence on public opinion	Aims to develop strategies to implement electric mobility especially urban mobility	– Nationwide interoperable charging network; accessible to all energy retailers and car manufacturers – Integrated payment system and more services -10% Share of Evs on the overall market until 2020	– Nationwide interoperable charging network; accessible to all energy retailers and car manufacturers – Integrated payment system and more services
Results	Various field-tests: – CLEVER (former ChoosEV): 300 EVs and 50 Quick Charge Stations – 4 hybrid buses – EV timeshare leasing	Preparation stage so far "in plan" Start of - various modell regions - further R&D projects	December 3, 2010: "Strategic Research Plan for Electric Mobility"	Effective 2011: 1.350 charging stations - pilot projects: e.g. 5000 police cars in Police Department	

(Source: Own Compilation based on IEA 2011)

While the German “Nationale Plattform für Elektromobilität (NPE)”, the Danish “Centre for Green Transport” were initiated by national governments, the “Italian Electrified Mobility Technological Platform” was founded by Italian key players (e.g. from industry, universities or associations). Presently, France and Spain do not have a national platform. Nevertheless, several projects[243] were started by national administrations in order to promote electromobility in Spain (e.g. MOVELE) or France (national plan for electric vehicles).

Concerning the objectives, the different platforms of the EU Member States are quite similar. They are mostly focused on the following tasks:

- **Standardization and national / international collaboration**
- **Research and Development**
- **Development of infrastructure**
- **Implementation of pilot projects.**

On the **European level**, the Green **eMotion project** is developing the European framework for an interoperable electromobility system. Within the Green Cars Initiative, launched in the context of the European Recovery Plan, the European Union supports R&D of road transport solutions which are considered to have potential in achieving a breakthrough in the use of renewable and non-polluting energy sources. The project Green eMotion was launched to enable a mass deployment of electromobility in Europe, involving 43 partners from industry, the energy sector, manufacturers, municipalities as well as universities and research institutions. The aim is to develop and to demonstrate a commonly accepted and user-friendly framework consisting of interoperable and scalable technical solutions in connection with a sustainable business platform. Therefore, smart grid developments, innovative ICT solutions, different types of electric vehicles as well as new mobility concepts will be focused on for the implementation of this framework. The four year project started in March 2011 with a total budget of 42 million Euro, funded by the European Commission with 24 million Euro.[244]

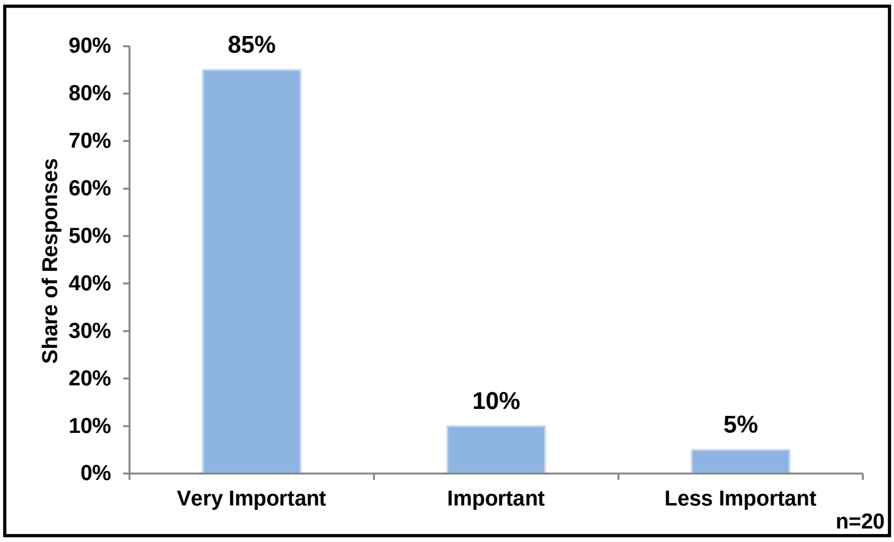
In **China**, **two national platforms have been formed in recent years to promote the development of electric vehicles**. As a first step, the China Association of Automotive Manufacturers (CAAM), a government sponsored grouping of automakers and suppliers, has launched the “Top10 Initiative” in 2008. As the name suggests, this initiative brings together China’s ten leading OEMs -- all CAAM members – with the aim to coordinate their business strategies, exchange information on current problems and opportunities of the electric vehicle market and define common standards, e. g. for batteries and battery management systems. [245] In 2010, the State-owned Assets Supervision and Administration Commission (SASAC) which is in charge of managing state-owned companies under the control of the central government, kicked-off the “State-owned Enterprise Electric Vehicle Industry Alliance” (SEVIA). Supported by RMB 1.3 billion from the central budget, this group enjoys a privileged position; it is suspected that companies only joined to obtain their cut of this funding.[246] The group comprises 20 member companies - all participating corporations are owned and controlled by SASAC on behalf of the central government.[247] Based in a large variety of industries, alliance members were divided into three separate groups assigned to focus on the development of electric vehicles, traction batteries, and supporting infrastructure. SEVIA supports implementation of government policies, promotes harmonisation of different technology standards among its members, conducts R&D in core technologies, coordinates the development of electric vehicles with upstream and downstream industries, advances technology development efforts, defines standards and organises the sharing of intellectual property.[248] The last item has proven a major stumbling block for co-operation in terms of bringing about any kind of meaningful progress of SEVIA’s activities, as no company was willing to let other members take advantage of its technological expertise. Owing to the lack of co-operation, SEVIA has done little to spur indigenous innovation and establish competitive players with strong brands.[249] As well as differences in membership and scope of activities, the two alliances also represent different conceptions of the development path of China’s electric vehicle sector. While the OEMs prefer a sequential approach that initially focuses on the promotion of Full Hybrid vehicles and gradually shifts towards plug-ins and Battery Electric vehicles, SEVIA endorses the leapfrogging approach which attributes little

[243] IEA (2011a), p. 266 ff.
[244] Green Emotion Project (n.d.)
[245] Sina Auto (2010)
[246] Tencent (2011)
[247] State-owned Enterprise Electric Vehicle Industry Alliance (n. d.).
[248] Id.
[249] Sina Auto (2010)

relevance to conventional hybrid technology and features a strong focus on full electric vehicles.[250] In any case, there appears to be no comprehensive platform like the German NPE. Neither consumers nor suppliers are involved in the discussions of China's future electric vehicle development organised by the platforms active in China today.

More than 80 percent of the surveyed experts consider national platforms such as the "Nationale Plattform für Elektromobilität" in Germany as very significant for competitiveness (see Figure 40).

Figure 40: Influence of National Platforms on the Competitiveness of National Key Players



(Source: Own Compilation based on Expert Interviews)

The following benefits of national platforms have been mentioned by a majority of experts complemented by some examples of the German NPE (see Box 5):

[250] Ifeng (2011)

Box 5: Benefits of national platforms complemented by some examples of the German NPE

- **Drafting of a roadmap** (setting of common goals, providing planning security).
  E.g. the German NPE has defined a phase model (market preparation, market running up, start of mass market) with milestones, definition/implementation of a roadmap called "Systemic Approach to Electric Mobility".
- **Integration/cross linking of all different (key) players** (from different sectors and social and academic groups). E.g. the German NPE focuses the integration of craft, SMEs and start-ups in its showcase activities. Furthermore, in June 2011, the "Working Group on Standardization" was upgraded to "Commission on Co-operation in Standardization" under the Sino-German government consultations aiming to facilitate the bilateral trade between the two countries, to continue to promote bilateral economic and technical cooperation, to strengthen the dialogue on standardization and to coordinate the activities in international standardization organizations.
- **Platform for exchange and reliable information**. E.g. organisation of workshops and conferences.
- **(Pre-competitive) Research and Development (working groups).** E.g. the German NPE focuses on a continuous cross-technology cooperation in the R & D lighthouses.
- **Academic and vocational education**. E.g. the German NPE organised the first "National Education Conference on Electromobility "in Ulm in June 2011 as a starting point of the competence roadmap in order to define measures such as preparation of handouts and implementation guides for occupational qualification (quality-assured training standards, modular training and qualification sections, learning platforms, networks of experts, etc).
- **Standardisation**. E.g. in terms of data formats and requirements for the various exchanges of information in telematics solutions.
- **Bundling of resources.** E.g. the German NPE implemented 21 Consortia from industry, SMEs and science, e.g. the consortia E-"Drive Battery 2015" and "SafeBatt". The composition of the consortium guarantees a hands-on research leading to synergies and optimal allocation of resources.
- **Improvement of the funding allocation process.** E.g. the German NPE defined showcases and 8 model regions. Furthermore, a variety of research and development and funding projects have been specified in **six "lighthouses"**:
  - Battery: 21 consortia; 601 million Euro project budget
  - Drive Technology: 28 projects, 230 million Euro project budget
  - Vehicle Integration: six projects, 113 million Euro project budget
  - Lightweight: eight projects, 100 million Euro project budget
  - Recycling: two projects
  - ICT and Infrastructure: 17 projects, 125 million Euro project budget

In conclusion, national or supranational platforms are suitable to promote electromobility. This is why a European platform for battery technology would be able to support the EU automotive industry in assuaging the missing capabilities in terms of battery technology. Furthermore, a formal training initiative in the field of electromobility could help build up competence in this area - both the idea of a European Platform for Battery Technology and formal training initiatives will be further discussed in Chapter 6.3.

Almost all respondents associated with OEMs have confirmed that the EU automotive workforce currently lacks essential knowledge and skills, particularly in the fields of electrochemistry and electronics. The majority of experts interviewed consider the German NPE as pioneer among the European national platforms with that respect. But nevertheless, experts also offered critical arguments that national platforms mainly focus on industry interests while ignoring the consumer interests.

3.2.5 Drivers of the Industrial Situation

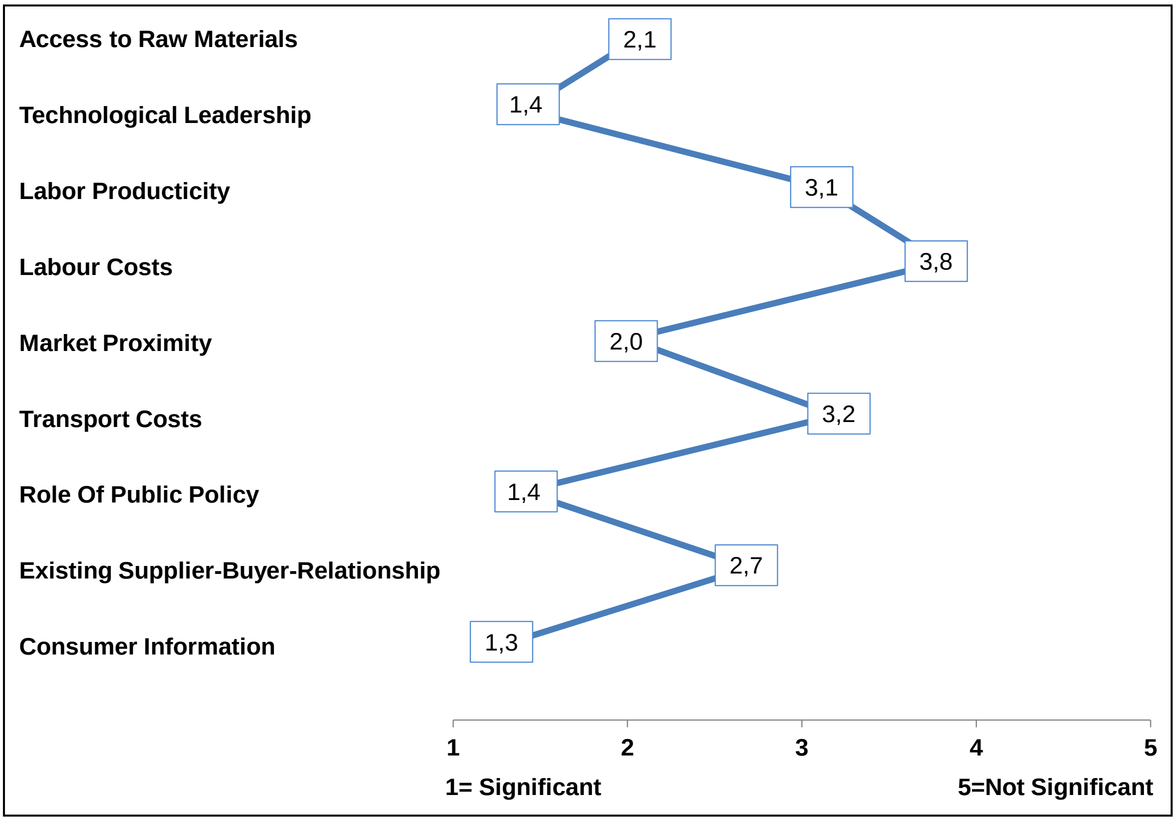
In order to **describe the current competitive position of the electric vehicle industry in Europe and its likely future evolution,** the following chapter provides an analysis of certain drivers of the industry.

Important drivers of the competitiveness of EU automotive industry in electric vehicles are:

- **Access to raw materials** (see Chapter 3.2.5.1),
- **Technological leadership** (see Chapter 3.2.5.2)
- **Labour productivity and cost** (see Chapter 3.2.5.3)
- **Consumer information**(see Chapter 3.2.5.4)
- **Market proximity and transport costs** (see Chapter 3.2.5.5)
- **Role of public policy**(see Chapter 3.2.5.5)
- **Existing buyer-supplier relationships** (see Chapter 3.2.5.5).

The majority of experts interviewed consider technological leadership and public policy as significant to the future competitiveness of the players (see also Figure 41).

Figure 41: Significance of certain Drivers on the Industrial Situation



(Source: Own Survey)

The results of our survey underline that the development of the automobile industry, especially the development of new technologies, strongly depends on public policies. Productivity and cost development, although playing minor roles, should not be underestimated. A difference in the opinions of various expert groups is particularly evident in terms of access to raw materials and transportation costs. While manufacturers evaluate the access to raw materials as significant, suppliers and government experts consider these drivers to be less critical. Transport costs, however, are judged by government experts as more significant than by the manufacturers and suppliers. In terms of the remaining drivers no group differences were observed.

3.2.5.1 Access to Raw Materials

The following chapter will analyse country specific access to raw materials.

In Europe, the prices of raw materials have been rising substantially since 2001.The sharp increase in energy costs and raw material costs (e.g. rubber, steel, or platinum) have had a very strong impact on the profit margins of the EU automotive industry.[251] Europe does not have notable deposits of key raw materials used in the production of electric vehicles, such as neodymium, dysprosium and other rare earth elements (electric motors)[252] or lithium (batteries).

Box 6: Lithium – an important raw material in the field of electromobility

Lithium plays a very important role in the production of battery cells because of its electrochemical potential. Therefore, in the medium term it will be indispensable for the production of batteries. With the electrification of the powertrain, the global demand for lithium will rise. In 2010, approximately 25,300 tons of lithium was produced. Global reserves are estimated at 13 million tons - representing a supply of about 500 years based on current consumption levels.[253] It is the geographical distribution of minable deposits that poses problems for the European industry. The world's largest lithium reserves exist in South America (Chile and Bolivia) and China. The bulk of lithium trade takes place in the form of lithium carbonate which is the base material for further chemical combinations. **Over the medium term, the availability of lithium will not constitute a supply risk and access to the material will not be a major issue**. An analysis by the International Energy Agency (IEA) confirms this assumption.[254]Battery manufacturers are currently characterised by a high degree of market concentration with the five largest companies controlling nearly 80 percent of the market. The *European Expert Group* argues quite rightly that supply risks may arise as a consequence of the present market structure.[255] It remains to be seen, whether countries such as Bolivia, Chile, or China will prove reliable suppliers over the long term.

At present, the mining of Lithium seems likely to be reserved for companies operating in China or South America. Nevertheless, the Australian mining company Global Strategic Metals NL (formerly East Coast Minerals NL) announced plans to mine Lithium in Koralpe (Austria) from 2013. A factory for lithium processing costing approximately 125 million Euro will be built. For preparation of the mine, such as drainage and electrification, 5 to 7 million Euro will have to be invested.[256]Today, only a few companies operate in the field of cell production in the EU (see Chapter 3.2.1.1.1), the procurement of raw materials for battery production currently plays a minor role. Leading manufacturers such as Renault procure complete cells or battery systems from suppliers e.g. from the South Korean LG group (e.g. for Renault Zoe Z.E.).[257]

Aside from lithium, **copper** is another important raw material for the production of electric vehicles. Despite the existence of local mining operations, the EU plays no significant role in the production of this raw material. The largest producer is Chile with a global market share of 34percent.[258]**Since copper is easy to recycle, the current recycling rate stands at 70 percent in the EU**.[259] At present, 25 to 40 kg of Copper are necessary to manufacture a single electric car.[260] The production of one million units would cause an increase of 0.25 percent of global copper output. The price of copper has almost doubled over the last ten years as the metal is used in many industries. The demand will continue to rise rapidly over the medium term. McKinsey (2011), for example, forecasts a 13-fold increase until 2030.[261]**In addition to copper and lithium, a large variety of other raw materials are required for the production of electric vehicles, such as antimony, beryllium, cobalt, fluorspar, gallium,**

[251] CCFA (2011)
[252] European Expert Group (2011): Future Transport Fuels, Report of the European Expert Group on Future Transport Fuels.
[253] Deutsche Bank Research (2011)
[254] IEA (2011a)
[255] European Expert Group (2011)
[256] Der Standard (2012)
[257] Further information concerning supplier-buyer relationships and sourcing is provided in Chapter 3.2.5.5.
[258] ZVEI/Commerzbank (2010)
[259] European Commission (2011a)
[260] Deutsche Bank Research (2011); Fraunhofer (2011)
[261] McKinsey (2011)

germanium, graphite, indium, magnesium, niobium, platinum group metals, rare earth elements, tantalum, and tungsten.[262] Three of these raw materials are characterised as critical raw materials by the EU particularly because of the scarcity of/demand for cobalt, platinum group metals, and rare earths bottlenecks.

Export restrictions contribute to increasing international raw material prices. Domestic consumers of raw materials often enjoy lower input costs for production. In certain countries, domestic consumers benefit from lower prices for raw materials. Therefore, the gap between domestic and international prices provides a crucial cost advantage for domestic consumers.

With its initiative "A resource-efficient Europe - flagship initiative under the Europe 2020 strategy"[263] the EU Commission has positioned itself to reduce the dependency on natural resources. It can be concluded that **Europe is greatly dependent on raw materials** from the rest of the world. We assume that EU battery manufacturers would be confronted with moderate supply risks, but higher price risks. The EU does have many natural resources, but the exploration and extraction are primarily affected by a highly regulated environment with increasingly high investment costs and competing forms of land use.[264]

We assume that prices will rise significantly due to the increasing demand on the world market. Furthermore, we expect an increase in transportation costs since raw materials like lithium are mined overseas. We also consider recycling as very important. Nevertheless, we assume that the returns of recycling will not be sufficient to minimise the supply and price risks.

In terms of raw materials, we expect that the **United States** have a better position than Europe. Chemetall and FMC are two U.S. companies which supply 50 percent of the world´s demand for lithium.[265] Chemetall, for example, produces around 135,000 tons of lithium carbonate a year[266] and purchases its lithium both from Chile and from the only operating source of lithium raw material located domestically in Silver Peak/Nevada.[267]In contrast to Europe's lithium dependency, the U.S. is subjected to other dependencies, such as certain raw materials which are integral to vehicle production.

In **Japan, due to the absence of rare earth reservoirs, the scarcity of raw materials is in general and simultaneously a large demand for its high-tech and automobile industry, Japan is heavily dependent on imports**.[268] Keiichi Kawakami (Japanese Ministry of Economy, Trade and Industry) conducting his speech on February 3, 2011 to the European Parliament described securing the supply of raw materials as a "really challenging task"[269]. The main measures taken by the Japanese government include an increase in research and development efforts in order to find alternative materials, therewith decreasing import dependency. Moreover recycling of used products such as mobile phones and computers shall be increased in order to recover critical raw materials. Thirdly, a core element of the Japanese policy in response to protectionist strategies, as evident in the case of China, is *stockpiling* (see box 7). Recent concrete actions have been included in Japan's offer to Bolivia to provide massive aid for Bolivia's further economic development in exchange for rare earth materials necessary for Japan's hybrid and electric vehicle industry.

[262] Fraunhofer (2011)
[263] European Commission (2011b)
[264] European Commission (2011a)
[265] CGGC (2010), p. 7.
[266] Deutsche Bank Research (2011)
[267] CGGC (2010)
[268] Fukuda (2008)
[269] Quoted in: Gardner (2011)

Box 7: Policies and Programs for Securing Non-Energy Raw Materials - Example from Japan

Early in 2008 the Japanese government published its "Guidelines for Securing National Resources"[1], which included the statement that the Japanese Government "will support key resource acquisition projects by promoting active diplomacy and helping these projects to be strategically connected to economic cooperation measures, such as official development assistance (ODA), policy finance and trade insurance". Potential projects must fulfill the criteria: 1) "projects to acquire exploration or development interests" and 2) "projects related to long-term supply contracts that contribute to supplying …resources to users in Japan". In 2004 the Japanese government created the Japanese Oil, Gas and Metals National Cooperation (JOGMEC)[2]. Among JOGMEC's important activities are providing financial assistance to Japanese companies for mineral exploration and deposit development; gathering and analyzing information on mineral and metal markets to better understand supply risk, and managing Japan's economic stockpile of rare metals. JOGMEC defines rare metals as those that (a) are essential to Japanese industry, sectors such as iron and steel, automobiles, information technology, and home appliances and (b) are subject to significant supply instability. JOGMEC took over and now manages the Japanese rare-metal stockpiles in cooperation with private companies, with the goal of having stocks equivalent to 60 days of domestic industrial consumption. Stocks exist for seven materials: chromium, cobalt, manganese, molybdenum, nickel, tungsten, and vanadium. JOGMEC is closely observing 7 other raw materials.

Note:
[1] Ministry of Economy, Trade and Industry (METI), source: www.meti.go.jp/english/press/data/nBackIssue200803.html
[2] Japanese Oil, Gas and Metals National Cooperation (JOGMEC), source: www.jogmec.go.jp/english/index.html

South Korea's endowment of raw materials is small[270] but the country is reasonably bequeathed with non-metallic minerals.[271] As domestic raw material supply is unable to meet the demand, South Korea is dependent on imports. As a producer of steel, cadmium and slab zinc, South Korea occupies a leading position.[272] There are no rare earths deposits in South Korea. Just like Japan, Korea pursues a stockpiling strategy in order to secure raw material supplies. A key player executing the government's policy is the Korea Resources Corporation (KRC) which is fully owned and financed by the Korean government.[273] The purpose of the KRC is "to develop mineral resources in Korea and overseas, conduct effective management of projects on mineral resources industry's growth and support, and ensure stable supply of mineral resources and thereby contribute to the development of national economy" (Article 1, Korea Resources Corporation Act, Act No. 9182, Dec. 26, 2008). Stockpiling of mineral resources is explicitly anchored in Article 10 (1) 3., next to other tasks, such as providing loans for mining funds and conducting research or mine management (see Appendix XXXIII).

Contrary to South Korea, North Korea is rich in raw materials. It is especially well endowed with rare earth metal deposits. Currently, there is no official information available on the exact size of rare earth deposits in North Korea but several sources believe that the deposits may amount to approximately 20 million tons.[274] North Korea is currently incapable of exploiting its rare earth resources but it seems to have launched mining and processing operations with the support of China. In exchange for fertilizer and corn, China is believed to receive 50 percent of extracted materials for free while the other 50 percent are sold to China at international market rates.[275] Inner-Korean activities are pursued by the Korea Resources Corporation (KRC) which has established a program to work with North Korea on mining their resources. Collaborative efforts are currently described as follows:

"Our Inter-Korea Mineral Resources Cooperation Department is engaged in various co-operative projects with North Korea, including the collection of data on the mines in North Korea, contacts and communications for development of the mines in North Korea, operation of the South-North Collaboration Council for Resources Development to assist the North Korea projects of private enterprises, etc. Since North Korea is abundant with various minerals in large reserves and is situated right next to our

[270] South Korea's small reserves include: antimony, gold, copper, iron ore, lead, molybdenum, silver, tin, tungsten and zinc.
[271] These are: kaolin, limestone, feldspar, quartzite and mica.
[272] MEAAI (2011)
[273] Total contribution of the South Korean government is 2 trillion Korean Won (KRW)
[274] Chosun Ilbo (2011a); Korea Joong Ang Daily (2011)
[275] Some amounts of rare earth are reported to be sold through illegal channels, Korea Times (2011).

country, our endeavours to develop the mineral resources of North Korea surely will contribute to securing a steady supply of material minerals at a low price."[276]

In the short run, it seems unlikely that North Korea alone will acquire capabilities to establish itself a major player in rare earths trade. Rare earths that are extracted so far are of low quality and modern machinery which is needed for mining seems to be non-existent.

China has some of the world's largest reserves of both lithium and rare earth elements providing it with significant advantages in the field of raw materials. Due to the favourable access to rare earth elements, EV manufacturers enjoy advantages in manufacturing electric motors that rely on permanent magnets. Meanwhile, companies from other parts of the world have to look into alternative technologies to reduce their dependence on deliveries of Chinese raw materials.[277]**China is just one of the countries where significant deposits of rare earth metals are known to exist.** Australia, Brazil, Canada, India, South Africa, and the US also have deposits large enough for mining operations, accordingly China has no natural monopoly for these materials. **In recent years, however, China has come to be the prime supplier of rare earth elements, estimated to deliver 97 percent of internationally traded materials.[278]** The Chinese domination of the world market has been a cause for great concern among rare earth element users in downstream industries. Even more concerning is that prices for most rare earth elements have skyrocketed in recent years, driving up production costs and threatening the survival of downstream industries. Four reasons can be identified for China's strong position as the world's lead supplier of rare earth elements and the massive spikes in prices witnessed.[279]

The Chinese government has introduced and intensified export restrictions to curb the outflow of rare earth elements.[280] In 2005, Chinese authorities removed the VAT rebates on exports that had previously allowed exporters to reclaim the full VAT initially paid on their products. At the same time, an export tariff of 25 percent was imposed on some rare earth products.[281] Furthermore, authorities introduced an export licensing system and annual export quotas to limit outflows more effectively. In recent years, China has consecutively reduced the number of companies allowed to export rare earth metals and gradually reduced the physical quantities of each rare earth element that could be shipped to international customers. In 2011 alone, export quotas were cut by 35 percent. [282]

As export restrictions have increased both in complexity and extent, overseas buyers of rare earth elements have suffered from supply shortages and steep price rises. The extent to which the administration of export controls has been used as a tool of foreign policy has been the subject of intense debate after China temporarily suspended shipments to Japan following a diplomatic spat in 2010.[283] Overall, there is no doubt that at present, Chinese users of rare earth elements enjoy preferential access to these materials thanks to a variety of protectionist trade policies.

China has the world's third largest lithium reserves, after Chile and Bolivia, and is home to 13.7 percent of global deposits.[284] Rich reserves are concentrated in salt lakes in remote locations such as Tibet and Qinghai where CITIC Guoan and Qinghai Lithium Co., the country's largest producers, operate the mines.[285] Since high impurities, mostly magnesium, complicate the purification with brine extraction, most Chinese mining companies rely solely on ore extraction. Annual output volume currently stands at 33,000 tons of which only about a third is battery grade material. This contrasts sharply with an annual market demand of 19,000 tons.[286] Driven by the high demand for cell phones and mobile devices, lithium carbonate demand in China has grown by 25 percent annually over the past few years.[287]

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[276] Korea Resources Corporation (2012)
[277] Humphries (2011)
[278] The Economist (2010)
[279] The Economist (2011)
[280] The Economist (2010)
[281] Global Security (n.d.)
[282] East Asia Forum (2011)
[283] Stratfor (2010)
[284] People Daily Online (2009)
[285] China Daily (2011a)
[286] China Market Report Center (2012)
[287] China Daily (2011a)

3.2.5.2 Technological Leadership

In this section, the technological leadership of EU automotive industry in traditional technologies will be analysed and compared with its main competitors Japan, Korea, China and the U.S.

The **European automotive industry is a leader in high-quality products as well as safety and environmental-performance technologies**. The EU automotive industry sells and produces vehicles in all major world markets.[288] Due to their technology, automobiles have become highly complex and innovative products and the industry continues to invest almost 30 billion Euro a year in R&D, which is about five percent of their turnover. Suppliers realise some 50% of research activities. The automotive industry is the largest private player concerning R&D expenditures in Europe.[289]

The EU automotive industry has its strengths particularly in the following areas:[290]

- **Global technological leadership in the areas of automotive engineering, powertrain technology** (e.g. diesel technology) **and electronics** (e.g. innovations like antilocking systems, electronic stability control systems, piezo injectors)[291]

- **Extensive materials research, chemistry and basic research, good infrastructure within universities and other research institutions** (e.g. ThyssenKrupp "tailored rolled blanks", "tailored tempering"[292], or BASF "thermoplastic rims" or Bayer/Saint Goban "Plexiglas for vehicle use")

- **Efficient production research with outstanding knowledge in the field of manufacturing technology** (e.g. in terms of lightweight materials: BMW/SGL, Fraunhofer ICT or ThyssenKrupp, Fraunhofer: Virtual Factory[293])

- **High levels of education and high level professional training**(e.g. University of Duisburg-Essen "Master Automotive Engineering & Management" or University of Applied Sciences in Regensburg "Master Electromobility and Grids", Daimler Training Concept "New drive technologies", see Chapter 3.3.1)

- **Mechanical and electrical engineering recognised worldwide, high quality and reliability, particularly in the medium-sized industry** (e.g. Albonair Dortmund: SCR systems [Selective Catalytic Reduction])

- **Leadership in design, premium models** (e.g. market success of EU premium vehicle exporters to China/U.S., like Daimler, BMW or Audi)

- **Environmental and safety performance**(e.g. Daimler "Beltbag", Volvo V40 "pedestrian airbag", ThyssenKrupp: "litecore" sandwich construction of steel material in order to reduce the weight)

The EU car manufacturers have also extensive system knowledge concerning the value chain,. Nevertheless, European manufacturers and suppliers have to build up new competencies, especially in the field of electrochemistry, materials science, electrical energy systems and production.[294]

The automotive industry is a core industry of the **Japanese** economy. It contributes 16.4% to Japan's total manufacturing shipments. Total employment in auto manufacturing and related industries is 8.7% of the workforce of 63 million. When comparing R&D investments within manufacturing industries, the automotive industry has the highest share of R&D investments (19.7%, FY 2010). Since decades, Japanese automotive makers are known for innovations that inspired the global automotive industry. In the 1980s the all-embracing use of lean production methods increased competitiveness sharply. Through diffusion abroad, with the monograph "The machine that changed the world" as an

[288] ACEA (2011a)
[289] ACEA (2010)
[290] Own estimation based on BMBF (2010) and Cars21 (2012e)
[291] Bosch (n.d.)
[292] ThyssenKrupp (n.d.)
[293] See more detailed information: Fraunhofer (2010)
[294] Deutsche Bank Research (2011)

important catalyser, it had regime-changing influence on the global motor industry of the 1990s. In the 1990s, the trend towards outsourcing and modularization further contributed to more efficient auto manufacturing. During the first decade of 2000 Japan became the global industry leader in terms of environmentally friendly vehicles, with the success of Toyota´s Prius hybrid car as the most visible symbol. In terms of total production volume the Japanese automotive industry is one of the largest in the world but lost its leading position to China in 2009.Japan manufactured automobiles even before World War I. It has since then developed into **one of the most competent and efficient automobile producing nations in the world.** Numerous innovations in automobile manufacturing were invented in Japan which inspired other automakers. Among the most prominent is the highly efficient Toyota production system, "Just-in-Time Production", and management principles such as "Lean Production" or "Kaizen".[295] In terms of technological competence relating to electric vehicles, Japanese car manufacturers appear to have sustained their leading position since Toyota introduced the first mass-produced hybrid car, the Prius in 1997.[296] As battery technology is the key factor in maintaining technological leadership, Japan uses its know-how in order to decrease dependency on imports of critical materials. In order to reduce dependency on China, Japan has invested in research and development aiming to develop batteries which are not dependent on rare earths materials. A research team led by Professor Nobukazu Hoshi from the Tokyo University of Science developed an electric rare earth-free motor named "Switched Reluctance Motor" for use in electric vehicles capable of creating an output of 50 kw with an efficiency of more than 95 percent. Unfortunately the Switched Reluctance Motor is not as energy efficient as current state-of-the-art electric vehicle motors, but further research efforts might promise equalising performance levels in the short term. Among the automobile makers, Toyota and others are reported to support research and development of rare earth-free electric motors.[297]

Why is today's Japan ahead of technological developments in the area of electric vehicles? Next to early and major investments into research and development of electric vehicles and governmental support, cooperation between the key players like manufacturers, suppliers, universities and infrastructure providers seem to be paramount to Japan's success.

The **Korean automotive industry is relatively young.** Starting in the 1960s with a knocked-down parts assembly, the first original development was brought forth by Hyundai in 1976 with the model "Pony" featuring a 1200cc engine. It sold 290,000 units by 1982 which was considered a success and milestone for Hyundai, the company started operations in overseas markets accordingly. Hyundai established its presence in the European market in 1978. **Today Korea is one of the world's major automobile manufacturers, mostly due to Hyundai's high volume sales of passenger cars.** Hyundai's success can be explained by its broad range of vehicles in all market segments and the frequent introduction of new models, a focus on exterior design (after 2000), good quality, reliability, and unusually high warranty periods as well as an efficient after sales network.[298]Although Hyundai is a major vehicle producer, technology-wise, it is not regarded as being driven by innovation in new advanced vehicle technologies. Hyundai achieved its leading position today, first and foremost, based on its decently priced vehicles, while concurrently offering more standard technologies compared to competitors, modern exterior design, long warranty periods and comprehensive services (see Chapter 3.3.2). Whereas Korean OEMs, in particular Hyundai, are strong in marketing, weakness can be seen in its domestic supplier base. Korean suppliers have been competitive on the pricing aspect but remain weak in advanced technologies. Disadvantages derive partly from structural weaknesses that stem from Korea's industrial organization. Moreover, the major Korean auto brands such as Hyundai and Kia occupy an aggregate collective domestic market share of 70-80 percent[299], and maintain an unusual high share of Tier1 suppliers with approximately 350 single firms each.

The low competitiveness of Korea's auto part makers is reflected in the industry's total sale figures. Most suppliers just have one customer in their portfolio. In the absence of innovative products attractive to other auto makers, international sales are weak; similarly weak are the total export sales.

A Mobis[300] Chief Executive was quoted saying, "our weakness is we lack the technology, and we don't have time to learn it. We aim to select top-ranked makers of automotive components and offer joint

[295] Monden (2012); Liker (2004)
[296] Deutsche Bank (2009), p.103.
[297] Yirka (2011); Nikkei Newspaper (2012); Herrmann (2011)
[298] BNP Paribas (2005)
[299] Reuters (2011)
[300] Mobis, a former in-house supplier of Hyundai, now spun-off, is the largest auto parts supplier in Korea.

venture production bases in Korea in exchange for the chance to supply parts to Hyundai and Kia" (quoted in: Doner et al. 2004, p. 179). Today Korea can be regarded as one of the global leaders in electric and hybrid vehicle technology next to Japan. At this point, however, it is unclear how fast Korean automakers will be able to market their know-how. Yang Woong-chul, Vice Chairman of Hyundai and Kia Research and Development, recently expressed concern about battery performance and infrastructure which represent the major hurdles in replacing cars equipped with internal combustion engines. While the full electric vehicle by Hyundai named BlueOn was released in 2010 for fleets in the domestic market only, Hyundai is currently tending to focus more on fuel efficient diesel and gasoline hybrids. In contrast, Nissan and General Motors expect a quicker spread of electric and hybrid vehicles. However, in efforts to reduce emissions and become the fourth largest electric vehicle market by 2015, the Korean government has made ambitious plans to cover all segments. According to the Ministry of Knowledge Economy and the Ministry of Environment, 1.2 million vehicles featuring electric-, plug-in hybrid-, and fuel-cell technology will be manufactured by 2015 by all five Korean automakers (Hyundai, Kia, GM Daewoo and Renault-Samsung). Between 2011 and 2016, $2.7 billion dollars may be invested by the five companies. By 2020 one million electric vehicles are targeted to drive on Korean roads. Purchasers are supported by tax incentives from the government in order to realise this goal.[301]

The modern Chinese automotive industry has a short history. Although there had been a production of motor vehicles ever since WWII, factories were focused on producing trucks and buses for military and civilian purposes. Hence**, the 1980s saw the beginning of the first meaningful manufacturing of basic passenger cars.** China began with the establishment of joint venture companies with Volkswagen and Shanghai Automotive Industry Co. in 1985. Most domestic companies started with old designs from western OEMs, such as the Red Flag limousine, or were based on technology assimilated through reverse engineering. While Chinese companies who had teamed up with overseas peers quickly started to improve capabilities and produce reasonably priced cars which appealed to the general population, independent automakers struggled to improve production technology, raise quality levels, and create designs which could be successful. It took until the early 2000s for companies such as Chery, Geely, or Great Wall to emerge from the shadows of their larger, state-owned peers and their foreign JV partners to finally conquer parts of the domestic market. While starting levels were initially very low for all companies, JVs expanded first, rapidly, and successfully. Relatively high prices and lack of localization provided independent companies with an opportunity to capture parts of the lower market. All companies have started to invest heavily in R&D and have hired world renowned designers to create the new model generations. The industry which had to rely on copying and imitation has matured and approached international performance and quality levels. Due to the relatively brief catch-up period, management still lacks the sophistication and production technology that is still not as refined as in OECD markets. **One way to overcome the typical latecomer problems of substandard technologies and a persisting performance gap is to leapfrog. Realising that Chinese carmakers will be unable to close the performance gap to western automakers in regards to ICE technologies, government authorities have advocated the move towards building electric vehicles**. Since the market was still in its infancy phase and no company had yet established a dominating position, they concluded that Chinese companies had a unique opportunity to step in and play out their advantages in fields of low labour costs, favourable access to vital raw materials, large market potential and expertise in battery manufacturing. While the R&D budgets and capabilities are still far below those found in western markets, Chinese companies have made a large leap towards indigenous innovation and independent technology development.

In the United States the automotive industry suffered as a result of the global economic recession in 2009. As vehicle production and sales declined, vehicle parts production and sales concurrently decreased. Automotive suppliers had experienced heavy debt and overcapacity caused by production cuts by automakers, especially the Detroit 3 (Ford Motor Company, General Motors and Chrysler).[302] The year 2009 was a very difficult year for U.S.-based automakers, as the economy struggled to emerge from a recession and customers reduced their spending on vehicles. Therefore, General Motors, Ford, and Chrysler continued to lose market shares to other automakers, but even foreign transplant manufacturers were faced with difficulties due to the decreasing market.[303] Nevertheless, the U.S. automotive industry is faced with growing competition due to foreign companies. Until recently,

[301] Seo (2010)
[302] United States Department of Commerce (2011)
[303] United States Department of Commerce (2011)

the U.S. automotive industry had to fight to survive in the crisis. During the recession, dramatic cost reductions and structural changes were required. In 2011, vehicle manufacturers, such as GM, took back shares from equity investments, which they had acquired during the crisis. For example, GM transferred 3.8 billion Euro back to Delphi. The supply of automotive parts and components from the EU to the United States will continue to rise due to the expansion[304] of production capacity of European manufacturers in the United States.[305]

The U.S. automobile manufacturers follow very different strategies. In the field of the traditional powertrain, Ford bets on the aggressive development of technology for internal combustion engines. The brand EcoBoost is an ecological option which can be purchased for the bulk of Ford's product line-up. EcoBoost is based on components from supplier Borg Warner, a global key player in terms of powertrain components, they consist of a turbocharged engine with reduced dimensions and direct gasoline injection, which is used instead of the more powerful standard engine. Ford plans to increase the sales of EcoBoost engines to 1.3 million p.a. in the short term.[306] Moreover, this type of engine should be available for 90 percent of North American vehicle types. This strategy is combined with a small number of electric and hybrid vehicle types in order to meet the CAFE standards by 2013.[307] GM is lagging in the development of environmentally friendly products. Instead, GM invested several billion U.S. dollars into the development of the Chevrolet Volt/Opel Ampera. GM recently announced to stop the production of its Chevrolet Volt in its Detroit-Hamtramck plant from Sept. 17th until Oct. 15th, in order to reduce the vehicles which are in stock.[308]

While Ford concentrates on its brands Ford, Mercury and Lincoln, GM focuses on its five core brands Chevrolet, Buick, GMC, Cadillac, and Opel (EU), withdrawing Hummer, Pontiac, Saturn, and Saab. Chrysler has decided to form a global strategic alliance with the Italian manufacturer Fiat S.p.A. However, the 'Big Tree' Detroit manufacturers had their comeback in 2010 due to a recovery in the global markets and extensive restructuring programmes. In 2010, Ford was already able to reach a 19 percent sales increase up to 1.9 million vehicles, while GM (7 percent, 2.2 million vehicles) and Chrysler (17 percent, 1.09 million vehicles) also improved their sales.[309]

Current developments in the U.S. automotive industry are dominated by capacity expansions, consolidations and outsourcing of components and parts from manufacturing companies towards suppliers. Faced with overcapacities during the last years, the car manufacturers were able to strengthen their position with new fuel-saving vehicle types, smaller vehicle types (e.g. the launch of Fiat 500 U.S.), innovative forms of propulsion (e.g. launching and promoting “clean diesel” technologies like Volkswagen TDI Clean Diesel, Mercedes Blue TEC or BMW Advanced Diesel), changing ownership structures, trimming costs and increasing supply advantages due to the dollar exchange rate.[310]

European car manufacturers like Volkswagen, BMW and Mercedes plan to expand their U.S. production capacities, e.g. BMW with the production of the 3Series and 5 Series. Presently, the BMW Group has a plant in Spartanburg, South Carolina, in order to assemble the X3, X5 and X6 vehicle type. Mercedes plans to complement the production of the M, GL SUV and R-Class in Tuscaloosa, Alabama, with the production of the C-class by 2014, possibly with MLC. By 2014, the automaker intends to invest 1.75 billion Euro. The consideration of whether Audi and Porsche will assemble vehicles in the U.S. is currently being examined. Furthermore, Volvo is also planning a production of cars in the United States. Whether the company will build up its own production facility, or prefer contract manufacturing, is not yet clear. **Competitors from Japan and Korea are also pursuing expansion strategies in the United States.** Honda plans to increase the production capacity of 1.29 million vehicles to about 2 million vehicles due to the high external value of the yen, which makes exports from Japan unattractive. Furthermore, the Hyundai-Kia Automotive Group plans to build a second production facility in 2012.[311]

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[304] n-tv (2012)
[305] E.g. Volkswagen Group of America in Chattanooga, but also manufacturers like BMW and Daimler, see n-tv (2012)
[306] Handelsblatt (2012e)
[307] Autoguide (2012)
[308] Autonews (2012f)
[309] Zacks (2011)
[310] GTAI (2012a)
[311] GTAI (2012a)

In the field of traditional combustion technology, the diesel engine has particular growth potential. The advantages of diesel engines have been ignored by the U.S. customers for a very long time. Diesel engines have been regarded as too noisy, smelly or unreliable. We expect that the attitude of the U.S. customers will change rapidly due to rising oil prices and the potential for improvement of diesel technology. Particularly the increasing costs will lead the U.S. customers to become more open minded towards new propulsion technologies. This market-driven trend has been identified by many manufacturers as well. Accompanied by a broad advertising campaign, manufacturers such as Volkswagen, Mercedes and BMW Group currently offer several diesel models in the United States.[312]

Compared to the EU and U.S., Japanese and Korean companies are especially benefiting from their know-how in the consumer goods industry (e.g. electronics). Most of the Japanese and Korean battery suppliers (e.g. Panasonic, LG or Toshiba) are not focusing solely on the automotive business. They have been working in the field of battery technology for several years. **In order to strengthen the competitive position, European manufacturers and suppliers have to build up new competencies, especially in the field of electrochemistry, materials science, electrical energy systems and production.[313]**

3.2.5.3 Productivity and Labour Cost

The following table shows an overview on productivity in the automotive sector, illustrated using the sample of value added per employee. The average of the productivity of EU automotive companies is more than three and a half times less than in Japan. Compared to South Korea and the U.S., the productivity of EU automotive companies is also weak. In a European comparison Austria has the highest value added per employee, followed by Hungary and Germany.

Table 28: Value Added per Employee (in current USD (in 1,000))

	Austria	France	Germany	Italy	Spain	Sweden	United Kingdom	Poland	Hungary	Average
2000	65,8	71,9	53,1	41,2	52,6	90,4	51,2	19,1	79,1	58,3
2007	138,7	82,2	112,9	78,2	88,5	103,7	89,2	61,7	135,7	99,0

	Japan	South Korea	US	Brazil	China	India	Thailand		
2000	242	142,4	190	53,6	…	9,7	…		
2007	359,3	251	244	120,3	47,5	46,1	166,1		

(Source: UNIDO2010)

In saturated domestic markets, it is increasingly difficult for OEMs to benefit from technology leadership and innovation alone. In order to attract new customers, almost all manufacturers are operating in different segments, e.g. offering several types of new models and derivatives (e.g. Golf/Golf Plus, Toyota Prius/Prius+). Despite all efforts to reduce the variance and diversity of parts and components, manufacturers have to deal with an overall greater complexity than before. The OEMs need to be able to produce several types of models on one shared assembly line.[314] This flexibility is necessary to use existing infrastructure productively. While some time ago, conducting Kaizen workshops was considered a sign of a lean organization, today the availability of a production system is a "must have". Toyota was one of the first manufacturers which developed a production system aiming for a lean organisation (e.g. focusing the production on the customer cycle, elimination of waste, synchronization of processes, standardization of processes, elimination of errors, improvement of production, qualification and training of employees and a continuous improvement process).[315]Global manufacturers like the Volkswagen group for example recently developed the new "Volkswagen Production System", which is also based on the continuous improvement process (see Box 8).

[312] Volkswagen (2012a); BMW (2012a); Mercedes Benz (2012)
[313] Deutsche Bank Research (2011)
[314]See Chapter 3.2.1.4.
[315]See also Liker (2004)

Box 8: The Volkswagen Production System (VPS)

The Volkswagen production system (VPS) is the basis for the development of Volkswagen into a synchronous company oriented towards value creation. The core elements of the Volkswagen production system (VPS) consist of a variety of basics and the four columns “Cycle”, “Flow”, “Pull” and “Perfection”.

- The **fixed customer cycle** sets the pace for production and the supporting processes, and creates a stable and constant cycle level. It is the basis for the integrated design of product, process, operating equipment and infrastructure. For this reason, suppliers also work within the fixed customer cycle of Volkswagen Group.

- The **pull principle** means that each process obtains only those parts and information from the previous process that are actually required. Simultaneously, the up-stream process produces only what the downstream process consumes. This keeps inventories to a minimum and reduces lead times. System control becomes simpler.

- The **flow principle** states that material and information flow in the customer cycle. Processes and work steps are arranged according to the production process and distributed among different workplaces according to the customer cycle. The only buffers used are necessary to the process. Deviations from the standard are visible and can be removed.

- **Perfection**: 100% quality from the process. The entire product can only be OK’d without breaching the standards if each sub-process transfers OK’d parts only. This system ensures that each error occurs only once, and that errors are not passed on to the customer. The goal is to pass on parts that are 100% OK to down-stream processes. (OK’d = validated as OK , or has been checked)

Volkswagen´s final objective is to create a company that is oriented towards value creation and has completely synchronized supply chains that are geared towards short lead times, small inventories and continuous improvement.

(Source: Volkswagen 2009)

Altogether, it is very difficult to discuss country-specific differences in the field of productivity, because the productivity is rather a specific property of a company or a production/assembly line. For example a manufacturer can produce two cars of the same type with different productivities in the same country e.g. in different plants (e.g. Volkswagen Golf in Mosel/Zwickau and Wolfsburg), due to different flexibility, investments, workload and capacity.

According to the experts interviewed, **productivity will not be a key driver of electromobility**, since all manufacturers engage in the field of process optimization, flexibility of production etc. A manufacturer can build up a new production facility with high productivity in Asia, but can also invest in the U.S. or in the EU. Electromobility requires high investments (new production facilities vs. integration/manufacturing at the same assembly lines like vehicles with internal combustion engines) leading to a **high degree of automation**, particularly in the area of EV components (battery production). According to the experts interviewed, **labour cost** will therefore not be a key driver either.

Between 2000 and 2010, the average annual growth rate in **unit labour costs** of EU manufacturing reached approximately 1 percent. The amount of unit labour cost is defined as the ratio of labour costs per employee to value added per employee. Unit labour costs cannot be interpreted as an exhaustive measure of cost competiveness since it is only focussing on labour costs. In the EU automotive industry, the unit labour costs increased with an average amount of 0.5 percent between 2000 and 2010. Between 2000 and 2009, the growth of the unit labour cost in the EU automotive industry had an average amount of 2.2 percent.[316] In 2010, the growth in unit labour costs declined sharply at an average amount of 15.2 percent. This sharp decline can be explained by increasing production volume[317] subsequent to the financial crisis (recovery of demand). The amount of unit labour cost depends on both output of production and the employment at given labour cost. In contrast, strong increasing growth

[316] European Commission (2011c)

[317] ACEA (2011a): EU 27: +8 percent passenger vehicles, +41 percent light commercial vehicles in 2010 compared with 2009

rates of unit labour costs are typical during recessions when the output of production decreases rapidly while adjustments of wage payments do not vary erratically.[318]

Currently, plants in Eastern European or in the BRIC markets benefit from a higher labour productivity, because most of these factories have been developed in the last 20 years. They have modern production lines with a modern logistical infrastructure (e.g. supplier parks close to the assembly lines). **According to most of the experts surveyed for this study, the labour productivity of car manufacturers will converge in the long term** since production facilities will be optimised. Due to a high degree of automation, modern and profitable assembly lines will arise in Western Europe as well (e.g 1 billion Euro investment of Volkswagen in its plant in Emden or the 125 million Euro investment of BMW into its German plants in Landshut and Dingolfing, see Chapter 3.3.1). The wage and salary payments of the EU automotive industry are characterised by huge differences among the Member States (see Table 29).

Table 29: Wage and Salary Payments in the EU Automotive Industry in 2008

Country	Euro
Germany	61,700
Sweden	53,900
Belgium	52,300
France	51,600
United Kingdom	41,200
Spain	39,600
Italy	39,000
Eastern Europe*	13,300

* average amount, Czech Republic, Hungary, Poland, Slovakia and Slovenia

(Source: CCFA 2011)

In Germany, the highest wages were paid in 2008. Both premium manufacturers like BMW, Daimler, Porsche or Audi and large scale manufacturers like Ford Europe and Volkswagen have their headquarters and research & development centres in Germany, i.e. BMW in Munich, Daimler in Sindelfingen, Ford Europe in Cologne and the Volkswagen Group in Wolfsburg. While these manufacturers benefit from lower wages in Southern and Eastern Europe (e.g. production of the Ford C-Max in Valencia/Spain or production of the Fiat Panda in Tychy/Poland), the companies are still managed by their headquarters in Germany.

In Eastern Europe, in countries like Czech Republic, Hungary, Poland, Romania, Slovakia, and Slovenia, significantly lower wages are paid at an average amount of 13,300 Euro per year. Clearly, Eastern European countries have a labour cost advantage although the gap is closing. According to Eurostat, in the second quarter of 2011 the index of gross wages and salaries of the EU-27 automotive industry was 5.9 percentage points[319] higher than in 2005 (100 percent). Compared to the rest of the industry (growth by 9.4 percentage points compared to 2005), this growth rate is moderate.[320]

The U.S. Centre of Automotive Research (CAR) determined the following country specific average wage per hour for the automotive sector: the average wage per hour in the U.S. is 34.59 dollars, in Europe higher wages are paid (e.g. Germany 52.60 dollars, France 33.03 dollars, Italy 29.41 dollars, Poland 7.65 dollars). With a value of 32.31 dollars Japan has approximately the same average wage per hour as the United States. Significantly lower wages per hour are paid in Korea (18.72 dollars) and

[318] European Commission (2011c)
[319] Index of gross wages and salaries, seasonally adjusted
[320] Eurostat (2011)

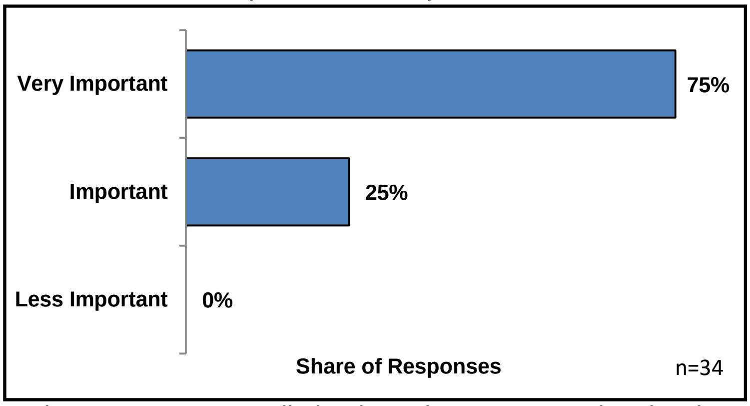
China (3.45 dollars) - and countries such as Brazil (14.61 dollars), Mexico (3.94 dollars) or India (1.32 dollars).[321]

In the transition to electromobility, the labour cost will play a minor role, as the production of components (e.g. power electronics or battery cells) is characterized by a high degree of automation.

3.2.5.4 Role of Consumer Information

All the experts interviewed in this study consider consumer information as important (see Figure 42). Consumer information is a very important driver of electromobility, because ultimately the customer decides whether and how quickly a technology will claim a stance in the market.

Figure 42: Estimations of Experts on the Importance of Consumer Information



(Source: Own Compilation based on Expert Estimations)

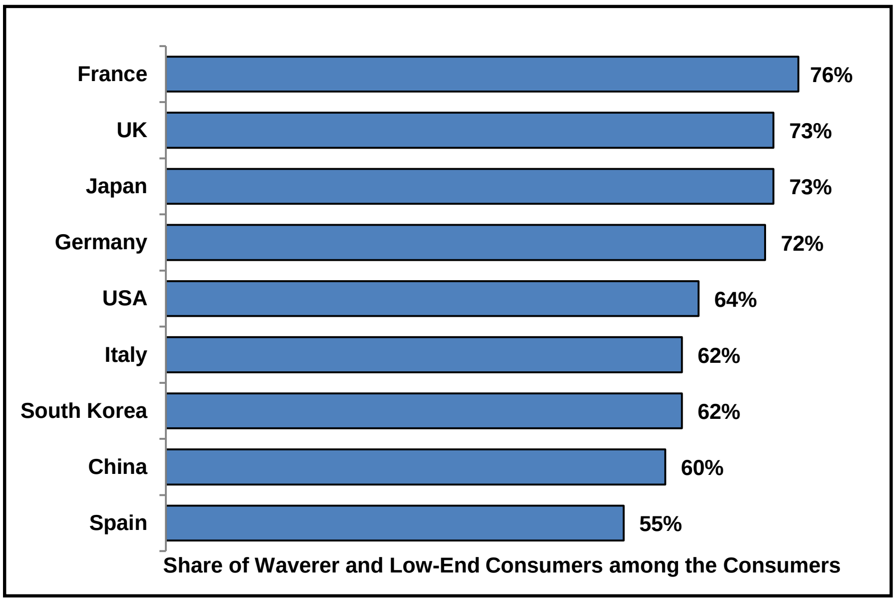
A global manufacturer stated:

“First of all, policy needs to ensure that customers see electric vehicles as positive potential solutions i.e. there should be no conflicting societal views like we have seen for bio-fuels where policy first pushed bio-fuels and later on needed to correct the overall positive view. This would lead to consumer confusion and would risk the EV market success.”

A potential gap between perception and evidence has to be identified at its earliest in order to avoid large numbers of customers refusing electric vehicle technology. The large percentage of private customers, who have a hesitant or sceptical attitude towards electromobility (see consumer segments of the Waverer and the Low-end Consumers in Table I, Appendix III) emphasise the high need of consumer information for the transition to electromobility (see also Figure 43).

[321] Car (2011a)

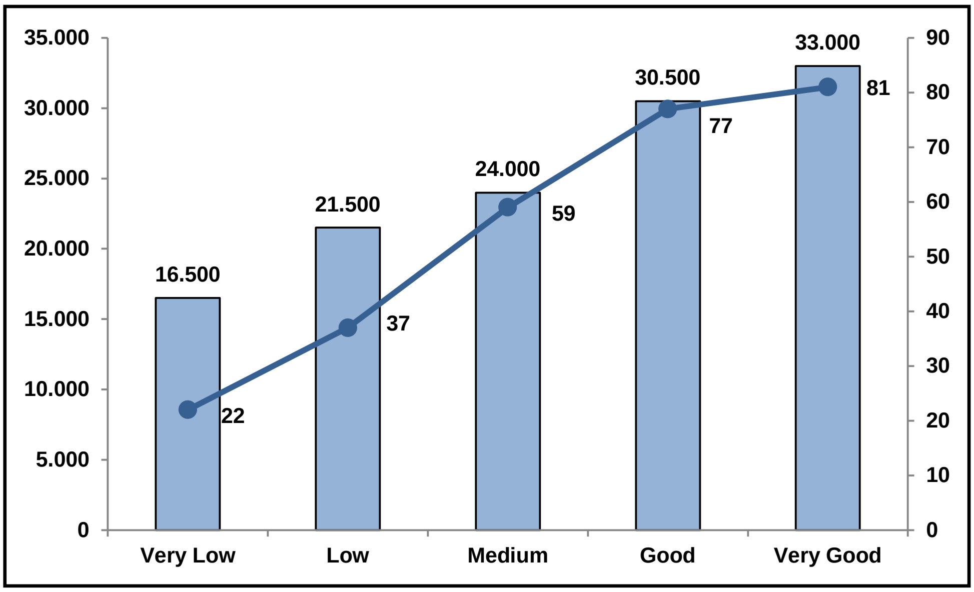
Figure 43: Share of Private Consumers with High Information Needs in Certain Countries



(Source: Own Compilation according to Table I, Appendix III)

The results of earlier investigations in the Cologne E-Mobil Project (led by Prof. Dr. Heike Proff) underline that customers who have a higher level of knowledge in electric vehicles also have a higher purchase probability than customers who have a lower level of knowledge or have prejudices toward electric vehicles (see Figure 44).

Figure 44: Maximum Willingness to Pay and Purchase Probability concerning BEVs 2011 – 2014 (according to Consumer Knowledge; n = 700)



(Source: Fojcik et al. 2011)

Many consumers do not have any idea concerning the advantages of electric vehicles, because they have had no contact with electric vehicles. In addition to consumer information, manufacturers could support the penetration of electric vehicles by expanding their marketing activities ("Let them drive!"). Driving experience will probably lead to enthusiasm (e.g. acceleration, vehicle handling hardly differs). This will diminish the concerns of many consumers. Customers need “certainty”, that their purchase decision will be a good decision. This can be supported by the industry e.g. with guarantees.

A very **important part of public policy, which has been confirmed by all experts, will be the reduction of the existing information deficit of many customers**. Using appropriate media activities, the market penetration of electric vehicles could be accelerated. **Designing an adequate media campaign is therefore one of the policy recommendations which will be presented in Chapter 6.3.**

Regardless of electromobility, experts interviewed agree that all consumers should first be educated on how to drive vehicles efficiently. Furthermore, public authorities should explain why electric mobility is so important, e.g. in terms of sustainability, zero emissions. Apart from that, standardisation of labelling requirements is very important. The labelling of range and energy efficiency should not be influenced by different cycles of the manufacturer. All manufacturers should have to test electric vehicles on the same terms, so that the properties are comparable. A policy compared to vehicles with internal combustion engine is currently lacking. Many consumers seem not to know their real mobility needs. Many consumers have suitable driving patterns, although they think they are an "unfit Consumer".A better understanding concerning individual driving patterns, which is often less than expected by the individuals, should be a further important aspect of consumer information.

There seem to be several positive developments. Government authorities and manufacturers have long joined hands to showcase new energy vehicles to the public. Urban residents are likely to get in to contact with electric vehicles with increasing frequency as the numbers of public buses and taxis with electric drive technology continue to grow. While car rental and car sharing businesses with electric vehicles are still in their early stages of development, these too, have started to make an impression.[322]

3.2.5.5 Further Important Drivers

Market proximity will play a major role in the selection of the manufacturing site for electric vehicles. This assessment has been confirmed by experts interviewed. Due to long transport distances, high transport costs and that the vehicles will initially enter markets which offer the greatest potential. **Due to high investments in production facilities, small volumes of vehicles with new (electric) vehicle architectures ("Purpose Design") will not be produced globally. Initially, the production is likely to take place at selected centres** (e.g. BMW produces it's i-brand vehicles in Leipzig/Germany), focusing both on high capacity utilization and economies of scale. In the wake of an increasing market development, the production will be located close to the market. Future changes will also result in the field of vehicle transportation. **In 2011, most of the electric vehicles which were available on the European market were produced in Japan (see Chapter 2.1.1).**

Renault is the first volume manufacturer who has built up a mass production of electric vehicles in the EU. According to Chapter 2.6, the EU exports of electric vehicles to Japan and South Korea will remain low in 2020 and 2030. Also Japanese manufacturers are expected to invest in a local production as soon it becomes profitable. Nissan for example will start the production of its battery electric vehicle Leaf in Sunderland/UK as soon as February 2013. Since not all components of the electric drive train can be manufactured in the EU until the start of production in early 2013 (a local battery production at Flins is currently being discussed), large parts of the battery system will be imported from Japan. Furthermore, Chinese exports to the EU are currently negligible but may rise in the future as modern production facilities established by Sino-foreign auto joint ventures may want to escape an escalating industry glut and capitalises on their superior costs and quality positions to serve Western markets.

Initially, the flow of parts and components will increase, as key players from the electronic sector (e.g. battery technology) are currently located in Asia (see Chapter 3.2.1.1). At the moment the most important components of batteries (e.g. anodes, cathodes, raw materials) are purchased from overseas (see Chapter 3.2.1.1. and 3.2.5.1). According to a KPMG study, electric component suppliers will gain a more significant role by 2025, reflecting the continued rise of electric parts in both vehicles with internal combustion engines and vehicles with electric powertrains. In terms of electromobility, OEMs will be faced with more new global suppliers from the technology and electronic sector. The following table provides an overview on current OEM-supplier relationships in the field of batteries for electric vehicles.

[322] Cars21 (2011e)

Table 30: Key OEM Customers by Battery Suppliers

Supplier	OEM
A123	Daimler, GM, SAIC, Fisker
GS Yuasa	Honda, Mitsubishi, PSA Group
Johnson Controls	Daimler, BMW, Ford
LG Chem	GM, Ford, Renault, Volvo, Hyundai
AESC	Renault, Nissan
SB LiMotive	BMW, Fiat, PSA Group, Volkswagen Group
Panasonic	Toyota, Ford
Sanyo	Volkswagen Group

(Source: Own Compilation based on Roland Berger 2011a)

Altogether, the electrification of the powertrain will have an impact on the current automotive supply chain. The importance of logistical processes will increase, **which can be explained using the example of the battery systems. Battery systems are on the one hand heavy and bulky, which corresponds to high transport costs, and on the other hand very expensive** (capital tied up in long distance transport). A practical barrier will be the existing weight limitation on the transport of Li-Ion batteries by air freight. Categorised as "transportation of dangerous goods" (UN recommendation, regulated by ICAO/IATA), the transport of these batteries with aircraft is limited to max. 35 kg and requires special cargo planes. The automotive industry will be faced with more expensive, logistically challenging (e.g. JIT-Production) and time-consuming transport options, including transport by ocean vessels. Therefore, it can be expected, that the mass production of battery systems (e.g. the battery packaging) will be located close to the assembly line of the automotive manufacturer.

In the case of electric vehicles, it might be difficult for European companies to enter into existing supply chains. For example, most of the Japanese companies have been members of a certain supply chain for many years, benefiting from their **existing supplier-buyer relationships.** In the past, relationships between suppliers and buyers have been developed, which are particularly based on trust and long-term co-operation. Due to the existing relationships (especially in the field of consumer goods), Japanese and Korean companies such as Panasonic or LG Chem benefit from higher volumes which lead to economies of scale and less investment risks.

Public policy will also play an important role in order to push electromobility's breakthrough into the market. Therefore, Chapter 5.1 provides an overview on the current public policy framework in the EU compared to Asia and the US. Chapter 6 includes recommendations on the future public policy framework in terms of electromobility.

3.2.6 First Mover Advantages

A company can reach a first mover status in different ways, e.g. producing a new product, using a new process or entering a new market.[323] First mover advantage means that a pioneer company can occupy an unassailable position over its competitors (e.g. a monopolist), which is expressed by a high return in a competitive marketplace. With the market entry of the followers the pioneer has already established its market position and learning curve economies that allow him to retain a strong and dominant market share with higher margins compared to the followers.[324] However, there is also a high risk for a first mover, as for example a new product always involves a high degree of uncertainty.

In transition to electromobility companies are faced with opportunities and risks. Concerning the market situation, **the risks for first movers outweigh the advantages**, because the market development

[323] Kerin et al. (1992)
[324] Kerin et al. (1992)

is weak, the consumer behaviour is mostly unknown and differs a lot between the regions and the technological development is very fast and expensive (see Appendix XXXIV).

However, in this case companies could possibly secure a leading position in the early stage of the market's evolution**. Companies with technological leadership benefit from their innovation potential, expertise and know-how in related industries**. They have a good chance to capture the market as first movers, especially in markets with a high intensity of competition.

In transition to electromobility, the **access to raw materials** is limited for many companies (see Chapter 3.2.5.1), but this could also be an advantage for a first mover. If the first mover has superior information, it can acquire plants, equipment and/or contract for suppliers e.g. at lower prices (supplier-buyer commitments).[325] Therefore, in electric mobility many partnerships are formed in order to keep pace with the competitors (see Chapter 3.2.3).

A **high product complexity leads to first mover advantages**, because complex products and technologies are difficult to imitate (e.g. power electronics, battery technology/production process). In the case of electromobility, a standardisation potential particularly in the field of electric engines is expected (see Chapter 3.2.1.2). It remains to be seen whether European companies are able to maintain their competitive position.

In terms of battery technology, a sharp drop in prices for Lithium-Ion batteries is expected (see Chapter 2.3.1.2.2). Roland Berger's (2011b) study observed a trend towards excess capacity in the market for Lithium-Ion batteries. U.S. suppliers such as A123 and Ener1 have already had economic difficulties. In terms of battery technology, a first mover advantage can be identified for Japanese and Korean battery manufacturers in particular (see also Chapter 3.2.1.1.3) while the European automotive industry benefits from its strong position in terms of power electronics and electric engines (see Chapters 3.2.1.2.1 and 3.2.1.3.1). **Without domestic expertise in the mass production of batteries suitable for vehicle propulsion, it will be very difficult for European companies to reach a high level of competence in the short term**. While battery technology and power electronics require a specific know-how, **electric engines are characterised by a high standardisation potential** (see Chapter 3.2.1.2.1). It remains to be seen whether the European key players can maintain their position or whether they can even catch up e.g. in terms of battery technology. In addition to the battery packaging (see Chapter 3.2.1.1.1) it is quite possible that in the course of market development more value-added activities will occur close to the market in the EU (e.g. manufacturing of components like anodes, cathodes or cell production).

Since almost all premium and volume car manufacturers will offer electric vehicles in the short and medium term (see Chapter 2.1.1 and 2.1.2), **a first mover advantage cannot be identified among the OEM yet**, as only a few vehicles have been launched into the market so far (see Chapter 2.1.1). The market penetration of electric vehicles is moving slowly. From a today´s perspective **it is unclear, which manufacturer will become a market leader in terms of electric vehicles in the medium- or long term**.

The European automotive industry is well placed since manufacturers like Renault, PSA and Smart have already been offering electric vehicles. Other volume and premium manufacturers such as Volkswagen, BMW, and Daimler will follow (see Industrial Plans in Chapter 3.3.1). In the case of electric vehicles, first movers will not only benefit from their product (e.g. range, usability) but also from the related services that build strong customer loyalty (see Chapter 4).

3.2.7 Interim Conclusion

The competition concerning technology for the electric powertrain and market share will increase rapidly. In the field of battery production the initial position of the European industry is rather weak. The major key players are located in the U.S., Japan, and Korea.

With investments announced of $600 million in Flins facility (FR), $356 million in Spain and $330 million in UK, AESC can be considered as a leader in terms of investment in the EU. If AESC implements

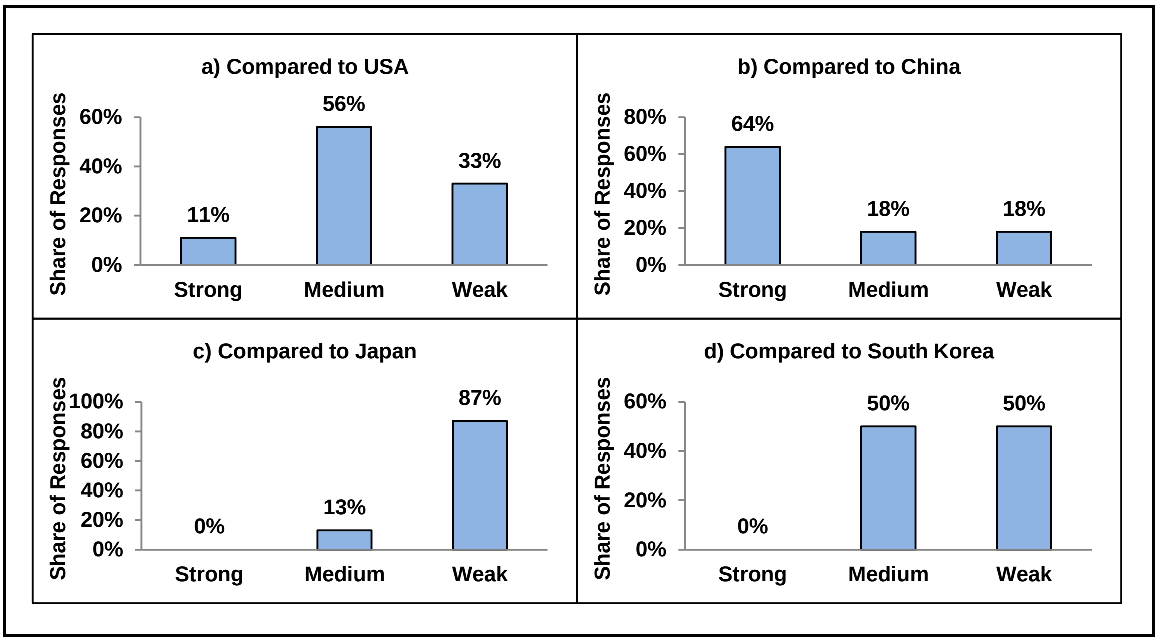
[325] Kerin et al. (1992), p. 42.

its plans by 2014, the alliance will also become the European leader in terms of capacities[326], followed by Bosch/BASF, SB LiMotive[327] and Li Tec.

Overall, the **European companies have shown a positive development in patent applications in EV Technolog**y in the last few years. However, despite this noticeable upward trend in Europe, it is doubtful whether European companies will catch up with their Asian competitors in the next few years. European manufacturers and suppliers have to build up new competencies, especially in the field of electrochemistry, materials science, electrical energy systems and production. **Battery technology and power electronics in particular have the highest potential for optimisation.**

Although the European automotive industry is in a weak competitive position compared to their Asian competitors in terms of battery technology, **European key players** (such as Continental, Bosch, Siemens and Infineon) **have a strength in the field of "Power Electronics"**. Figure 45 provides an overview of expert estimations concerning the position of European automotive industry compared to the U.S., China, Japan and South Korea.

Figure 45: Position of European Automotive Industry Compared to the U.S. China, Japan and South Korea



(Source: Own Compilation according to the Expert Interviews)

Figure 45 shows that European manufacturers have a medium competitive position compared with competitors from Asia and the United States.

According to the majority of experts interviewed, the EU automotive industry commands a medium competitive position in electromobility **compared to the U.S.** (see Figure 45a).The majority of the experts emphasised that the U.S. key players "have done their homework", making the right decisions while trying to overcome the impacts of the crisis. Nevertheless, due to less market development of electric vehicles, the U.S. battery supplier A123 generated a loss of $258 million in 2011, after a loss of $152 million in 2010. Recently the company A123 reported a second-quarter loss of $82.9 million. The factory is faced with overcapacities. Furthermore, the U.S. Lithium-Ion battery maker Ener1 filed for bankruptcy in January 2012.In the U.S., production capacity has been built with high subsidies. As the market grows slowly, companies such as Ener1 and A123 are faced with economic difficulties. It remains to be seen when and which major manufacturers will produce electric vehicles in the U.S. other than the big 3. Presently, the Chevrolet Volt is powered by batteries from the Korean supplier LG

[326] Capacities for more than 300,000 units see Chapter 3.2.1.1 and Appendix XVIII.
[327] Recently, Bosch announced to split up with Samsung. Therefore, no data on the continuation of investments and capacities are available.

Chem. The production of the batteries is located in Holland/Michigan.[328] Johnson Controls manufactures the Lithium-Ion batteries for the Ford Transit Connect Electric.[329] The Korean supplier LG Chem produces the batteries for the Ford Focus BEV.[330] The Lithium-Ion cells for the packs will initially be sourced from Korea through LG Chem. LG Chem and CPI will be localizing cell production at their new site in Holland/Michigan[331]

Furthermore, Mitsubishi is planning the production of the i-MiEV in Smyrna/Tennessee by the end of 2012, but it remains to be seen who will supply the batteries for this vehicle. In Japan, Mitsubishi has a joint venture with GS Yuasa in order to produce Lithium-Ion batteries for the i-MiEV (see Chapter 3.2.1.1).

The experts surveyed for this study stated that European companies have a strong competitive position **compared to their Chinese rivals**(see Figure 45b). In China for example, the majority of experts expect that the country will play a leading role in the field of electric vehicles due to its market size and market growth. Chinese manufacturers have already built up competence in the development and production of individual components. Nevertheless, the relative strength in this field is offset by weaknesses regarding vehicle integration. While Chinese manufacturers are able to follow market trends very quickly, they have deficits in terms of the production management and technology. Presently, Chinese manufacturers cannot offer high-quality in mass production. Mass production at a high level of quality currently belongs to foreign companies/partners, due to their superior production technology.

European manufacturers are considered to have a weak competitive position in electromobility **compared to Japan** (see Figure 45c).A majority of experts emphasise manufacturer's progress in terms of the efficiency of their production system, but particularly in the area of the components (e.g. battery technology). Europe's deficiency however, is due to lack of experience and limited know-how.

According to experts consulted, the EU automotive industry commands a medium competitive position in electromobility **compared to Korea** (see Figure 45d). This expert assessment is primarily based on the lack of experience in the field of battery technology on part of European companies.

Based on current sales, it is apparent that Japanese manufacturers have a strong competitive position in the production of electric vehicles. Nevertheless, the European automotive industry has been catching up since Renault began the mass production of electric vehicles in Europe last year. The following table provides an overview on current sales of electric vehicles by the global key players.

[328] LG (2011)
[329] Johnson Controls (n.d.)
[330] Autotrends (2012)
[331] Ford (2010)

Table 31: Sales of Electric Vehicles by Manufacturer

Vehicle	Type	Plant	Global Sales 2012*	Global Sales 2011	Market Share 2012*
Mitsubishi i-MiEV	BEV		**~ 3,000**	**5,084**	**6%**
Citroen C-Zero	BEV	Mizushima (Japan)	1,200 (Jan-June)	2,074	**2%**
Peugeot iOn	BEV	Mizushima (Japan)	900 (Jan-June)	2,400	**2%**
PSA Group			**2,100**	**4,474**	**4%**
Nissan Leaf	BEV	Oppama (Japan)	**~ 11,000 (Jan-June)**	**22,150**	**21%**
Renault Kangoo Z.E.	BEV	Maubeuge (France)	2,678 (Jan-June)	124	**5%**
Renault Fluence Z.E.	BEV	Bursa (Turkey)	1,198 (Jan-June)	75	**2%**
Renault Twizy	BEV	Valladolid (Spain)	6,057 (Jan-June)	n.a.	**12%**
Renault			**9,933**	**199**	**19%**
Bolloré Blue Car	BEV	Pininfarina Turino (Italy)	**1,383 (Jan-June)**	n.a.	**3%**
Chevrolet Volt	REEV	Hamtramck (U.S.)	8,817 Jan-July)	7,700	**17%**
Opel Ampera	REEV	Hamtramck (U.S.)	2,861 (Jan-June)	n.a.	**5%**
General Motors			**11,678**	n.a.	**22%**
Toyota Prius Plug-In	PHEV	Tsutsumi (Japan)	**13,300 (Jan-July)**	n.a.	**25%**

Notes: SOP = Start of Production * Half year figures

(Source: Own Calculation based on Annual Reports, Press Releases and Global Insight)

Nissan has been the market leader since the production of its battery electric Leaf started in Oppama (Japan) in 2010, selling about 35,000 units of its Leaf.[332] Furthermore, Mitsubishi belongs to the most successful Japanese manufacturers of electric vehicles. Until the end of 2011, Mitsubishi had produced more than 20,000 units of its battery electric i-Miev, including the volume of the PSA Group.[333] In 2012, the European sales of the Peugeot iOn and C-Zero have been decreasing. In the first half of 2012, about 6,000 units of the iOn and C-Zero were produced at Mitsubishi's plant in Mizushima.[334] In the same period, PSA Group had only sold about 2,100 units, while Mitsubishi had sold about 3,000 i-MiEVs.[335]

The French manufacturer Renault is the first European manufacturer that started (European) mass production of electric vehicles last year. In the first half of 2012, about 10,000 electric vehicles had already been sold by Renault. This trend is expected to develop positively because in the second half of 2012, a fourth battery electric vehicle will be added to their portfolio: the Renault Zoe Z.E. (see Chapter 2.1.2).

General Motors was able to double the sales of its Chevrolet Volt and Opel Ampera in comparison to the previous year, but current sales of the manufacturer are still below the expectations (sales target: 60,000 units in 2012). GM recently announced to stop the production of its Chevrolet Volt in its Detroit-Hamtramck plant from Sept. 17th until Oct. 15th, in order to reduce the vehicles which are in stock.[336] In the European sales, the Opel Ampera and Chevrolet Volt reached a total amount of about 3,100 vehicles in the first month of 2012.[337] Opel was recently announced to be the market leader of electric vehicles in the European markets.[338]Next is the Nissan Leaf, followed by the Renault Kangoo Z.E. Furthermore, Renault sold 6,000 units of its microcar Twizy Z.E. This vehicle does not have a passenger car registration in all countries (according to the EU regulation the Twizy is a L-cat vehicle), however, these 6,000 units have to be considered as well as additional to the European market leader in electric vehicles. In this case, Renault would be the market leader in the EU market (with about 10,000 units in the first half of 2012).

332 Own calculation, based on Nissan Europe (2012b) and Global Insight
333 Own calculation, based on press releases and InsideEVs (2012a)
334 See also Chapter 2.1.1
335 Own calculation, based on press releases and Global Insight.
336 Autonews (2012f)
337 Detroitnews (2012)
338 Opel (2012)

In terms of market shares, **Toyota has become the market leader with its Prius Plug-In in the first half of 2012** (25 percent), followed by General Motors and Nissan. Since Renault will launch its fourth battery electric vehicle in the compact segment in early 2013, the French manufacturer is expected to catch up. The registrations of the first half of 2012 underline this trend.

The increasing EU-production of electric vehicles shows that the European automotive industry is on the rise. From 2013, Nissan will also produce electric vehicles in the EU. The manufacturer is currently investing in the production of the Nissan Leaf in Sunderland/UK. From 2013/2014, manufacturers like Volkswagen, Daimler and BMW will follow, starting their production of electric vehicles in the EU (see Chapter 2.1.2 and 3.3.1).

Nevertheless, **in terms of components, the European automotive industry currently has a weak position compared to their Asian competitors, particularly in the area of battery technology** (e.g. due lack of experience and limited know-how). Without domestic expertise in the mass production of batteries suitable for vehicle propulsion, it will be very difficult for European companies to reach a high level of competence in the short term.

National platforms represent a suitable approach of public policy in order to support companies in the development and market penetration of new technologies. A cross national network of industry, scientists, policy makers, utilities, transport associations, and social groups will be a very important step in order to combine strengths in the EU. Furthermore, special depreciation programmes can be used to promote investments in production technology of electric vehicles and their components (on the level of the individual EU member country). This will reduce the threshold for investments in value added for electromobility which will lead to an acceleration of the transition to this new powertrain technology (see Chapter 6.3).

3.3 Evolution of the Industrial Situation

In order to estimate the evolution of the industrial situation, the main drivers are first considered (see Chapter 3.3.1). Followed by an analysis of the industrial plans of the European manufacturers (see Chapter 3.3.2) a forecast on the development of value added in the European automotive industry will be provided (see Chapter 3.3.2.3).

3.3.1 Industrial Plans of EU Automotive Companies

The following chapter summarizes industrial plans of the most important manufacturers of the global automotive industry.

BMW is **investing 125 million Euro** into its plants in Landshut and Dingolfing in the field of electromobility.[339] At both locations, 500 additional jobs will be created. The plants will produce components for the BMW i-electric drive vehicles e.g. the BMW i3, to be launched at the end of 2013, and the BMW i8 to be launched in 2014. Both vehicles will be assembled in Leipzig. Thei3willbe equipped with a body made of carbon fiber. BMW formed a joint venture with the carbon fiber specialist SGL Carbon in order to manufacture the carbon fiber in the United States. BMW uses the material In its German plants in Wackersdorf, Landshut and Leipzig. BMW holds a share of 43percent of the supplier SGL-Carbon, while 8 percent belong to Volkswagen.[340] In terms of the R&D of fuel cells, the premium car maker BMW recently shelved its plans for an alliance with the U.S. carmaker General Motors. Both manufacturers decided to go separate ways. Furthermore, it is still a matter of debate whether BMW wants to dissolve its alliance with PSA. It has been discussed that the manufacturer will take over the shares of BMW Peugeot Citroën Electrification itself. It has been argued that the partnership with the French manufacturer had burst because GM had joined in activities with PSA. Whether the newly hired employees will be taken over by BMW is still open. At the beginning of 2012, the joint venture employed more than 430 workers. The joint venture comprises a R&D center in Munich and a manufacturing plant in Mulhouse, France. The BMW Group and PSA Peugeot Citroën have invested more than 100 million Euro in their joint venture in order to electrify about 10,000 vehicles starting in 2015.[341] Instead, BMW and Toyota announced participation in the fields of hybrid drive components,

[339] Automobilwoche (2012c)
[340] Handelsblatt (2012b)
[341] Autonews (2012g)

fuel cells and lightweight components. BMW and Toyota are already working together on diesel engines and Lithium-Ion battery technology.[342]

Chrysler delivered four plug-in hybrid versions of its Town & Country minivan to the city of Auburn Hills, Michigan, for testing purposes. These vehicles are part of a test fleet of only 25 vehicles, whose development was jointly funded by Chrysler with $15.8 million and the U.S. Department of Energy, which contributed $10 million. At the moment, Chrysler does not manufacture hybrid and electric vehicles at all. The manufacturer briefly built Dodge Durango and Chrysler Aspen, large sport-utilities, with a non-rechargeable hybrid powertrain in 2008, but the entire model line was canceled during the financial crisis which ended with Chrysler's bankruptcy in early 2009. In 2010, the manufacturer also rejected plans for a Dodge Ram Hybrid pickup truck, which would have used the same Two-Mode Hybrid transmission from General Motors as the Durango and Aspen Hybrids. Recently, CEO Sergio Machionne announced that Chrysler will offer both a Chrysler 300 hybrid sedan and a hybrid version of its minivan in the medium term, most likely as 2014 vehicles to be launched next year. Furthermore, Chrysler will manufacture the Fiat 500 electric car, which will be assembled in Toluca/Mexico (see Fiat).[343] In order to develop further electric vehicles, **Chrysler invested $137 million in its facility in Auburn Hills (Michigan).**

Daimler recently started the production of the new Smart Fortwo Electric Drive in Hambach/France. With an investment of **200 million Euro** in order to expand the production facility for the electric Smart, Daimler secured the future of the plant.[344] Furthermore, Daimler contracted Tesla to develop an electric powertrain for its new battery electric B-class. So far, no concrete plans for an electric version of the B-Class have been announced. Recently a Daimler spokesman explained that the move to a pure electric drive was for the more favourable classification of a zero-emission vehicle, particularly in the United States. Daimler plans to launch the electric B-Class in 2014 at the latest. The introduction of the B-Class with a range extender will be postponed. Originally, the compact model was to be launched as a Range Extender with a small internal combustion engine in 2014.[345] In the past Daimler has established alliances with Tesla Motors which mainly supplied batteries for the Smart ED, the Chinese car manufacturer BYD, and Deutsche Accumotive, a joint venture with the German chemical company Evonik. The Daimler AG plans on manufacturing its batteries in Germany through this subsidiary. The 50:50 joint venture between Daimler and the Chinese manufacturer BYD is developing a battery-electric vehicle under the new brand name Denza. The first vehicles are planned fordelivery next year.[346] Concerning Fuel Cells, Daimler shows the most activities of all European automakers. In early 2011, three FCVs finished a world tour, emphasizing the suitability of fuel cell technology for daily use. Furthermore, Daimler has founded a joint venture with the German supplier Bosch in order to produce electric motors.[347] Hybrid powertrains that influence the vehicle weight significantly will be reserved to the higher vehicle classes. In the medium term, all models from C-Class upwards can be ordered with hybrid propulsion.[348]

Fiat is currently developing a fully-electrified version of the Fiat 500 with a 100 mile range, using battery technology developed by Chrysler Group. Due to its compact size and weight, the Fiat 500 is particularly well-suited for electric propulsion. Chrysler plans to design, manufacture and sell this version of the Fiat 500 in North America. Production is scheduled to begin in 2012 in Toluca/Mexico.[349]

Ford´s global electrification strategy aims to cover 10 to 25 percent of its global sales by electrified vehicles by 2020, including non-rechargeable full hybrids, plug-in hybrids and full electric vehicles. This year the company will introduce the C-MAX Hybrid and plug-in Energi variants: Focus Electric, Fusion Hybrid and Fusion Energi plug-in hybrid. Ford will produce the C-MAX Hybrid along with the Focus, Focus Electric and Focus ST at its Wayne, Michigan-based Assembly Plant. The Focus EV for example will compete with Nissan Motors' Leaf and General Motors' Chevrolet Volt in the compact segment. Ford and its suppliers are **investing $220 million to prepare** the production facility in Van Dyke, Michigan for **the production of hybrid transmissions for electric and hybrid models** of Ford.The Van Dyke investments belong to a $632 million commitment of Ford and its suppliers to in-

342 Automobilproduktion (2012c)
343 Green Car Reports (2012a)
344 CarIT (2012b)
345 Automobilwoche (2012d)
346 CarIT (2012c)
347 IEA (2011c)
348 Handelsblatt (2012c)
349 Fiat (2011)

crease capacity and flexibility at three North American transmission facilities by 2015. The investments at Van Dyke include manufacturing, capital equipment, launch and engineering costs, and supplier tooling upgrades.[350] **Apart from that, Ford invested $441 million in Dearborn (Michigan) in HEV/Plug-In Hybrid and Lithium-Ion battery technology, $80 million in Wayne (Michigan) for the production of Focus/Focus Electric parts and components and $10 million in Rawsonville (Michigan) in the field of Lithium-Ion battery packs.[351]** Presently, Ford's strategy differs from both GM and Nissan, which build individual platforms for the Volt and Leaf. By electrifying the platform Ford is able to maintain "reasonable margins" on its electric vehicles, which tend to be costly because of the high price of the battery packs.[352] Within the last five years, Ford has doubled the number of engineers working on the R&D of electric vehicles to about 1,000 people. Ford will hire dozens of engineers this year as part of its plans to add more than 12,000 hourly and salaried jobs by 2015 in the United States. Ford's Advanced Engineering Center is located within the company's "Henry and Edsel Ford Research & Engineering Center". The 500-acre technical complex in Dearborn was opened in 1953 serving as headquarters for R&D efforts. Until 2013, Ford will triple its production capacity of hybrid, plug-in hybrid and electric vehicles in the United States from 2011 levels. Ford recently announced to build more than 100,000 passenger cars with hybrid powertrains in 2013.[353]

General Motors wants to start an e-campaign in China. Despite the low demand of the Chevy Volt, General Motors is keen to launch more vehicles with alternative powertrains, including in the Chinese market. Conceivable options are the luxury Cadillac coupe ELR or an electric version of the Chinese-blockbuster Chevy Sail. While Volt sales are minimal, due to the Chinese import duties which push the price to almost double the $40,000 cost of the vehicle in the United States, GM is counting on the vehicle to establish the automaker's presence as it develops similar vehicles with alternative-energy in the future. However, the manufacturer announced that there are no plans to build the Volt in China.[354] GM launched its Chevrolet Volt which is a Range Extender identical to the Opel Ampera in late 2010. **The manufacturer invested $336 million in its production facility in Hamtramck/Michigan, a further $40 million investment in Brownstown (Michigan) in battery pack production, (plus $15.7 million for battery testing and lean combustion engines) and $112 million for the development of hybrid electric vehicles (HEV) in Warren (Michigan).[355]** Due to low sales of the Chevrolet Volt,GM recently announced to stop the production in its Detroit-Hamtramck plant from Sept. 17th until Oct. 15th, in order to reduce the vehicles which are in stock.[356]

Hondarecently started the pre-sale of the Honda Fit EV in the U.S., with a three-year lease price of $389 per month. The Fit EV will be available for lease-only in key markets in the U.S. like Oregon and California, after which availability will expand to six East Coast markets in early 2013.[357] The Fit EV will be manufactured by Honda at the New Model Center in Tochigi, Japan, the same facility the FCX Clarity (FCV) is produced**. Honda will invest $40 million and will create 300 jobs by the end of the year.** The Civic Hybrid is made in Japan now, but the U.S. production will start in the Greensburg/Indiana (U.S.) plant next year. The strong Japanese yen is eroding profits on imports and forcing Honda and other manufacturers to shift production from Japan to abroad. Honda also announced plans to manufacture the Honda Fit in Mexico in 2014.The plant in Greensburg/Indiana, that started the production of the Civic in October 2008, is able to assemble 250,000 vehicles a year. It also produces natural gas-powered Civic models and began to produce the Acura ILX and ILX Hybrid in 2012. The Acura ILX Hybrid is the first hybrid produced by Honda in North America. The plant launched a second production shift in late 2011 and is currently employing about 2,000 workers. Production of electric vehicles in North America is quite possible, however, the company has not yet published any information explicitly. In 2011, about 85 percent of the Honda and Acura automobiles sold in the U.S. were built in North America, using domestic and globally sourced parts; the highest rate of any international manufacturer. Honda has announced a plan to increase their local production by more than 90 percent in the coming years.

In October 1992, Honda launched its own production in the United Kingdom, which has been continuously expanded and has now once again increased significantly. 500 additional employees are cur-

[350] Green Car Congress (2012c)
[351] Car (2011b)
[352] Autonews (2012h)
[353] Autohaus (2012b)
[354] Autonews (2012i)
[355] Car (2011b)
[356] Autonews (2012f)
[357] Honda (2012a)

rently being hired for their car plant in Swindon. **Honda aims to double their European production in 2012 to 180,000 units.**[358] In May 2012, the production of the new Civic started in Swindon in two shifts, in autumn Honda will begin production of the new European CR-V.[359]Furthermore, Honda CR-Z will launch the Honda Insight and Fit hybrid in China, where they will also be preparing for the production of their hybrids. The local procurement of major parts, especially batteries and electric motors, will lead to decreasing costs and thereby contribute to a rapid spread of hybrid technology in China. In the second step plug-in hybrid vehicles for middle and upper segments are planned. Furthermore, Honda plans to launch the first electric vehicles in China very soon. The production will start at the end of 2012 at Guangqi Honda, a joint venture between Honda Motor and Guangzhou Automobile. Another joint venture, Dongfeng Honda, is currently developing its second new plant.[360]

Hyundai recently confirmed that it will deliver a "limited" number of fuel-cell electric vehicles this year for testing purposes, with a goal of producing as many as 10,000 units annually by 2015. The manufacturer is among a number of companies like Toyota, General Motors and Daimler that have targeted 2015 for starting FCV mass production. Whether the optimistic objectives are met remains to be seen.[361] It also remains to be seen which Korean manufacturer will be the pioneer in launching an electric vehicle in the domestic market. Since 2011 Hyundai has been manufacturing small numbers of fuel cell cars called Tucson (“ix35” in Europe). In 2013, Hyundai will start the production of plug-in hybrid cars, while the mass production of electric cars isn't expected to start until 2015 due to the production of the "Blue On" terminating in October 2011 only an approximate year after its launch in 2010.[362] The vehicles have been used for testing purposes. Kia is on course to launch its first Battery Electric Vehicle called Ray. Kia plans to produce 2,500 units of Kia Ray EV in 2012. All vehicles belong to the government fleet. Presently, it is not yet clear when the vehicle will be sold to retail customers. Kia’s competitor Renault Samsung Motors Corp., the South Korean unit of Renault S.A., has however, announced that it will launch the SM3 ZE electric car in 2013.[363]

Infiniti plans to produce its new compact hybrids Etherea at meaai Steyr in Austria. This is the first time an Asian manufacturers contracted a European Tier 0.5 supplier in order to develop and produce the complete car. The assembly will probably take place in Graz. A production of the vehicle in Poland has also been discussed. Altogether, the Nissan-order will create about 1,000 new jobs. The production of the car, which is being developed at Magna using Daimler components (platform, engines) will start in 2014, with an annual capacity of up to 50,000 units.[364] The first all-electric Infiniti, which is supposed to be launched in 2014, will likely be built at the same Tennessee factory as the Nissan Leaf EV. Two Nissan spokesmen told reporters that the company’s assembly plant in Smyrna/U.S. would be the most likely place where the Infiniti LE battery-electric would be built. Nissan is expected to start U.S. production of the Leaf at the same factory by the end of the year. The Infiniti will use the same, or at least, very similar battery pack as the Nissan Leaf. Infiniti, which has recently presented a concept version of the EV at the New York Auto Show, stated that the car will have about 22 percent more horsepower and 14 percent more torque than the Leaf, but will also be larger with a very similar size to the Infiniti G sedan.[365]

Mazda Motor Corp. recently announced its plans to use a hydrogen-fueled rotary engine technology as a range extender for an electric vehicle based on the technology of the 2009 presented Premacy Hydrogen RE Hybrid. The Premacy Hydrogen RE Hybrid featured a series-hybrid powertrain, which combines Mazda’s hydrogen rotary engine with an electric motor.[366] Furthermore, Mazda is testing its Mazda2 with battery electric propulsion. The test fleet of the Mazda 2 (called Mazda Demio in Japan) will be restricted to Japan. The company plans to lease 100 Demio EVs in Japan only, particularly to local governments and corporate customers in its headquarters region of Chugoku. Mazda's engineers have historically been resistant to electrification, preferring the optimisation of gasoline and now diesel powertrains.[367]

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[358] Comprising all types of propulsion
[359] Honda (2012b)
[360] Honda (2012c)
[361] Autoblog (2012b)
[362] GTAI (2012c)
[363] Foxbusiness (2012)
[364] Kleinezeitung AT (2012)
[365] Ev-olution (2012)
[366] Green Car Congress (2012d)
[367] Green Car Reports (2012b)

Mitsubishi Motors Germany announced that the company will expand the supply of electric vehicles in the following years. Until 2015, Mitsubishi plans to launch about 8 new models with electric and hybrid propulsion, covering 5 percent of the global production capacity in 2015 and 20 percent in 2020. Aside from the i-MiEV, several SUV models will be offered, particularly that use plug-in hybrid technology.[368]

Nissan recently announced plans to sell 1.5 million zero emission cars by 2016at the 2012 New York Motor Show. The company aims to triple sales of its Leaf electric car in Europe this year, with starting the production of the Nissan Leaf in Sunderland/UK. The manufacturing of the car in the UK will reduce lead times, increase supply, mitigate currency fluctuations and reduce the carbon footprint of bringing the car to the customer.[369] 200 additional jobs will be developed.[370] The Leaf will be produced on the same assembly line as the Qashqai compact SUV with a potential capacity of 60,000 a year. Furthermore, Nissan will start the Leaf production at its Smyma, Tennessee plant for the U.S. market later this year. The facility will be able to build up to 200,000 Leaf models and 150,000 battery packs per year.[371] Nissan will create 1,300 additional jobs to produce a U.S.-built Nissan LEAF and Lithium Ion battery packs.[372] The LEAF production in Tennessee is set to commence in late 2012, with the first U.S.-built units set to hit dealer lots in early 2013. Altogether, Nissan has a larger global capacity for its Leaf than its French partner Renault, but lower sales ambitions in Europe. The Japanese automaker is creating capacity to build 250,000 Leafs a year, with annual production of 25,000 planned in Sunderland, England; 150,000 in Smyrna, Tennessee in the United States and 50,000 in Japan.[373] Furthermore, Nissan announced plans to produce the e-NV200, which is a light-duty commercial vehicle, in Europe. The concept for the e–NV200 was shown at the Detroit Motor Show. Nissan has recently confirmed that the vehicle will be built in Barcelona.[374] Nissan is investing 41 million Euro into the project estimated to create 700 jobs for Nissan and Spanish suppliers. More than just a light-duty commercial vehicle, the e-NV200 will also be equipped as a van (family car). Nissan stated that the e-NV200 will deliver a driving range similar to the Nissan LEAF on which it is based, along with a similar performance. Apart from that, Nissan is planning to sell cars with hybrid technology in Europe. Currently only Nissan's luxury brand Infiniti sells a hybrid model in Europe.[375]

The joint venture of Nissan with Dongfeng Motor Group announced the development of a new manufacturing facility in Dalian, Liaoning Province, China with an investment of about $785 million. The Dalian plant, scheduled to start production of Nissan passenger vehicles, will have an initial annual production capacity of 150,000 units in 2014, with an opportunity to expand up to 300,000 units. DFL recently signed a contract to deliver 1,000 Venucia-branded electric vehicles to the pilot program conducted by Dalian Municipal Government by 2014.[376]

PSA Peugeot Citroën is currently developing a rechargeable multi-functional vehicle with hybrid technology that can be recharged on an ordinary electric socket. An enhanced battery pack will enable the plug-in to run in all electric mode for between 15 and 50 kilometers. It therefore offers all the benefits of an EV for day-to-day use, but can also be used for longer distances due to its internal combustion engine. The long-term objective is to reduce these plug-ins' CO_2 emissions to less than 50 g/km. The market launch is expected to be in 2015. Other than the battery electric vehicles Peugeot Ion and Citroen C-Zero, no further plans have been published by the PSA Group. Both vehicles are manufactured at a Mitsubishi plant in Mizushima/Japan. Recently Mitsubishi Motors has drawn some initial conclusions from the ongoing European crisis. The delivery of electric cars was stopped to the French PSA group. In spite of current contracts, it is unclear whether the supplies will be resumed. According to press releases, Mitsubishi has not only stopped the delivery of the two electric cars to PSA, but has also stopped production temporarily, due to the low sales of PSA. In the first half of the year, only 935 C-Zeros and 852 Ions were sold in Europe. Mitsubishi has been delivering cars to the French PSA group since 2010 as part of an agreement to supply a total of 100,000 vehicles. Since starting the production of the i-MiEV in 2009, the C-Zero and iOn in 2010, Mitsubishi has only built 28,000 units of

[368] Autohaus (2012c)
[369] Green Car Congress (2012e)
[370] The Green Car Website (2012)
[371] Autoblog (2012d)
[372] Hybridcars (2012d)
[373] Electric Vehicle News (2012a); Autonews (2012j)
[374] HybridCars (2012e)
[375] Autonews (2012j)
[376] Green Car Congress (2012f)

the three models.[377]In addition, Mitsubishi will forego any diesel engines of he French PSA group, which are incorporated into its European models. With Mazda, the French will lose another consumer of diesel engines. The Japanese automaker had previously built the engines in three of its European models, but with the change to the next generation of vehicles, the manufacturer will use its own engines.[378]

In the longer term, the PSA Group is exploring possible applications of hydrogen fuel cell technology as well. The Genepac fuel cell developed with the CEA offers one of the highest energy-to-size ratios in the world. Presently, fuel cell vehicles do not yet have the technical and economic maturity needed to support mass-market production. Although considerable progress has been made, hydrogen fuel cell technology must still overcome a number of obstacles, including the cost of the fuel cell system, the fuel cell's lifespan, the size, mass and cost of the hydrogen storage system and the deployment of the required infrastructure to launch Fuel Cells to the general public.[379]

Renault will launch its fourth battery electric vehicle Zoe Z.E. soon. The manufacturer has already received about 14,000 orders. Renault aims an annual production capacity for the Zoe of 150,000 units.[380] The subcompact will be the volume model among Renault's battery electric vehicle fleet and will complement the Zero Emission (Z.E.) fleet of the French manufacturer, who has already launched three battery electric vehicles in different vehicle segments: the Renault Fluence Z.E. (middle class segment), the Renault Kangoo Z.E. (light commercial vehicle) and Renault Twizy Z.E. (microcar). In terms of R&D, about a 4 billion Euro investment has been made on electric cars as part of the Renault-Nissan alliance.[381] Renault SA will not use proprietary battery technology for its electric vehicles in the medium term, and will instead rely more on a South Korean supplier. Renault recently signed a draft agreement with LG Chem Ltd., which is a unit of South Korea's LG Group, in order to purchase battery packs.[382] Originally the Renault Zoe was expected to use the same cells as the Nissan Leaf. As the sales of the Nissan Leaf have been lower than expected, it should be possible to use components of the production from the Japanese factory that supplies the batteries of the Leaf to the Zoe. Instead, Renault recently stated that the Zoe will get cells from South Korean LG. Renault was expected to start a new battery factory in Flins near Paris, requiring a large investment. With EV sales still very soft, purchasing battery packs from an external supplier could be a cheaper and less risky option without reducing Nissan's capacities in case of a possible strong rise in EV sales. At least until 2014, the Renault Zoe will build LG batteries built in South Korea.[383] Nevertheless, both partners recently announced that they will sign an agreement to build a new manufacturing facility in Franc ein the second half of 2013. The production is scheduled to start from the year 2015.[384]Together with its partner Nissan, Renault plans to sell 1.5 million electric cars globally by 2016 and estimates they that electric vehicles will cover 10 per cent of the global market by the end of the decade.[385] Furthermore, Renault and Dongfeng plan to co-produce electric vehicles in China. Both companies recently concluded an agreement. Both an electric car and an SUV are planned to be manufactured in China. Dongfeng is the second largest manufacturer in China.[386]

Toyota wants to consolidate its strength as the largest supplier of hybrid vehicles and has plans for ten new models in the next three years. By 2020, the Japanese manufacturer announced an offer of vehicles with a combination of fuel and electric powertrains in almost every relevant segment. Diesel hybrids however, will not be offered by Toyota. In addition to the recently launched Yaris Plug-In Hybrid, the Prius+ will be launched in Europe. The car is slightly longer and higher than the normal Prius and is the first seven-seater among hybrid vehicles. Furthermore, Toyota announced to start the production of its successful Prius in the U.S. in 2015.While the manufacturer currently only produces small numbers of the Toyota Camry Hybrid in Kentucky using components imported from Japan, the Prius would be its first vehicle using components built in the U.S. Toyota is also planning to develop key components for the Prius at a local research centre in China, supplemented by the assembly of a new hybrid vehicle in 2015.So far Toyota hybrids had only manufactured in Japan to prevent the out-

[377] Autonews (2012k)
[378] Automobilproduktion (2012d); (Heise 2012b)
[379] 2011 Registration document, 06/03/2012
[380] Electric Vehicle News (2012a)
[381] IEA (2011c)
[382] The Wallstreet Journal (2012)
[383] Motornature (2012b)
[384] ATZ Online (2012)
[385] Electric Vehicle News (2012b)
[386] Reuters (2012b)

flow of advanced skills to abroad. But due to increased costs in the two largest auto markets in the world , Toyota decided to move to local production.[387]Last year, the Toyota Group sold 630,000 hybrids, almost half of them overseas.[388] The 2013 Toyota RAV4 EV, a battery-electric SUV developed with the assistance of Tesla Motors, will be launched by selected California dealers later this summer. Twenty-two months after the project announcement, Toyota and Tesla engineers revealed the vehicle at the Electric Vehicle Symposium in May 2012. Sales volume is planned for about 2,600 units until 2014.[389]Furthermore, Lexus is expected to have at least eight hybrids in its global product portfolio by 2015, including the Lexus GS 450h (2013), and Lexus RX 450h (2013) or a compact crossover smaller than the current RX line.[390]More concrete plans have yet to be announced by the Toyota subsidiary.[391]

Volkswagen expects to sell 300,000 electric vehicles by 2018. If this is the case, Plug-in-Hybrid- and Battery Electric Vehicles will cover 3 percent of the global sales.[392] In summer 2013 the serial production of the E-Up will start, followed by the Golf e-motion about six months later. Volkswagen Group will produce the transmission DQ400e used for vehicles with hybrid technology in its plant in Kassel. Furthermore, the electric powertrains for the battery electric versions of the Up! and Golf will be produced in Kassel. Therefore, about 1**,000 to 1,500 additional qualified professionals are required**.[393] Apart from that, Volkswagen **invested about 50 million Euro** in its Braunschweig plant in order to manufacture battery packs for its hybrid and battery electric vehicles.[394] Additionally, Volkswagen is investing about one billion Euros over the next five years in the Emden plant. Recently, the major reconstruction began, as the foundations were laid for a great hall (used for coach building) and a logistics center. The body of the assembly hall will be more than 500 meters long, accommodating the production of the next generation of the Passat (series B8), starting in May 2014. The assembly hall will allow for a flexible production that is needed for the next generations of vehicles with petrol and diesel engines, electromobility and lightweight construction.[395] Besides the production facilities in Europe, Volkswagen is investing in China as well. Between 2013 and 2014, VW will start manufacturing electric vehicles in China. According to its development strategy, the manufacturer expects that over two-thirds of all its funding in 2016 will go towards manufacturing more energy efficient automobiles and power systems.[396] The VW subsidiary **Audi** plans to invest in products and locations. Altogether, the Ingolstadt-based premium car manufacturer plans to invest **13 billion Euros in new products and technologies** and the expansion of its locations until 2016.[397] Nearly 8 billion Euro will be invested into the German production facilities in Ingolstadt and Neckarsulm. In terms of electromobility and lightweight construction, the workforce in the coming year will also be increased by 1,200 experts.[398]

Volvo has always proclaimed that the C30 Electric will be a limited program. When the company started making the battery electric vehicle last summer, the public plan was to make just 250 units. Approximately 200 cars have been built from the first generation; another 50 were supposed to have been built this summer. From the second generation, starting in late 2012, 100 cars will be produced in co-operation with Siemens and Siemens technology. Instead of reporting that Volvo is stopping C30 Electric production, the manufacturer is adding 100 vehicles to the build order. Whether Volvo will expand its activities in electric vehicle propulsion beyond its C30 program remains to be seen.[399] The first edition of the Volvo V60 plug-in hybrid (1,000 units), which will be delivered from December 2012, is already sold out.[400]

Altogether, the industrial plans of the automotive companies are mainly influenced by the actions and strategies of the manufacturers. An evaluation of the industrial plans of the companies which have been interviewed in this study, shows three strategic groups of companies, which can be distinguished by the axes risk acceptance and penetration speed of new technology (see Figure 46):

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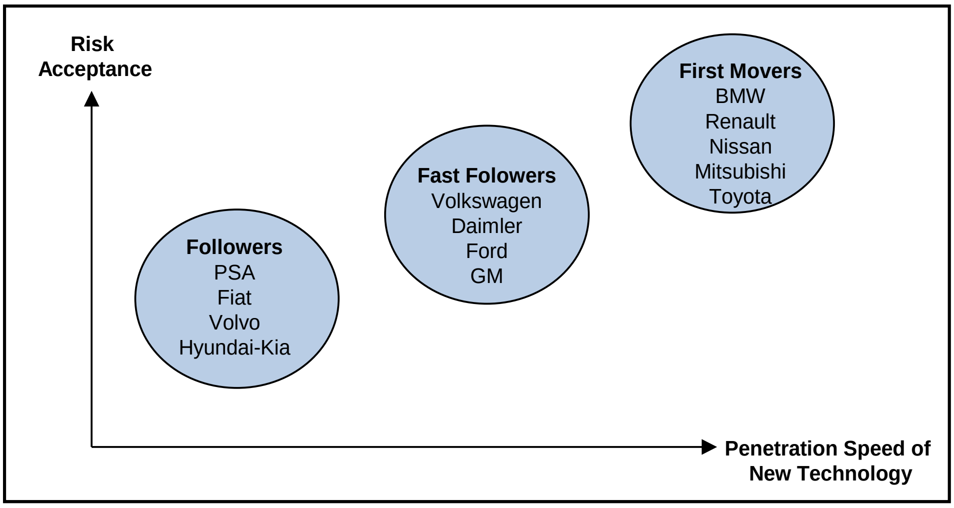
[387] Green Car Reports (2012c)
[388] Automobilproduktion (2012e)
[389] Puregreencars (2012b)
[390]The Detroit Bureau (2012)
[391] See current Lexus portfolio: Aol Autos (n.d.)
[392] Hispanic Business (2012)
[393] HNA (2012)
[394] Braunschweiger Zeitung (2012)
[395] GA Online (2012)
[396] Autonews Gasgoo (2012)
[397]Not EV-specific
[398] Automobilproduktion (2012f)
[399] Autoblog (2012e)
[400] Handelsblatt (2012d)

1. The **“First Movers”**, especially BMW and Renault accept higher risks in the transition to electromobility in order to establish leading positions in the new market very quickly. In terms of R&D they are focusing on specific areas of technology (e.g. BMW almost exclusively on BEVs). Developing new vehicles with an independent vehicle architecture, the first movers move to a new path of the design including new opportunities e.g. in terms of space or vehicle use. Due to the independent vehicle architecture, a production of electric vehicles and traditional vehicles on a shared assembly line is not feasible. Therefore, first movers build up separate production capacities for new electric vehicles.

2. In contrast, the **“Followers”**, such as PSA, Fiat, Volvo and Hyundai-Kia are mainly trying to integrate electric powertrains into existing vehicle concepts. They have a rather broad R&D focus, which does not leave out any option. Focusing an efficient flexible production, they produce electric vehicles and traditional vehicles on a shared assembly line. Thus, these companies try to reduce risks, assuming that electromobility will penetrate slowly.

3. In between these two groups **“Fast Followers”** exist, which are currently also mainly trying to integrate electric powertrains into existing vehicle concepts and produce electric vehicles and traditional vehicles on a shared assembly line like the Followers. However they are observing the first movers very closely and are building up competencies in specific areas of technology to come up with customer tailored, optimized new vehicle concepts only shortly after the first movers. Volkswagen, Daimler, Ford and GM consider themselves as “Fast Followers”.

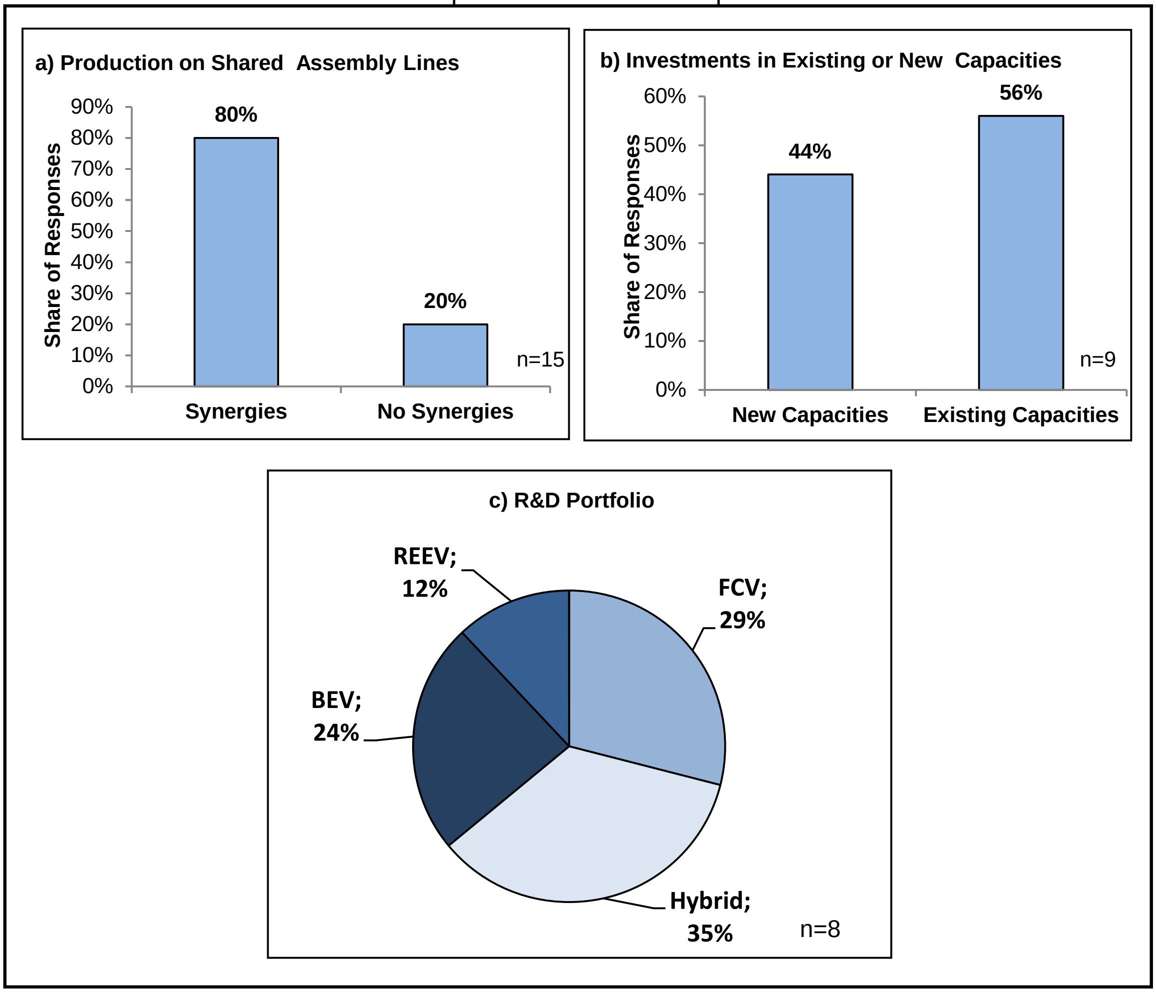
Figure 46: Industrial Plans of Different Strategic Groups of European Vehicle Manufacturers



(Source: Own Compilation on the Results of the Expert Interviews)

The results of our survey show different opinions of the experts interviewed in this survey, in terms of novelty of the concept vehicle, investments in new or old capacities and the focus of R&D activities (see Figure 47). Since first movers and followers benefit differently from economic policies, distinction will also have an influence on defining the future public policy framework.

Figure 47: Level of Novelty of Vehicle Concepts, Investments in Capacity and R&D Portfolios of European Automotive Companies



(Source: Own Compilation According based on the Results of Expert Interviews)

The majority of the 80 percent of experts, who have been surveyed in this study, expect that a production of electric vehicles and vehicles with combustion technology on a common assembly line is possible (see Figure 47a). Basically, it depends on the vehicle architecture. For example, Plug-in Hybrids or Battery Electric Vehicles such as Ford Focus BEV or Volkswagen E-Up, which have an electric powertrain, but are based on a traditional vehicle concept, can easily be integrated into existing assembly lines (flexible production) aiming for economies of scale. As long as the market volume remains low, an independent production of electric vehicles on separate assembly lines will not be profitable for OEMs. Manufacturers and suppliers who will offer electric vehicles based on new vehicle architecture ("Purpose Design") are not focusing on the integration of the electric powertrain into conventional vehicle architecture. From an economical perspective, a huge potential of cost reduction can be expected from developing new vehicle concepts, particularly due to standardization and modularization. However at the moment these first movers have to invest significantly.

The experts surveyed disagree whether new or existing capacities will be established in the transition to electromobility (see Figure 47b). Since no additional sales will be generated by electromobility, **most experts assume that no new capacities will be established; mainly existing capacity will be used**. However, the premium manufacturer BMW is building up new capacities in a new energy-efficient factory of BMW in Leipzig/Germany. Other manufacturers like e.g. Renault, Nissan or Mitsubishi are using existing capacities in their plants even for new vehicle concepts, e.g. Valladolid/Spain (Renault Twizy), Flins/France (Renault Zoe), Oppama/Japan (Nissan Leaf), Sunderland/UK (Nissan Leaf)[401] and Mizushima/Japan (Mitsubishi i-MiEV).

[401]Start of production in 2013.

In 2010, the automotive industry increased their R&D investments by an average of 8 percent, after the crisis-induced restraint in the years 2008/09. According to the latest "Global Innovation 1000" study by Booz & Company, manufacturers increased their R&D budget by a total of $8.8 billion to $ 82.5 billion. They cover 15% of the global R&D investment with an amount of $550 billion in coming.[402] The following table shows a ranking of companies from the automotive industry in terms of their R&D investments in 2010.[403]

Table 32: Top 10 R&D Investments in the Automotive Industry

Ranking	Company	Headquarter	R&D Investments in Billion $
1.	Toyota	Japan	8.5
2.	GM	USA	7
3.	VW	Germany	6.1
4.	Honda	Japan	5.7
5.	Ford	USA	5
6.	Nissan	Japan	4.7
7.	Daimler	Germany	4.6
8.	BMW	Germany	4.1
9.	Denso	Japan	3.4
10.	Peugeot	France	2.8

(Source: Booz&Company 2011)

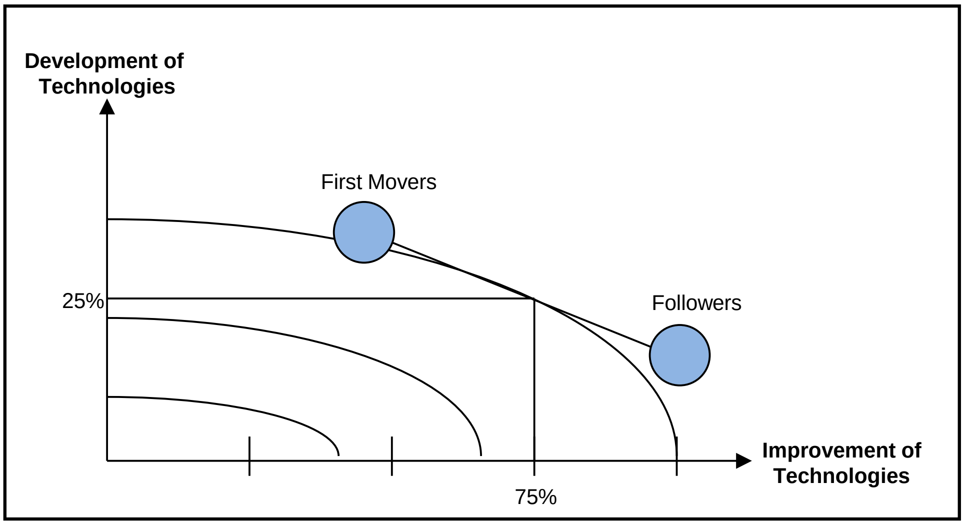
While the R&D investment by Toyota in 2010 has remained relatively stable compared to 2011 (+0.7 percent), Volkswagen has increased its R&D investments by 19.4 percent. GM has increased its investments by 16%, while Honda has reached a plus of 5.2 percent.[404]The increased expenditure can be ascribed to high investments in the transition to electric vehicles.

Despite the economic uncertainties of the EU debt crisis, drastic cuts would be a completely wrong reflex, because the automotive industry is both structurally and technologically in a transitional phase. **According to the experts interviewed, most of the European manufacturers will invest about 25 percent of R&D expenditures in electromobility**; some of them with a more specified focus while others will follow a broader investment pattern (see Figure 47c). The survey shows that the majority of experts consider that in the medium term plug-in hybrid technology will prevail; and the majority of automakers will offer plug-in hybrids (see “Future Generations of Electric Vehicles” in Chapter 2.1.2).

In order to implement the strategies presented in Figure 48 all European car companies must combine their strengths (e.g. vehicle integration or expertise in diesel technology). Furthermore, all European manufacturers should continue to optimise internal combustion technologies while developing new technologies. Nevertheless, the focus of their R&D activities will vary in terms of the optimisation of old technologies and development of new technologies. While the first movers will rely more heavily on the development of new capabilities, the followers prefer to improve their existing skills in the medium term.

[402] Booz (2012)
[403] Data which provide a splitting in "share electromobility / alternative parts" are not available.
[404] Booz (2012)

Figure 48: Implementation of Industrial Plans in Strategic Groups of the European Automakers



(Source: Own Compilation based on Expert Estimations)

A large spectrum of the surveyed companies plan to expand or maintain their competitive advantages while focusing on R&D and the education of their employees. A German automotive premium manufacturer stated that particularly in the area of new distribution channels, future competitive advantages can be expected. In this context it will be important to develop new skills and competencies, since electromobility can be associated with a change in consumer behaviour as well as mobility needs.

The majority of European suppliers and manufacturers consider the development of electrical, electronic and carbon technology skills (e.g. lightweight construction) to be most important in securing competitive advantages. Additionally, a German volume manufacturer underlined the importance of skills in relation to new business models (e.g. Vehicle-to-Vehicle communication in order to avoid accidents or Vehicle-to-Grid applications). Concerning future competencies, a U.S. American manufacturer emphasised the importance of a "holistic understanding of the system" for electric mobility. **Most of the large companies, which have been surveyed in this study, consider the integration of skills as not all too difficult (evolutionary process).** Therefore, much of the EU manufacturers have been recently implementing **internal training programs**. Since 2010, Opel for example has offered a qualification and training program called "system engineer electromobility" for skilled workers of various professions together with the German Chamber of Commerce. The training program in which one must have an electrical engineering degree includes eight semesters, focusing on automation technology, energy technology and information- and communication technology.[405] Daimler developed a training concept called "New drive technologies" for its trainees of the profession and "vehicle mechatronics" as part of its qualification in the field of "electric powertrains in automobiles".[406] BMW offers two part-time bachelor programs in co-operation with the University of Applied Sciences in Ingolstadt, in order to qualify supervisors and technicians. Furthermore, BMW offers a part-time Master's degree in electric mobility in order to qualify its mechanical engineers in this promising technology. The manufacturer aims to qualify its staff for new challenges in the field of electric mobility.[407]Therefore, the BMW Group set up a training centre for electric vehicles in Munich. By the first quarter of 2011, BMW had qualified about 1,000 employees at the new training centre in electromobility – ranging from apprentice to engineer levels.[408] Almost all major manufacturers have established training programs in order to build skills among the existing core staff. The German manufacturer Audi, which is part of the Volkswagen Group, has recently opened the project house “High-Voltage Battery" in Gaimersheim near Ingolstadt (see Box 9).

405 Auto (2012)
406 Universität Ulm (2011)
407 Hochschule Ingolstadt (2009)
408 BMW (2012b)

Box 9: Audi Project house “High-Voltage Battery in Gaimersheim

Audi is pushing ahead its R&D activities in terms of electromobility. Consequently, a new project house called “High-Voltage Battery” in Gaimersheim near Ingolstadt has been built. More than 100 specialists work in the field of energy storage devices for electric drives covering all important aspects - from development to production and testing of battery systems. With an area of over 3,500 square meters, the project house has three major parts: the "batterie-technikum", a "testing area" and an "office area" with 84 workstations. In this "centre of excellence", different specialists from R&D and manufacturing as well as corporate partners work together in order to develop a prototype for battery cells. Audi is developing skills in terms of the design and manufacturing of high-voltage batteries with a vision towards future vehicle concepts. In the future a small-lot production is conceivable. Two graduate students from the University RWTH Aachen (ISEA Institute) complement the team. As a key external partner, Panasonic provides the battery cells. So far 70 batteries for the Audi A1 e-tron concept and the Audi R8 e-tron have been produced.

(Source: Audi 2012)

Almost all manufacturers and suppliers focus on recruiting young professionals from universities, competing for the best graduates. However, responses from the different experts surveyed in this study vary considerably in regards to access to specialists. **While the large European manufacturers do not anticipate any problems concerning the acquisition[409] and advanced education of employees, the majority of European associations, suppliers, and public policy makers expect a shortage of skilled labour, even in the long run.**

3.3.1 Development of the Value Added in the EU Automotive Industry

The following chapter analyses the evolution of the value added of the EU automobile industry until 2030**.** The methodology of the forecast is introduced in Appendix II. According to the latest accessible data from Eurostat, about 19.6 million motor vehicles[410] were produced in the EU in 2007 (including passenger cars and light commercial vehicles). The automotive industry realised a total turnover of approximately 847 billion Euro.[411] The profits amounted to 49 billion Euro.[412] This represented a profit margin of ca. 5.8 percent in 2007. The share of personnel costs measured by the total turnover amounted to approximately 106 billion Euro (12.4 percent). The value added at factor cost[413] can be calculated as the sum of profits and personnel cost. The gross value added obtains interest, depreciation, and taxes. In 2007, the EU automotive industry generated value added at factor costs in the amount of 155.4 billion Euro.[414]

In 2011, approximately 17.1 million motor vehicles were produced in the EU. Based on the production volume, we assume that the EU automotive industry generated about 720 billion Euro of total turnover (at current prices).[415] In 2011, exceptionally high returns on sales were realised. While the supplier could generate average returns on sales of around 6 percent, the EU carmakers reached an average of 10 percent.[416] We estimate that the return on sales of the total EU automotive industry in 2011 was higher than in 2007 by an average of about 8 percent in 2011.[417]Accordingly, in 2011 profits of about 57 billion Euro were realised. The personnel costs measured by the total turnover amounted to approximately 93 billion Euro (13 percent). Therefore, the current value added at factor cost of the EU automotive industry in 2011 can be calculated at about 151 billion Euro. Due to higher returns on

[409] Most of them emphasise their force of attraction caused by their “strong employer brand”
[410] Eurostat; ACEA (n.d.)
[411] Eurostat: NACE Rev 1.1 until 2008
[412] Eurostat: NACE Rev 1.1 until 2008
[413] See: Official Journal of the European Union, Code 12150
[414] Eurostat
[415] Estimation is based on a statistical context of production volume and sales revenues from the past (see Eurostat data NACE Rev 1.1 until 2008 and NACE Rev 2 – C29.1 “Manufacture of motor vehicles” since 2009)
[416] Automobilwoche (2012e), p. 3 and p. 12.
[417] Own calculation based on data from Automobilwoche (2012e) and expert estimations

sales, the amount of value added at factor cost was only slightly lesser than the amount of the pre-crisis year of 2007, although fewer total vehicles were manufactured.

The following table shows the continuous development of the value added at factor cost in the EU automotive industry (see Table 33).The table shows that the value added at factor cost rose steadily in the pre-crisis years.

Table 33: Development of Value Added in EU Automotive Industry in the last Decade

Year	Value Added at Factor Cost (in Billion Euro)
1999	114
2000	114
2001	122
2002	118
2003	128
2004	134
2005	132
2006	144
2007	155
2008	n.a.
2009	99
2010	n.a.
2011*	151

Note: Rounded Values; Figures for 1999 until 2002 represend EU25 Data;
Figures from 2003 until 2005 are estimated by Eurostat

Data 2000-2007: Eurostat NACE REV 1.1, DM 34
Data 2008 and 2009: NACE REV2, C29
n.a. = not available
2011*: own estimation (see chapter 3.3.3)

(Source: Own compilation based on Eurostat, NACE REV 1.1 (DM34) and NACE REV 2 (C29))

The forecast on value added in the EU automotive industry in terms of electromobility (Section 3.3.2) includes two steps. At first (Section 3.3.2.1) the value added of EU automotive industry will be calculated for 2020 and 2030, excluding electromobility (baseline). Based on assumptions, which have been validated in the expert interviews, both forecasts (2020 and 2030) will be adjusted, including electric vehicles in capacity of the EU motor vehicle production (Section 3.3.2.2).

3.3.1.1 Calculation of Value Added in EU Automotive Industry for 2020 and 2030 – excluding Electromobility

For the year 2020, we assume that about 18.5 million vehicles (passenger cars and light commercial vehicles) will be produced in the EU-27. With this forecast, we are well below the forecasted value of Global Insight, which we consider to be very optimistic. The majority of the experts who have been interviewed in this study agree with our calculation of the total production of 18.5 million vehicles in 2020. Nevertheless, most of the experts believe that no additional capacity will be built up in the south-western EU-27 markets (e.g. France, Italy and Spain, see also Section 3.3.2). Instead, the experts believe that the existent surplus capacity ought to be reduced. With a production volume of 18.5 million vehicles within the EU-27, the EU automotive industry will be able to generate about 774 billion Euro in total turnover in 2020. The return on sales will account for an average of 6 percent.[418]Due to a

[418] Own calculation based on AID Newsletter (2012); Roland Berger (2011c) and expert estimations.

high degree of automatisation[419], increasing cost (e.g. of raw materials) and rising competition, the high amount of current return on sales of 8 percent in 2011 will not be reached in 2020.[420] After a period of increasing profits[421], AID Newsletter[422] expects that profit margins will decrease in 2012. Manufacturers of "everyday cars" already now have to reduce prices and provide significant discounts.[423] Altogether, with the assumption of 6% average return on sales in 2020 approximately 46 billion Euro in profits will be realised (at current prices) by the EU automotive industry. Concerning the personnel costs we expect a near-constant share of 13 percent (in terms of revenues). The personnel cost will rise to 100.1 billion Euro in total. **Overall, a value added at factor cost with an amount of 147 billion Euro can be calculated for the year 2020 (see Figure 49 in Chapter 3.3.2.3, 2020 left bar).**

For the year 2030, we assume that about 19.6 million vehicles (passenger cars and light commercial vehicles) will be produced in the EU-27. With a production volume of 19.6 million vehicles, the EU-27 automotive industry will be able to generate about 823 billion Euro in total turnover in 2030. The return on sales will remain at an average of 6 percent. Altogether, in 2030 approximately 49 billion EUR profits will be realised (at current prices) by the EU automotive industry. Concerning the personnel costs, we expect a share of 13 percent (in terms of revenues). The personnel cost will rise to 107 billion Euro in total. **Therefore, the value added at factor cost of the EU automotive industry in 2030 can be calculated about 156 billion Euro (see Figure 49 in Chapter 3.3.2.3, 2030 left bar).**

3.3.1.2 Calculation of Value Added in EU Automotive Industry for 2020 and 2030 – including Electromobility

In order to estimate the development of the value added of EU-27 automotive industry in electromobility, the following key assumptions have been made. All assumptions have been validated in the expert interviews:

- Production volume passenger cars and light commercial vehicles in 2020 (18.5 million vehicles) and 2030 (19.6 million vehicles)
- Share of EU electric vehicle production in total motor vehicle production: 20percent (2020)[424] and 50percent (2030), including non-rechargeable Full Hybrid Vehicles[425]
- The production capacity of the electric vehicles includes the production of different types of (electric) vehicles. The segmentation of these vehicle types is based on the segmentation of electric vehicles in the European market
- A third of the battery production will be located in the EU, especially the battery packaging[426]
- A third of the electric engine production will be located in the EU[427]

[419] Due to the optimisation of production systems, the European automotive industry has been able to realise a significant increase in productivity in recent years. Further improvements can be expected but not as extensive as in the last decade.
[420] See also AID (2012) and Roland Berger (2011c).
[421] See Eurostat: Annual detailed enterprise statistics on manufacturing subsections DF-DN and total manufacturing (NACE Rev.1.1 D), Manufacture of motor vehicles (DM341), timeframe: 2005-2007.
[422] AID (2012), Newsletter 1215, 15.08.2012.
[423] AID (2012)
[424] A study of Roland Berger (2011b) is even more optimistic, assuming the following production shares of EV/PHEV by 2015: Renault-Nissan (38%); GM 19%; Ford 7%; Volkswagen 6%; Toyota 6% and Daimler 3% and share of non-rechargeable HEV by 2015: Honda 22%; Hyundai 19%; Ford 15%; GM 11 %; Toyota 6%; Daimler 5%; and Volkswagen 5% (see Roland Berger 2011b, S. 24).
[425] Although Full Hybrid Vehicles are not considered as Electric Vehicles in the definition of the EU Commission, full hybrid vehicles will be regarded in the calculation because they also use components such as small batteries, electric motors and power electronics. The production figures in 2020 and 2030 also include non-rechargeable full hybrids (compare the results of the market forecast in chapter 2.3.2). In 2020 about 3.7 million electric vehicles will be produced in the EU (20 percent of the total production). According to the experts interviewed, the EU is expected to be a net exporter particularly in the field of non-rechargeable hybrids (expected production of 2,190,000 units) since most of the vehicles of the premium segment (e.g. SUVs, luxury cars) will use a hybrid-electric powertrain in order to fulfil the restriction on CO2 emissions. The production figures cover all types of electric vehicles and non-rechargeable full hybrids, e.g. in terms of 2020: 222,000 BEV; 222,000 PHEV; 2,109,000 non-rechargeable full hybrids and 1,147,000 PHEV (in sum 3.7 million vehicles). The allocation of the vehicle types results from the market forecast (see Chapter 2.3.3). The same methodology was used to calculate the 2030 EU electric vehicle production forecast.
[426] According to Roland Berger, about 33 percent of the value added of the lithium-ion battery production belongs to the packaging (battery assembly), see Roland Berger (2011b), p. 8.
[427] Based on expert estimations

- Half of the power electronics production will be located in the EU[428]
- Remaining shares of components (e.g. 50 percent of the power electronics) will be purchased from suppliers in third countries
- Rapid cost reductions among the electric vehicle components even until 2020

The majority of European experts interviewed consider these assumptions as realistic. The EU automotive industry currently has a good competitive position concerning the manufacturing of power electronics (see Chapter 3.2.1.3). In the near future the battery production volume will increase. While the manufacturing of components such as cathode, anode, electrolytes and separators will mainly take place in Asia, the assembly of battery systems and cell production will increase in the EU. Due to market proximity, logistical requirements of the manufacturers (e.g. JIT Production), particularly the battery assembly will be located close to the manufacturers.Furthermore, due to a high degree of automation, it will be possible to perform large shares of R&D and production of power electronics in the EU. Instead, the value added of electric engines, which will be generated in the EU in the future, will be not more than a third. Electric engines have a high potential for standardization. The majority of experts, which have been surveyed in this study, expect that electric motors will be produced globally even in the medium term. Both the R&D and production of electric engines do not require significant skills.

Due to an increasing market development (see our market forecast in Chapter 2.3.2) we expect, that 20 percent[429] of theEU-27 vehicle production in 2020 and 50 percent in 2030 will be electric vehicles and full hybrid electric vehicles. 60 percent of the experts surveyed consider these assumptions as realistic, while the rest were mainly indifferent. Based on these different assumptions, the following development of the value in EU automotive industry including the production of electric vehicles can be calculated for 2020 and 2030 (see Figure 49 and Table 34).[430]

Table 34:Calculationof Value Added in EU Automotive Industry for 2020 and 2030

	2020	2030
Value Added at Factor Cost (excluding EVs and HEV)*	**147,071**	**156,411**
-Profits Manufacturing of Components (Non-EU)*	748	1844
-Personnel Costs (Non-EU)*	1367	3536
-Less Value Added in ICE-Technology*	3515	9310
Value Added at Factor Cost (including EVs and HEV)*	**141,441**	**141,721**
* in million EUR		

(Source: Own Calculation)

In 2020, approximately 744 billion Euro revenues can be reached in the EU automotive industry. This slight shift of revenues can be explained by the fact that in 2020 only 20 percent of vehicles are electric vehicles or full hybrid. Furthermore, the costs of EV components such as battery systems, electric motors and power electronics have already been strongly decreased. Most of the EV components such as electric engines or certain components of power electronics represent affordable supply parts in 2020. Overall, a value added at factor cost of 141 billion Euro can be achieved in 2020. This value added at factor cost is about 4 percent less (141 billion Euro) compared with the base case scenario without electromobility (147 billion Euro). In 2030 a total turnover of approximately 749 billion Euro can be generated in the EU automotive industry including the production of electric vehicles and full hybrids. This greater shift of revenues can be explained by the increasing capacity of electric vehicles and full hybrid vehicles in the EU motor vehicle production (50 percent). Overall, a value added at factor cost of 142 billion Euro can be achieved in 2030. In 2030, **the value added at factor cost is about 10 percent less (142 billion Euro) compared with the base case scenario without electromobility (156 billion Euro)**,because in the production of the electric vehicle powertrain more parts and components are expected to be purchased from third countries compared to the parts used in the production of vehicles with internal combustion engines. **Nevertheless, thedecrease in value added**

[428] Based on expert estimations, several key players are located in the EU, e.g. Bosch, Siemens, Infineon, Valeo or Continental

[429] In comparison, A.T.Kearney 2012 expect a global production share of 18% electric vehicles and 8% non-rechargeable hybrids in 2025 in the moderate scenario

[430] R&D volumes which belong to the EU manufacturers and suppliers are not considered.

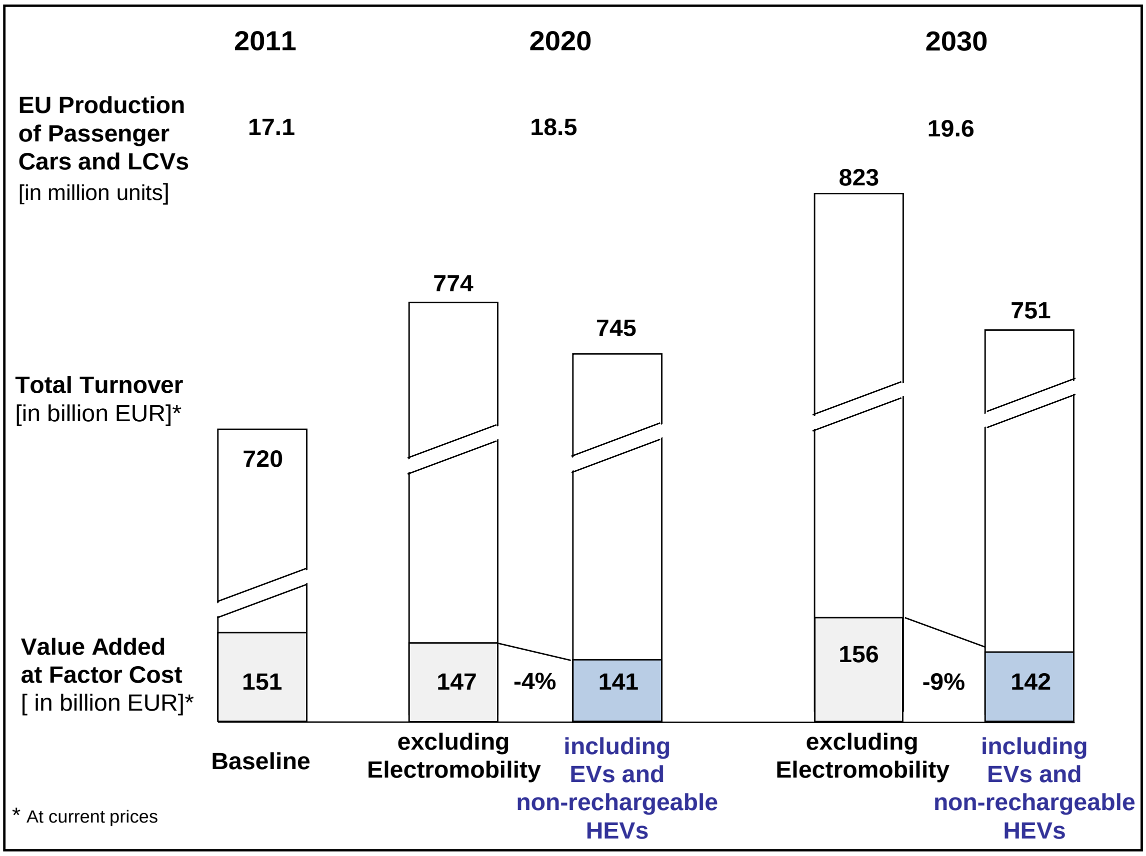
will be compensated by new business opportunities particularly downstream activities like new services (e.g. the infrastructure build-up or energy production of renewable energy).[431]

As a result, electromobility will not a have a detrimental effect on the value added in the EU industry in the long term, as there are always new business opportunities for companies (e.g. new business areas like the vehicle-to vehicle communication or vehicle-to-grid communication, new forms of co-operation even across industries, new entrants etc.). The trend of de-motorisation is expected to be balanced by an increasing use and popularity of car-sharing services, as in the larger cities there is still a need for individual mobility (see Chapter 4.4).

3.3.1.3 Forecast on the Development of the Value Added in the EU Automotive Industry

Figure 49 provides an overview on the evolution of the value added in the EU-27 automotive industry until 2030.

Figure 49: Forecast on Value Added in EU Automotive Industry until 2030



(Source: Own Calculation)

The forecast shows that the value added will remain stable despite globalisation and market development in the BRIC markets. Therefore, a relatively stable core employment in the automotive industry in Europe can be expected. However, particularly the skills of the young professionals, which are needed in the field of R&D of the automotive companies, will need to change significantly. In the future, chemists and materials scientists will have significantly higher proportions among the employees than today.

[431] See Chapter 4.

3.4 Situation of the Electric Vehicle Industry in Europe – Conclusion

The transition to electromobility will lead to fundamental changes in the automotive value chain: On the one hand a lot of new services such as the provision of electricity and its infrastructure can be expected. On the other hand, the vehicle itself will change. Electric vehicles are less complex because of less parts and modules, especially in terms of the powertrain. A combustion engine and exhaust system are no longer necessary, axles, transmission and drive shafts will be modified. Altogether, the (additional) costs will simultaneously rise by 65percent. To prevent electric vehicles from being more expensive than vehicles with internal combustion engines, they have to be developed as independent vehicle or mobility concepts, in order to be desired and purchased by customers. **The combination of traditional vehicle concepts with an electric motor will always lead to additional costs, even in the long term**. Therefore, batteries and power electronics have to be developed.In this way, optimised electric vehicles could lead to a decrease of costs by 10 percent compared to today's ICE vehicles.

In terms of the R&D and production of Lithium-Ion batteries, intense competition takes place between the South Korean companies LG Chem and Samsung and the Japanese company Panasonic. This results in overcapacities and could lead to dropping prices. While the activities of most European companies are market driven, Asian companies benefit from government funding.Presently, Japanese and Korean companies account for approximately three quarters of global Lithium-Ion battery production**.With regard to the R&D and production of power electronics and engines, the EU automotive industry currently has a good competitive position compared with Asia and the U.S.** According to the majority of the European experts, who have been surveyed in this study, European companies will have a competitive advantage in terms of power electronics even in the future, while the Asian experts tend to expect a shift to Asia. In electric motors, it is currently unclear where future R&D and production will be located.[432]

The European companies show a positive development in terms of patent applications in the last few years. However, whether this noticeable upward trend in Europe is sufficient to reverse competitive position in electric vehicles batteries and assembly or not remains a query; it is doubtful that the European companies will catch up with the Asian companies within a few years. In the past decade, around 4/5 of all innovations and patent applications in the field of electric vehicles were performed by only ten OEMs. Starting from a nearly oligopoly of manufacturers: Toyota Motor, Nissan Motor, and Honda in the years 2004/2005, the number of patent application was distributed overa larger number of OEMs in 2011. It appears quite interesting in this context, that the patent application numbers of the major OEMs, such as General Motors, Ford, and Volkswagen, which are among the TOP 5 worldwide in annual turnover, are very small. While General Motors had a considerable share of the patents at the beginning of the last decade, it has now almost plummeted to zero. Both Ford and Volkswagen have remained constant at a low level however, between 2009 and 2011 a slight positive trend can be identified.

High R&D costs, risks, and the lack of skills in battery manufacturing means that European companies will lead towards further co-operation in R&D and production. **Our overview on international co-operation in terms of electromobility show that in all three regions suppliers and manufacturers have already been acting internationally**. This trend will continue. The market power of individual competitors (e.g. in terms of purchasing, technological leadership, synergies, mass production and supplier networks) will lead to consolidation in the near future. Therefore, further collaborations can be expected.

To ensure the global forefront of innovative technologies from European Member States, national and supra-national encouragement to form platforms seem to be a suitable measure of public policy in order to support national companies in the development and market penetration of new technologies, especially in terms of (pre-competitive) research and development, integration/cross linking of different key players, standardization, setting of common goals (e.g. creation of roadmaps) and academic and vocational education.

Among several drivers of the industrial evolution, technological leadership and public policy have an especially strong influence on the competitiveness of the automotive key players. This is also reflected in expert estimations. **Productivity and cost development, however, play a smaller role, yet should not be underestimated**. **A difference in the results of various expert groups particularlyexists in terms of access to raw materials and transportation costs**. While manufacturers eval-

[432] See more information on R&D potential of electric engines in Chapter 3.2.1.2

uate the access to raw materials as significant, suppliers and experts in the field of politics consider these drivers to be less critical. Market proximity will play a major role in the selection of the manufacturing site for electric vehicles.Due to long transport distances and high transport costs the vehicle assembly will initially take place in those areas which offer the greatest market potential.

The industrial plans of the European automotive companies are mainly influenced by the actions and strategies of competitors.**The first movers, especially BMW and Renault accept higher risks in the transition to electromobility in order to establish a leading position in the new market very quickly**. In terms of R&D they are focusing on specific areas of technology (e.g. BMW almost exclusively on BEVs).In contrast, the followers, such as VW, Mercedes Benz or PSA are mainly trying to integrate electric powertrains into existing vehicle concepts. They have a rather broad R&D focus, which specifically rules out any particular avenue of developmentor implementation of technology.

The current value added in the automobile industry in the European Union amounted to 151 billion Euro in 2011. The value added in vehicle manufacturing is expected to remain stable with an amount of approximately 141 billion Euro in 2020 and 142 billion Euro in 2030. Despite increasing capacities in the BRIC countries, the value added of EU automotive industry will slightly decrease by 4 percent in 2020 (6 billion Euro) and by 10 percent in 2030 (15 billion Euro). This is because in the production of an electric vehicle's powertrain more parts and components are expected to come from third countries compared to the parts used in the production of vehicles with internal combustion engines.

It can be deduced that the distribution of value added in the automobile industry in 2020 will change to 21 percent for OEMs; 75 percent for the suppliers, and 4 percent for new competitors (from 27 percent, 70 percent and 3 percent respectively in 2011).

In summary, this chapter shows that there is a strong rationale for public policy support for a European Platform for Battery Technology as well as a formal training initiative in the field of electromobility, special depreciation for investments in production technology and a media campaign to inform the customers about electric vehicles, are suitable policy recommendations, in which will be further detailed in Chapter 6.3.

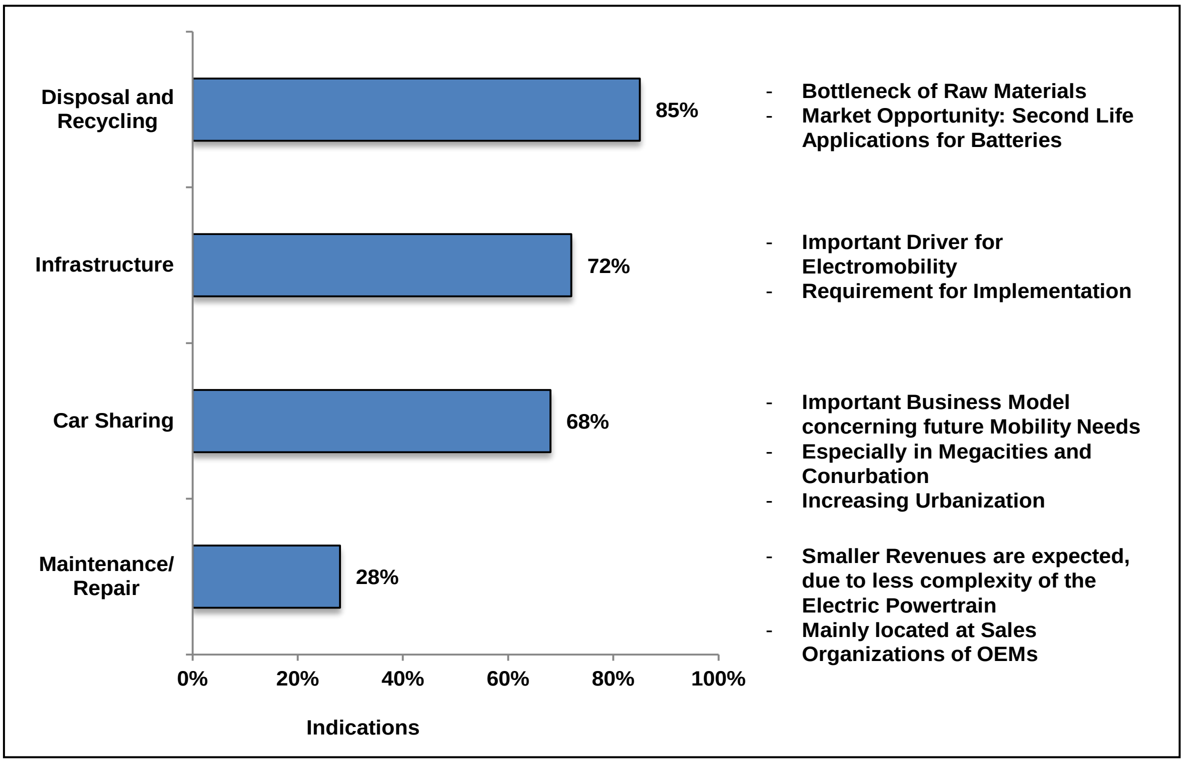
4 Services linked to Electromobility

4.1 Overview: Services linked to Electromobility

In this chapter services linked to electromobility, which are likely to be influenced by an increasing percentage of electric vehicles in the EU, will be described, explained, and analysed in regard to their future market development.

The interviewed experts consider maintenance and repair services, car sharing services, charging technology and recycling of batteries from electric vehicles as the most important services linked to electromobility (see Figure 50).

Figure 50: Most important Services linked to Electromobility



(Source: Own Estimation according to Expert Interviews)

In chapter 4.2 the main services presented above will be described and analysed with regard to their today's market volume. In chapters 4.3 and 4.4 the future development of these services will be evaluated.

4.2 Main Services linked to Electromobility

4.2.1 Maintenance and Repair Services

In this chapter the maintenance and repair services for electric vehicles are described and compared to the maintenance of conventional vehicles. As currently only a few electric vehicles have been introduced in the market, there is almost no specific data available considering the costs for these services.

Focusing on the electric vehicle and especially the powertrain, it becomes clear that these components require less maintenance compared to conventional combustion engines. Due to the fact that an electric vehicle has less parts and components than a conventional vehicle the overall costs for maintenance and repair will be lower. A study by B.A.U.M consulting expects that maintenance and service costs for electric vehicles are 60 percent lower while a study by NOW GmbH expects that the costs are 23% lower[433] than for ICE vehicles. However, based on discussions with experts we consider 60 percent as too optimistic. Instead we assume a cost reduction of about 30 percent on average with regard to a study performed by the Europe-wide operating company DAT (Deutsche Automobil Treuhand), which displayed the average costs and number of appearances of service and maintenance measurements in vehicles in 2010[434].

As for solely electrically powered vehicles costs for traditional services like oil changes, engine-repairs, repairs of the exhausted-gas system, renewing of spark plugs and other parts are eradicated in regards to the costs of service and maintenance. Additionally the maintenance costs for the brake system are reduced in comparison to conventional vehicles due to use of a regenerative brake system using the kinetic energy of the vehicle during the braking process to recharge the battery.[435] Thus using such a braking system reduces the brake wear of electric vehicles. Considering these facts, it is logical that the service costs will significantly decrease. Regarding maintenance work required for electric vehicles, the actual components (especially the battery) can be stated and analysed quite simply: the propulsion battery can be balanced as needed and the cooling system can be maintained. The cooling system, the electric machine, the battery pack (relays) and the drive inverter (relays) are the only components that contain mechanical parts, which can over time show wear. A disadvantage, focusing on the maintenance service, is that the high voltage powertrain is a new (vehicle) technology, which requires extensive training measures in order to guarantee safety for the service personnel. These required safety training measures involve additional costs. The regulation BG 8686[436] explains these safety measures for the service personnel in Germany (see Box 10).

Box 10: Explanation of the content of BG 8686

German accident insurance publishes regulations describing measures to provide safety for personnel working on electrical systems in order to avoid accidents. Additionally the qualification measures required are set by this regulation. The BG8686 focuses particularly on safety issues (safety rules) when performing service and maintenance work on electric vehicles.

In summary, the maintenance costs for electric vehicles, assuming that the service personnel is appropriately trained, are less costly compared to vehicles with combustion engines including hybrid vehicles.

4.2.2 Car Sharing Services

Consumer behaviour, concerning the individual need to own a car and therefor**e** to also have a maximum of personal mobile flexibility continuously, evolves towards a more rational view and a willingness to adjust the conservative beliefs of mobility, if and when economic benefit is involved. An economical benefit can be realised, if the accumulated costs to buy and use a personal car are higher than those when using a shared car. According to two studies from the year 2001 this break-even-point can be narrowed down to a yearly driving distance of 9,000 – 10,000 km[437];[438]; making car-sharing an economically attractive alternative for 43 percent of all car drivers (based on a survey in Germany)[439].

A survey from 2010 by Fraunhofer IAO and PWC asked 503 potential users in Germany from age 18 to 70 about their personal mobility-behaviours. While in the year 2001 13.5 percent of the registered cars in Germany were owned by 18 to 29 year olds, by 2009 this number was almost reduced by half totalling about 7 percent[440], showing that the younger generation has a different understanding of mobility than the previous generation. In addition to this trend another study predicts, that in the near future the percentage of citizens, who –in regards to their income – belong to the so-called “middle-class” will decrease, leaving citizens with less money to buy their own car[441].

[433] NOW (2011)
[434] DAT (2011)
[435] Contionline (n.d.)
[436] DGUV (2010)
[437] BCS (2001)
[438] Franke & Stutzbach (2001)
[439] Öko-Institut (2004)
[440] Fraunhofer & PWC (2010)
[441] Adolf & Huibers (2009)

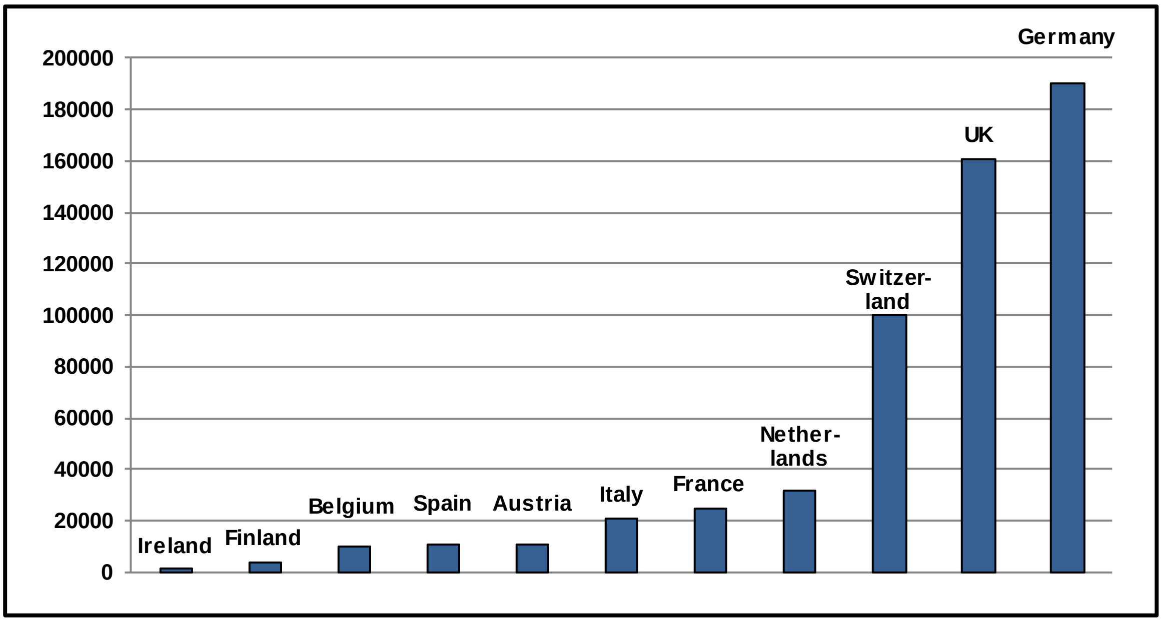
The international consulting company Frost & Sullivan identified a similar trend for urban users in all developed markets. They analysed and forecasted that by 2025 the average number of cars in megacities will decrease by up to 15 percent in Europe[442]. Similar trends can be observed in markets of the other "Triad"-states, Japan and the U.S. Using New York and Tokyo city as examples, Frost & Sullivan predicts, that the degree of private car-ownership is likely to decrease until 2025 – the first decline since the introduction of the motor-vehicle.[443]

Therefore, while in the developed markets the trend shows that the importance of owning a car decreases, this trend cannot be transferred to the emerging markets, like China, India, and Brazil. In the emerging markets which have a far smaller average GDP per person than the developed triad-markets, private ownership of a vehicle still represents one of the main symbols of status. Due to this fact, Frost & Sullivan predict a rising demand for privately owned vehicles in all emerging markets.[444]

A study by Fraunhofer IAO and PWC (2001 to 2009) reported that the number of users registered in car sharing organizations in Germany increased from about 65,000 users in 2001 to almost 140,000 in 2009. This number has increased further with heights of 190,000 registered German users by the end of 2011 utilising about 5,000 shared cars.[445]

Although Germany is the most developed market (in absolute numbers) for car sharing in Europe, a similar trend can also be observed in other European countries, such as the UK (2008/2009: about 63,000 users, 2011: about 161,000 users) and Switzerland (2008/2009: 83,000 users, 2011: 100,000 users). Large growth rates have also been realised in France, Spain, the Netherlands, and Italy, although the car sharing market in those countries is still relatively small in comparison to the countries mentioned above. In 2009, 11,900 cars were available to car sharers in the EU.[446]Detailed numbers can be reviewed in the following figure.

Figure 51: Number of Car Sharing-Customers in Selected European Countries



(Source: Momo 2011)

442 Frost & Sullivan (2011a)
443 Frost & Sullivan (2011a)
444 Frost & Sullivan (2011a)
445 BCS (2011); Zukünftige Technologien Consulting (2011)
446 BCS (2010); BCS (2011)

In the European Union there were 400,000 car sharersaltogether in 2011.[447] Further, car sharers exhibit a steady growth rate in numbers. The potential market volume of the car sharing market is expected to grow fast and will be further analysed in chapter 4.3.2.

4.2.3 Charging Technology

Firstly, when looking at the introduction of electric vehicles in individual traffic, a matching charging infrastructure has to be established to recharge these vehicles. This charging infrastructure can be mainly divided into two segments: private charging at home and public charging. When using such charging infrastructure, communication between the vehicle and the grid is necessary for the charging process, and furthermore implies the possibility of providing several additional services such as internet access for the user during the charging process. Another aspect is that such an electric or hybrid vehicle, when for example charged overnight at home, represents an energy storage device with a considerable capacity, which can be used to modulate the power load profile in order to stabilize the grid.

4.2.3.1 Vehicle-to-Grid-Communication and Smart Charging

Electric and hybrid electric vehicles are currently using a Lithium-Ion battery to supply the powertrain (see also Chapter 3.2.1)**.** Due to the fact, that the driving range of electric vehicles is limited, an appropriate infrastructure (charging stations) is needed in order to recharge the battery. These charging stations can be distinguished by their installation location and by their maximum charging power. Focusing on the individual traffic, a charging station has to be implemented in e.g. the user's garage, so that the vehicle can be recharged overnight. Additionally, public charging stations can be used for recharging the battery at e.g. the workplace, public car parks or parking places. When looking at the vehicle manufacturer Nissan respectively the electric vehicle Nissan Leaf, a simple charging device which can be used in combination with every standard wall socket is included in the purchase price. As this charging device has a low charging capacity resulting in a recharge time of approximately 10 hours, an additional charging station has to be installed in e.g. the customer's garage[448].Such charging stations (wall boxes) are normally provided by energy distribution companies and reduce the recharge time due to their higher charging capacity. For public charging in Germany, energy distribution companies like e.g. RWE[449], Eon, Rheinenergie are establishing appropriate infrastructure with public charging stations for electric vehicles at the moment. Public charging infrastructure is also developing in other European countries. For example in Italy, companies like Enel Energia and A2A, in France mainly the company EDF, in the Netherlands the company Essent, and in Spain the energy distribution company Endesa. In London, UK the company British Gas has established a public charging infrastructure with a total of 300 charging stations and additionally offers charging stations for private use[450]. In Denmark, in addition to the conventional charging infrastructure, mainly provided by the company SEAS-NVE, infrastructure consisting of battery charging stations provided by the company Better Place in co-operation with Dong Energy is being developed.[451] In order to further decrease the recharge time of electric vehicles, DC quick charge stations with a connected power of 50kW can be used. Vehicles such as the Nissan Leaf and the Mitsubishi i-MiEV are supporting such a quick charge function. These quick charge stations have been introduced in several countries of the EU[452] and as well as in Japan.[453]

Box 11: European examples for the installation of Quickcharge stations

Chademo establishes a test network of DC-Quickcharge stations in cooperation with the energy distribution company Endesa and Cepsa in the city of Barcelona. In Amsterdam there will be 20 DC- Quickcharge stations installed within the next 3 years.

[447] Momo (2011)
[448] Nissan Europe (2012c)
[449] RWE (2012a)
[450] Sourcelondon (n.d.)
[451] IEA (n.d.)
[452]Website: www.chademo.com
[453] Chademo (n.d.)

Using such recharge stations, it is possible to recharge the battery in approximately 30 minutes[454], which is still long compared to the time needed to refuel a conventional car. The company Nissan quotes a price of 10,000 Euro for such a DC-Quickcharge station[455]. The purchase price for AC charging stations from smaller companies like Ebitsch Mobil quote a price of 5,000 Euro (excluding costs for installation)[456], while an actual study by Emobility-Experts GbR, which focuses on the market for charging stations, states an actual price of 6,800 Euro (including costs for installation)[457]. A possible additional charging concept, is the inductive charging method. The advantage of this is that it is wireless; the energy is transmitted inductively. Figure 52 presents the different types of charging stations.

Figure 52: Different Types of Charging Stations

(Nissan Quick Charger (left)[458]; Inductive Charging Concept (top right);
RWE Charging Station (bottom centre)[459]; Eon Wall Box Charger (bottom right)[460])

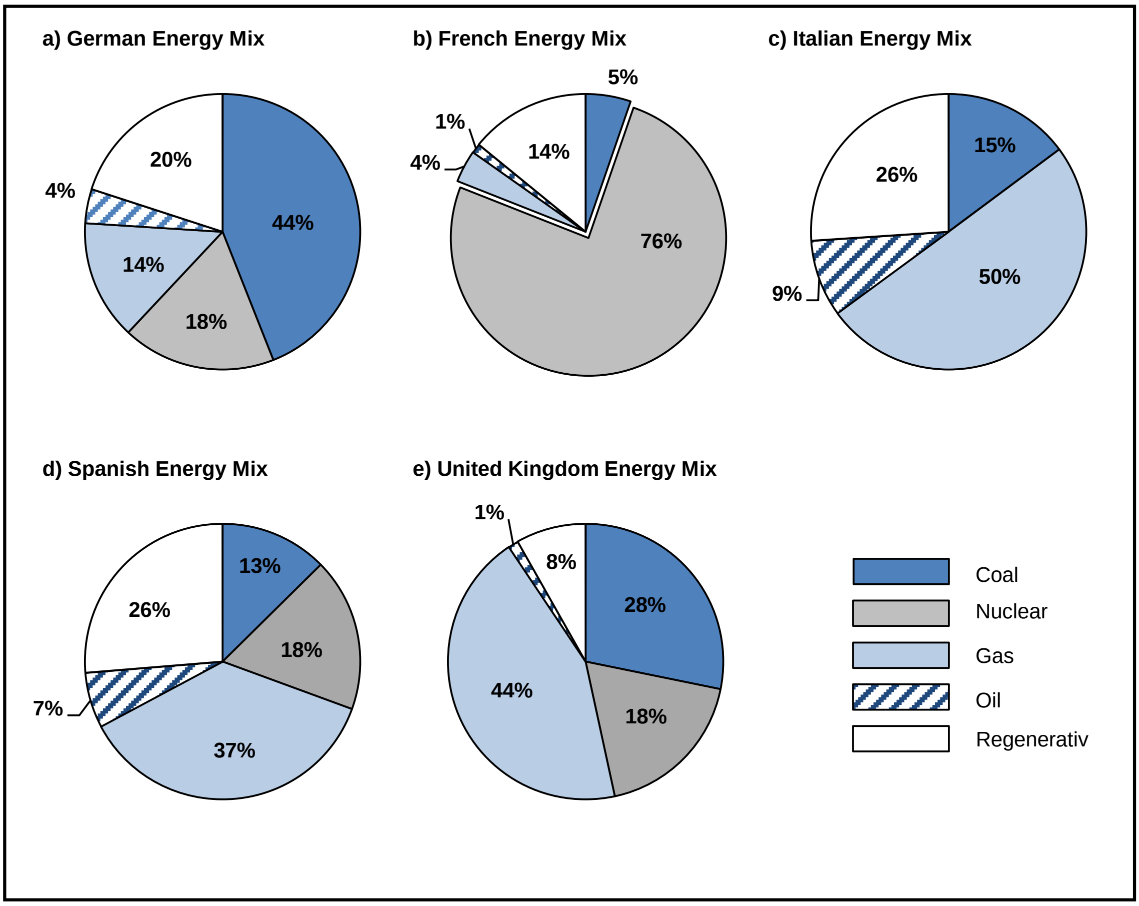
When connecting an electric vehicle via the charging station to the grid, an additional communication between the vehicle and the grid is necessary. This communication is needed for an authentication of the vehicle so that the customer can be identified and the amount of energy taken from the grid can be detected for billing purposes. When charging Lithium-Ion batteries in particular, communication between the charging station and the on-board charger is needed for exchanging information on e.g. the maximum charging current and charging profile. Additionally, other communication services, like providing internet access to the customer during the charging process or the download of actual routing information, can be implemented in this process. Thus when looking at the process of recharging electric vehicles, infrastructure has to be installed (private and public charging). This is mainly done by the energy distribution companies purchasing the current and implementing the charging station into their energy distribution network. Additionally, when focussing on the communication infrastructure needs it is mainly the telecommunication companies and companies producing mobile navigation systems that have to realise this infrastructure (in co-operation with the automotive industry) (for additional information on vehicle-to-grid-communication and smart charging see Appendix XXXV).

4.2.3.2 Energy Storage in Automotive Batteries

The expansion of renewable energy generation is politically and socially pushed, which has an impact on the future of energy supply. These effects and the role of electromobility in this context are presented in detail in the following figure. In Figure 53 the current energy mix in Germany and the energy mix of other EU countries in 2009 are presented.

[454] Automobilindustrie Vogel (n.d.)
[455] ElektroAutoNews (2012)
[456] Ebitsch (2012)
[457] EmobilityWeb(2012)
[458]Auto (n.d.)
[459] RWE (n.d.)
[460] Eon (n.d.)

Figure 53: Schematic of Energy Production in selected European Countries 2009/2011



(Source: Own Compilation based on Hirsch et al. 2012)

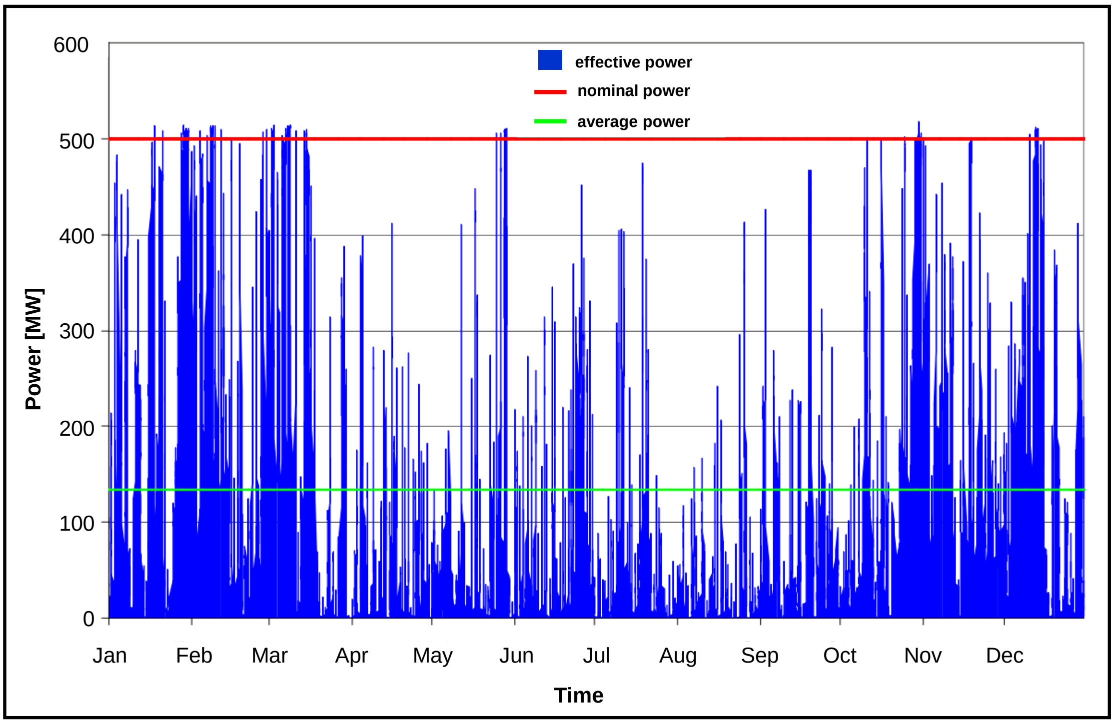
When looking at the German energy mix in Figure 53a, it is clear that until 2011 20 percent of the electric energy was generated using regenerative sources where, within this breakdown, wind energy has had the largest amount ca. 40 percent

Considering the fact that fossil energy sources like e.g. hard coal, lignite, gas and oil are limited; the proportion of energy renewably generated will continue to increase in the future worldwide. The main disadvantage of this energy production structure, especially when focusing on the generation of wind energy and photovoltaic systems, is the volatility. Due to the fact that up until today there has been no efficient energy storage technology besides pumped storage power plants available, and that in Germany the energy feed law (EEG)[461] guarantees the feed-in of renewable energies, the existing medium load power plants have to compensate for these fluctuations.

In the following figure, two examples describing the main problems of wind energy generation are presented. In 2009 in Germany, an installed power generation capacity of 21 GW in the form of wind turbines generated 37.8 TWh in total. This result in a daily power generation capacity is approximately 4.3 GW, which is quite minimal compared to the total installed power generation capacity. As the feed-in is guaranteed by the EEG, the grid has to be dimensioned for the transmission of the total installed capacity of 21 GW. In Figure 54 the wind energy generation at the German North-Sea coastal region in the year 2000 is presented.

[461] EEG (n.d.)

Figure 54: Wind Power Feed-in East Frisia in 2000[462]



(Source: Hirsch et al. 2012)

Clearly, feed-in wind power varies significantly. The red curve represents the total installed capacity of 500 MW while the green curve represents the average power of approximately a 140 MW feed into the grid, which is only 30 percent of the installed capacity. Due to the fact that renewable energy generation is on the one hand volatile, and on the other hand a decentralized feed-in, today's energy networks have to be adapted to these conditions. The traditional concept implies a fixed load curve and centralized base-load, medium load, and peak load power plants feeding the needed power. With the increase of varying renewable energy generation, the medium load power plants have to be controlled in order to compensate for these variations, which have a negative impact on the efficiency of these power plants. Assuming, that renewable energy generation will further increase in the future, the load has to be modulated depending on actual regenerative energy generation in order to minimise the control of these power plants and to stabilize the grid. In this future scenario, electromobility will contribute to the modulation of the load curve. Focusing for example on electric vehicles in private households, where the vehicle is recharged in the garage by night, it becomes evident, that the load can be modulated by a matching control of the charging process. As actual electric and hybrid vehicles include propulsion batteries with capacities between 5 kWh and 25 kWh, these vehicles have a large load modulation potential compared to other electric devices used in households like dish washers or washing machines. Additionally, such vehicles represent energy storage for regenerative energy generated in low-load periods.

4.2.3.3 Energy Consumption Metering

The realisation of energy consumption metering is an important aspect, concerning the recharge process of electric vehicles, as the energy distributor needs detailed information on the amount of energy used for the recharge process due to billing purposes. Energy consumption is determined by measuring the voltage which stays nearly constant and the current over time.Exemplary an electronic energy meter by Kamstrup is presented in the following box.

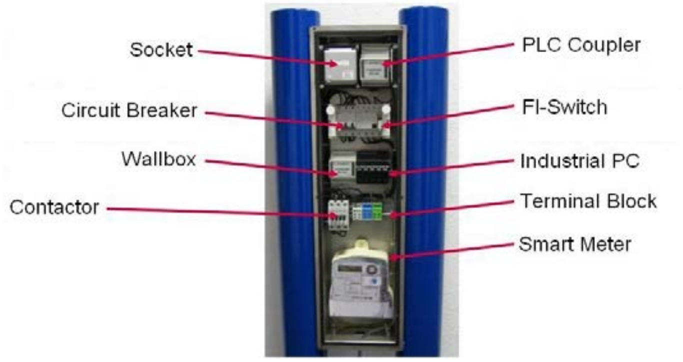
[462] Hirsch et al. (2012)

Box 12: Exemplary Electronic Energy Meter by Kamstrup

The consumed energy is measured as described in the previous chapter. Additionally the energy meter can be equipped with several communication interfaces like e.g. PLC, TCP/IP, GSM for transmitting the data to the energy provider. This product costs 162 Euro (excluding the installation costs)

Using these values, the consumed power over time, which is equivalent to the energy, can be determined. Instead of using traditional Ferraris meters[463] in new house installations, electric vehicles will use electronic energy meters in charging stations.[464]For example, in an actual charging station by Mennekes,[465] an electronic energy meter in combination with an additional device for data collection and transmission is used to provide data to the supplier concerning energy consumption (see Box 13).

Box 13: Basic Structure of a Charging Station for Electric Vehicles



A charging station for electric vehicles mainly consists of a smart meter measuring the energy consumed during the recharge process. This data is collected by an industrial PC and afterwards is transmitted to the energy supplier by the PLC modem (PLC coupler). Additionally such a charging station has several switches like the main contactor, the circuit breaker and the FI switch to provide safety during operation. For further details concerning the costs please refer to chapter 4.2.3.1

4.2.4 Recycling of Batteries from Electric Vehicles

The automotive industry's successful transition to electromobility in the European Union is closely related to the availability of the necessary raw- and basic materials for the batteries of electric vehicles. For the first generation of electric vehicles mainly lithium-ion batteries will be used as energy-storage devices, since they combine a high volumic energy with a constant voltage curve during the discharge. The three raw materials with a strategic relevance for the production of these batteries are lithium, rare earths (mainly Neodymium) and cobalt[466](see also Chapter 3.2.5.1 "Access to Raw Material").

The supply of all three strategic relevant raw materials is believed to be unsecure. This leads to the necessity of a large-scale recycling concept for batteries in electric vehicles. Until today no large-scale economic and ecologically bearable process has been developed that allows the return of secondary

[463] Mühl (2008)
[464] Kamstrup (2012)
[465]Mennekes (n.d.)
[466] Nationale Plattform Elektromobilität (2010)

material in the battery-production-cycle.[467] While researches in the U.S. and Japan have been working in this field for several years, the first projects in the EU have only recently started. The two largest projects concerning the reuse and recycling of batteries from electric vehicles are the LithoRec-Project and the LIBRI-project, both being financed by Germany's environmental ministry in co-operation with private companies.[468] The LithoRec-project, being by far the largest European project with a research-budget of 18 million Euro, is developing a process to analyse batteries which have been sorted out of electric vehicles and – regarding the degree of their abrasion – decide if those batteries can be used for energy storage or should go directly into the recycling process.[469] All large current projects which focus on the recuperation of secondary raw material may be reviewed in the following table.

Table 35: Current Projects which focus on the Recuperation of Secondary Raw Material

Region/Country	Type of Recycling Project	Company	Funding	Metalls	Additional Information
USA	Pilot Production faciliy for the recycling of Li-batteries	Toxo Inc. Anaheim, CA	7.3 million €	Ni, Co, Li	none
Japan	Installation of a pilot facility for Li-batteries	JX Nippon Mining & Metals; Tsuruga Waseda; Nagoya University	11.3 million €	SE, Li, Co, Mr	developed for Li-batteries containing Co and Mn
Japan	Recycling process for the recuperation of SE from magnets	Hitachi; Ministry of Economy and Industry, Tokyo	unknown	SE, Li, Co, Mr	2009-2013
EU, Germany	Recycling of Lithium-Ion-batteries	Audi; Chemetall; Evonik Litarion GmbH; TU Braun-schweig u.a.	8.4 million €	Co, Ni, Li	LithoRec-project / BMU
EU, Germany	Recycling process develop-ment for Co-based Li-Bs from EVs	Accurec Recycling; RWTH Aachen	0.6 million €	Co, Ni, Li	BMBF/PTJ focused on Co-based batteries
EU, Germany	Recycling concept for high perfor-mance batteries of future EVs	Umicore; Daimler; Öko-Institut Darmstadt; TU Clauthal	1,6 million €	Co, Ni, Li	BMU-project LIBRI
China, Jiangsu	Development and construction of a pilot facility for the recycling of 1000 t Li-Batt./a	Yancheng Ltd., Jiangsu, Yandu; CEEA, Ministry of Industry, Inform. Techn.	> 10 million €	Co, Ni	none

(Source: Nationale Plattform Elektromobilität 2010)

The subsequent recycling-process is a hydrometallurgical process in which lithium and cobalt are re-captured and may be reused in new battery-cells[470].

[467] Lindner (2010)
[468] Nationale Plattform Elektromobilität (2010)
[469] Bärwaldt (2010)
[470] Bärwaldt (2010)

4.3 Forecast on Market Opportunities, Profitability and Entrants of New Playersin the Service Sector

This chapter analyses the future market potential and – structure of certain services linked to electromobility.

4.3.1 Maintenance and Repair Market

In the long run the transition to electromobility will lead to smaller market potential of the service and maintenance sector in the future. This trend will manifest itself in the years after 2030 and will be presented in this section.

As presented earlier, by 2020 approximately 1 million or 7 percent of the total 14.8 million new registered vehicles will be electric vehicles (including BEVs, Range Extenders and Hybrids). By 2030 this number will have increased to approximately 4.6 million electric vehicles or 31 percent of the total 14.8 million new registered cars in the EU-27.

Assuming that the calculated decrease of 30 percent of the total maintenance and service costs is only correct for BEVs, the decrease will apply for 160,000 of the new registered cars (1.1 percent) in 2020 and approximately 1.6 million of the new registered cars (11 percent) in 2030. Based on the results of our market model, 945,000 BEVs and 8.2 million hybrids will be on European streets by 2020 (assuming a lifetime of at least 7 years). By 2030 this number will have risen to 9.85 million BEVs and 41.6 million hybrids (assuming a lifetime of at least 9 years).

For all forms of Hybrid-Vehicles the service and maintenance costs are assumed to rise by approximately 5 percent due to higher complexity of the powertrain which will lead to higher prices for services in this field.

A.T. Kearney assumes that the rising life-time of vehicles and the decreasing use of vehicles, due to economic and ecological reasons, will lead to a decrease in the demand for wear parts by 20 percent by 2020. The market volume of the electronic-aftermarket is, on the other hand according to A.T. Kearney likely to rise significantly in the upcoming years by 7 percent per year due to the rising complexity of repair services.[471]

Box 14: Maintenance Costs in Germany

These presented findings go along with a report by the German DAT which analysed the service and repair market in Germany. It was found that the so called “do it yourself” repair quota has sunken significantly from 7 percent in 2001 to 4 percent in 2010. The authors of the report explained that this trend accompanies the higher complexity of modern cars.[472]

The DAT analysed that in 2010 German customers spent 201 Euro per car on repairs for wear parts and 230 Euro on the maintenance of their cars. Assuming that these numbers are alike in the other EU-countries indicates that the volumes of the maintenance sector and the repair of wear parts sector are on a similar level today. If on average 690 Euro had been spent per car in the EU in 2008[473] this would mean that these two sectors would account for approximately 62 percent of all repair and maintenance services.

(Source: DAT 2011)

By combining the findings of A.T. Kearney and the DAT we can assume that maintenance and repair costs will have risen by 10 percent for each car in the market by 2020. This scenario is more conservative than the scenario which was performed by A.T. Kearney. It is believed that the level of new electric applications - and therefore the level of necessary repair and maintenance services - will rise

[471] A.T. Kearney (2008)
[472] DAT (2011)
[473] A.T. Kearney (2008)

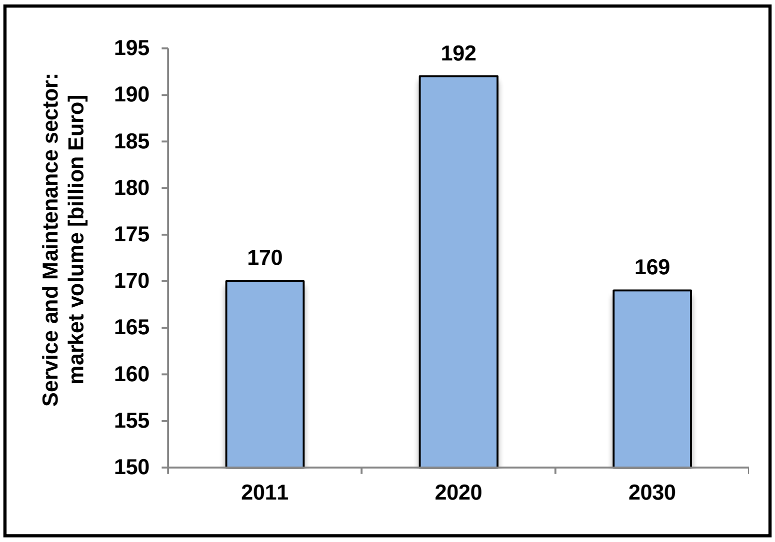
more slowly. Electric applications are assumed to raise the weight of a vehicle and therefore do not go along with the observed trend to build cars that are more fuel-efficient. It is further assumed that this trend will then slow down and that the costs will only rise by another 3 percent until 2030, as vehicles and their operation will become more expensive in the future due to several price-boosters (e.g. oil-price/ lightweight construction) and therefore extra-applications will become less important for the average customer.

According to statistics which were published by the European Union, the level of motorisation was at a level of 0.473 cars per EU-27 citizen in 2009 or in absolute numbers, at a level of about 240 million cars. It is assumed that this level has been relatively constant until today. In the short run - until 2020 - the number of cars per European citizen is expected to rise slightly due to the rising income in eastern European Union members' states. It is assumed that by 2020 the level of motorisation will be at approximately 0.5 cars per European citizen. As some developments, such as the rising oil prices or the roll-out of car sharing organizations function as an alternative to the use of a private car and will likely influence the level of motorisation until 2030.

It is assumed, that these changes will affect motorization development levels between 2020 and 2030. Therefore it is assumed that in the long run, the level of motorization will decrease until 2030 when the level will be at 0.43 cars per EU-citizen. The population density in the EU is assumed to be constant (505.5 million citizens).

According to A.T. Kearney the volume of the European (EU 25) automotive aftermarket was 165 billion Euro in 2008.[474] Based on A.T. Kearney and Eurostat we assume a total turnover of 170 billion Euro in 2011. This would mean that approximately 690 Euro had been spent for maintenance and repair per vehicle in the EU. A.T. Kearney expects that until 2020 the market volume will rise by 40 percent to reach 230 billion Euro. **Our calculations, which have been more conservative, believe a height of about 192 billion Euro by 2020 as more realistic. By 2030, the market volume of the service and maintenance sector will decrease in our scenario to approximately 169 billion Euro (see Figure 55).**

Figure 55:Market Volume Service and Maintenance Sector



(Source: Own Calculation)

Recent studies predict the market potential of the automotive maintenance and service market to rise in the upcoming years. While our findings go along with these predictions we believe that the market volume of the maintenance and repair sector is likely to decrease in the years after 2020. The degree of this development largely depends on the future market share of electric vehicles and consumers mobility behaviour, mainly as the growing number of BEVs and the predicted decrease of vehicles in the EU after 2020 will be responsible for the presented market volume.

The interviewed experts are largely complacent with this scenario. They judged the maintenance market to be the least important service sector of the four given alternatives. While 85 percent of the inter-

[474] A.T. Kearney (2008)

viewed experts believe that the recycling of batteries will be an important business model in the future, 72 percent judge the infrastructure sector to be of high importance. 68 percent believe car sharing to be an important future business model, while only 28 percent believe that the maintenance sector will be a sustainable future business model. For example, a Korean expert emphasizes: “Maintenance and repair is not expected to be successful as modularization of electric vehicles does not allow for much manual work!” The majority of the experts, who have been surveyed in this study, believe that maintenance and repair will not constitute independent business models in the medium term due to reasons of safety, education, and regulations in terms of warranty/guarantee. These activities are mainly expected to be part of the manufacturers´ value chain or in the value chain of their sales/service organization.

4.3.2 Car Sharing Services

Based on the data presented in chapter 4.2.2 the future market potential of car sharing organizations will be analysed in this chapter. Using field data of car sharers in Switzerland, where 100,000 users are registered in car sharing pools facing a total population of roughly 8,000,000 citizens, the Momo-Group extrapolated the number ofcurrentpossible users to 6,000,000 in the EU-27, requiring investments of about 9 billion Euro.[475] For 2015 Frost & Sullivan forecast similar numbers, also assuming about 6 million users by this time. They predict a further growing market with about 14 million registered users by 2020 and possible revenues of up to 7 billion Euro.[476]

To extrapolate the numbers and trends, a formula has been developed to increase the comparability of the several national markets of EU-members (see Appendix XXXVI).

Three different models for the concrete use of shared cars exist. One model (multi-port scheme) enables users to leave the rented car at any of the provider’s collection points, a second model in which users have to return the car to the central collection point where they picked it up (single-port scheme), and a third model in which users are enabled to leave the car wherever they want within a defined area (mainly inner city). In all cases, the availability and location of the cars may be reviewed via smart phone or internet.[477]In the near future primarily the multi-port and single-port models are assumed to embody great potential for employing electric vehicles in car sharing fleets because the cars have to be returned to fixed collection points, where the set-up of charging infrastructure can be realised. With an increasing number of public charging stations within urban regions, the market potential of the third model, where users do not have to return the car to a central collection point, will also increase. Therefore this development is closely correlated with the general development of electric mobility and its infrastructure.

In addition to the presented economic benefits of sharing electric vehicles, there are many other incentives why users are likely to accept the use of electric vehicles. The most important incentive for electric vehicle users in car sharing fleets is perhaps the prestige connected with the use of an electric car. In recent years heightened climate change awareness, its causes and reasons, have culminated in increasingly negative perceptions of combustion engines. Meanwhile electric cars exemplify a positive image in society. Using electric vehicles in car sharing fleets is a cheap way to profit from this image.

In recent years car sharing organizations have proved their potential to operate with economic success[478]. Due to this fact and other - non-monetary - benefits for certain groups of operators, namely car sharing providers with a variety of different backgrounds, know-how, and motivations have started to build up car sharing organizations. In this chapter we will concentrate on the public organisations, neglecting those organisations which may only be used by certain private groups such as the internal car sharing organisation operated by the Siemens AG in Munich, which was founded to enable their employees to travel between the company’s different locations throughout the city. Five groups of car sharing organizations have been identified, which often operate in co-operation with governmental organizations (e.g. cities) or – in cases of employed electric vehicles – with utility companies.

475 Momo (2011)
476 Frost & Sullivan (2011a)
477 Niches (2010)
478 BCS (2011)

These groups are:

- New car sharing organizations which were founded only to operate car sharing fleets (e.g. Stadtmobil-Gruppe)
- Operators of other mobility services (e.g. Deutsche Bahn AG)
- OEMs (e.g. Daimler AG with its car sharing organization car2Go)
- Car rental agencies which also offer car sharing for short term customers (e.g. Denzeldrive)
- Oil companies with gas station networks (e.g. Shell Drive)

Box 15: New Car Sharing Organizations which were founded only to operate Car Sharing Fleets

Examples of *Paris Autolib*
Paris Autoblib is the first large scale car sharing project which employs electric vehicles (Bluecars) within an urban area. The project started in November 2011 with 250 cars and has since then continuously grown. Until June 2012, 1,740 Bluecars[479] have been available at 1.100 Stations using about 5.000 charging points and parking places within the centre of the Paris Metropolitan region. By 2014 the number of available cars is planned to grow to 3.000 Bluecars. Furthermore, another 1.100 charging stations are planned to be installed until the end of 2013/beginning of 2014. The total capital investment is estimated to be around 200 million Euro[480]

(Source: Autolib 2012)

Box 16: Operators of other Mobility Services

Example of *Deutsche Bahn "Flinkster"*
DB Flinkster is the Carsharing-Organization with the largest distribution network of shared cars in Germany. It provides about 2,500 cars (including 100 electric cars) at 800 stations around Germany, mainly at railway-stations. Their business model allows the user (together with the railway-network and DB "Call a bike") to choose between several mobility solutions, according to his or her current requirements. DB Flinkster also provides 2,000 shared cars in Austria, the Netherlands and Switzerland.[481]

(Source: Flinkster 2012)

Box 17: OEM Activities

Example of *Daimler`s Car2Go*
In contrast to most other CarSharing providers, the concept of Daimler`s Car2Go allows the customer to use the car with a maximum of flexibility, as the cars don`t have to be returned to fixed stations but may be left wherever the customer wants (within a defined area, mostly inner-cities of metropolis-areas). The location of the cars can be detected by using a smartphone-app. Car2Go is active in selected large cities in Germany (e.g. Berlin – 1000 cars and Düsseldorf – 300 cars) as well as in the USA (e.g. Austin – 300 cars and San Diego – 300 cars), France (e.g. Lyon – 200 cars) and the Netherlands (e.g. Amsterdam – 300 cars)..[482] As Daimler produces the cars itself the migration in the carsharing business is a vertical integration, which offers Daimler the possibility to generate more of the value within the value chain. Another example for an OEM which provides car sharing is BMW with its car sharing organization DriveNow.

(Source: Car2Go 2012)

[479] In the first half of 2012 1,383 new Bolloré Blue Cars were registered in France.
[480] Autolib (2012)
[481] Flinkster (2012)
[482] Car2Go (2012)

Box 18: Car-Rental Agencies which also offer Car Sharing for Short Term Customers

Example of *DenzelDrive*
In addition to its classic car-rental business DenzelDrive also offers the possibility for regular or periodic short-term CarSharing. DenzelDrive has therefor widened its value chain horizontally. DenzelDrive operates in Austria.[483]

(Source: Denzeldrive 2012)

Box 19: Oil-Companies with Gas Station Networks

Example of *Shell Drive*
Shell Drive was founded in 2003 and sold in 2006. The business model of Shell Drive used the synergetic effects which occurred by being both, a provider of carsharing and of gas and maintenance stations. Existing gas stations were partly used as pick-up places for the cars and the shared cars were refuelled and maintained at the same stations.[484]

(Source: Shell 2004); Herodes & Skinner 2005)

In addition to the obvious economical motivation all providers commonly share, there are some additional incentives for some of the presented groups to create a car sharing organization.
For operators of other mobility services such as railway companies or airlines, the offer of car sharing options for their customers may increase their added value and helps to increase the commitment of customers to a special airline or venue of mobility (e.g. train). Car rental agencies may maximise the number of hours their vehicles are in use by offering short term rental options, such as car sharing[485]. For OEMs the motivation is – as presented earlier – mainly marketing concerned. It is assumed that the five groups presented above will also be the providers who will together account for the largest part of the car sharing market in upcoming years.

The future market share of the several providers and groups cannot be predicted with any certainty, as this number largely depends on the particular investments in cars, infrastructure, and marketing. Although some of the large automotive companies are relatively new in the market (e.g. BMW DriveNow, Daimler Car2Go), they possess big funds, large parts of the necessary know-how and seem to have discovered the car sharing market as an attractive future market. This group is assumed to increase its market share in the upcoming years. In the last few years the first signs of concentration in the car sharing market have been observed. Many smaller companies now operate in networks and have therefore been able to realise improvements in efficiency. Examples for this trend are exhibited with Cambio, an amalgamation of former independently operated car sharing companies from the German cities of Bremen, Aachen, and Cologne, and Shareway AG**,** totalling 14 car sharing companies in Germany, operating in over 100 cities and communities.[486]

The car sharing market is therefore likely to develop in the same direction as the closely related car rental market, where a continuous concentration process has been observed in the past few decades[487]. As larger, supra-regional operating car sharing companies hold benefits both for users as well as for providers it is assumed, that the described trend will continue in the years to come. The benefit for users is mainly the ability to use shared cars nationwide – or at least in several large cities – while only having to register once. An example of a company which enables their users to do so is the car sharing initiative operated by the German Railway company Deutsche Bahn AG. With increased efficiency and a larger negotiating power concerning the acquisition and the operation of their cars, car sharing companies may also be able to realise reduced prizes, generating a benefit for their users and a competitive advantage for themselves.

The business model of car sharing is judged to be of high importance for the upcoming years. 68 percent of the interviewed experts judge car sharing as an efficient business model which will become widely accepted in the upcoming years and is also a driver for the transition to electromobility. Other

483 Denzeldrive (2012)
484 Shell (2004)/Herodes & Skinner (2005)
485 Herodes/Skinner (2005)
486 Öko-Institut (2004)
487 Groß (2011)

important future business models are, – according to the interviewed experts, - the installation of an area for charging infrastructure (72 percent) and the disposal and recycling of batteries (85 percent).

Concerning the market potential of car sharing in terms of electromobility the responses of the experts interviewed vary greatly. While the experts from Europe and the U.S. expect huge market potential (particularly in urban areas and megacities), the Asian experts believe that car sharing will be unsuccessful in Japan and Korea even in the long run, due to the differences in consumer preference. The following statements of Asian experts underline this assumption: "Car sharing is a good idea but not popular in Korea", "The least thing Koreans like to do is share their car!" or “Car sharing is so far not successful in Japan!” In China, consumers currently prefer to possess a private car as well (status symbol).Furthermore, a global supplier located in Germany stated that the main limitation on the market potential of car sharing may be the long charging time and the short range: "With car sharing vehicles you can earn money if they are in use, but not while they are waiting to be charged!"

4.3.3 Charging Technology

The number of future public charging points in the European Union is strongly correlated to the number of sold, or estimated sold electric vehicles at a particular point in time; as charging points are installed by private, economically operating companies (the costs for the installation of a public charging station are estimated from 4,700 to 9,000 Euro[488]) [489]. On the other hand, areas that have installed public charging stations will encourage possible customers to purchase an electric vehicle.[490] One possibility to deal with this problem would be through governmental subsidies for charging infrastructure[491], which some countries already offer.

In order to give a forecast on future public charging stations, which will be installed in the European Union until 2020, several studies have been examined, which offer a wide range of forecasts.

A rather optimistic forecast has been performed by the consulting company Frost & Sullivan.[492]It predicts the number of public charging points in Europe to reach 2 million by 2017. Frost & Sullivan do not distinguish between the European Union and other European countries. Therefore the given number of public charging points has to be adjusted by the number of public charging points in European countries which are not part of the European Union. Currently about 740 million people live in Europe[493], of which 505.5 million live in the European Union, which is an average of 0.002703 public charging points available per European Union citizen. Extrapolated this would mean that by 2017 about 1.3664 million public charging stations would be installed in the European Union. As the countries of the European Union have a significantly larger average GDP per citizen than the European countries which are not part of the Union this number is expected to be significantly higher; as by 2017 electric vehicles will still be more expensive than vehicles with a conventional engine and governments with high revenues from taxes (due to a higher GDP) are more likely to subsidise the transition to electromobility. Therefore the number of public charging stations in the European Union is (based on the findings of Frost & Sullivan) expected to be about 1.7 million by 2017. As this forecast was performed in the year 2011 when less than 10,000 public charging points were installed (using data from the year 2010), this would mean that each year an average of about 282,000 new public charging stations would have to be installed. Assuming that this trend continues until 2020 this would lead to approximately 2.5 million public charging points in the European Union by that time.

Another also very optimistic forecast was performed by the “Nationale Plattform Elektromobilität” concerning the amount of charging infrastructure needed to reach the aim of 1 million electric cars in Germany by 2020. It was calculated that the number of charging points will need to be 0.9 million by that time.[494]This number includes private charging stations and charging stations on company grounds. Until 2014 the study gives concrete numbers about the number of charging stations in inner cities, suburbs, and surroundings. Of the forecasted 118,000 charging stations by that time, 43.6 percent are installed in inner cities, 35.8 percent are installed in suburbs and 20.6 percent are installed in

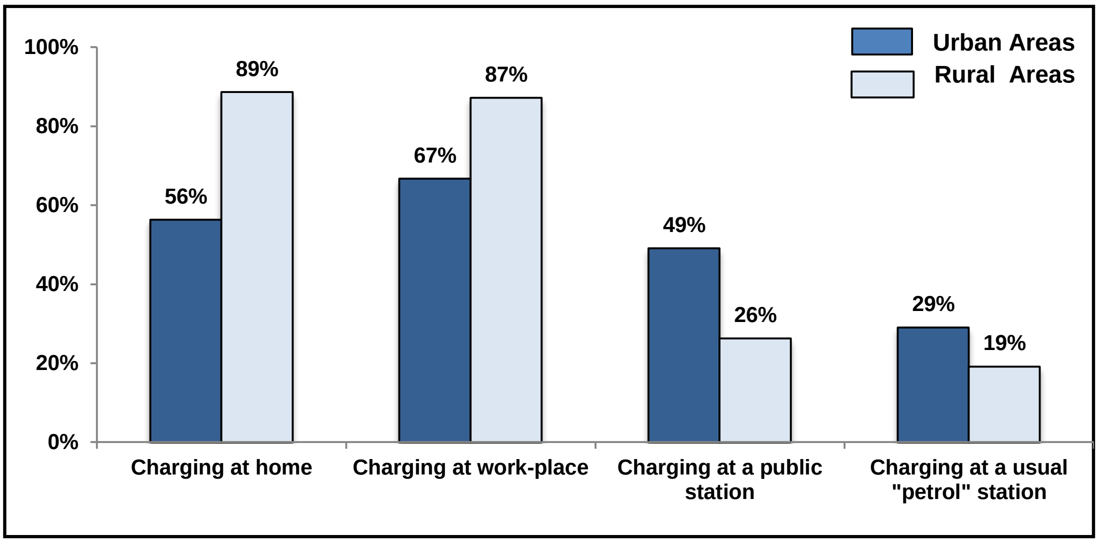
[488] Nationale Plattform Elektromobilität (2011)
[489] Nationale Plattform Elektromobilität (2011)
[490] Berenberg Bank/HWWI (2009)
[491] Berenberg Bank/HWWI (2009)
[492] Frost & Sullivan (2011b)
[493] Deutsche Stiftung Weltbevölkerung (2011)
[494] Nationale Plattform Elektromobilität (2011)

the surroundings of cities. 19,495 charging stations are estimated to be public. For the following two benchmarks (2017 and 2020) no numbers apart from the cumulated number of charging points are given. Still, the study presents bar charts showing the development of the percentage of charging points in relation to their location (private/company/public) in the three geographical areas. Assuming that the distribution of the charging stations in the geographical areas stays on the same level as 2014, by 2020 roughly 290,000 public charging stations are forecasted for the German market or 0.00354 public charging stations per German citizen. By extrapolating this number to the largest 11 European economies, which account for 72.8 percent of the EU-citizens, and adjusting it by 0.5 for the rest of the European Union, the total number of public charging stations is expected to be about 1.79 million by 2020.

Both of the presented scenarios are judged to be very optimistic and have only been presented to give an impression about the huge divergence in the research in this particular field of study. A more conservative approach has been performed by the Berenberg Bank in co-operation with the German “Hamburgisches Welt WirtschaftsInstitut”. This study extrapolates the possible number of public charging stations in Germany to 10,000 by 2023. By using the same restrictions as before (same percentage for the largest 11 EU-economies / adjustment factor of 0.5 for the rest) the total number of charging stations in the European Union can be extrapolated to 53,350 or 0.053 million.

This scenario is similar to the results of a survey performed in Cologne and surrounding cities in 2011 by the Chair of General Business Administration & International Automotive Management (Prof. Dr. Heike Proff) of the University of Duisburg-Essen. About 2,600 citizens in six cities or rural districts in and around Cologne have been questioned (900 of those in Cologne) about their preferences concerning several issues which are of high importance for the transition to electromobility (see Figure 56). One of these important issues is the preference (concerning the location to recharge an electric vehicle. After 2020 a technological breakthrough in the battery-technology can be expected. Zinc-air-, lithium-sulphur- and lithium-airbatteries are the main fields of research, concerning electrodematerials of future generations of batteries for electric vehicles.[495]

Figure 56: Preference Concerning the Location to Recharge an Electric Vehicle
(Multiple answers possible)



(Source: Own Research)

The study found out that while 56.3 percent of the questioned Cologne-citizens would charge their vehicle at home and 67 percent would recharge their vehicle at their working-place, only 49.1 percent consider a public charging station as attractive and even less citizens (21.3 percent) would use a service comparable to today’s petrol stations. The same trend has been detected for the other cities in which the survey has been performed. The willingness to use public charging stations differs within the range of 39.2 percent in Bochum and 56.2 percent in Duisburg. On average only 46.05 percent of the questioned citizens in cities close to Cologne consider the occasional use of public charging stations as attractive, while 54.2 percent would prefer to charge their vehicle at home and 62.65 percent reported they would use charging stations at their workplace. In rural areas this trend is even clearer, as

495 Nationale Plattform Elektromobilität (2010)

in the county of Wesel where only 26.3 percent of the questioned citizens' found public charging stations attractive, while 87.2 percent would utilise the possibility to charge their vehicle at their workplace and 88.5 percent would charge their vehicle at home. This deviance can be explained by the higher percentage of citizens who own their own house in rural areas.

The survey asked citizens if using charging stations at the several presented locations would be possibly attractive for them. Therefore double answers were possible. It is assumed, that not each citizen for which the use of one of the charging locations is hypothetically attractive, would in fact use such an offer at all or at least not necessarily frequently. For the providers of public charging stations the number of users who are likely to use their offers on a regular basis is of high importance, as only such users make the installation of charging stations – especially in residential areas – an economical attractive business. The cumulated percentage values of the analysed returned answers lie between 189.3 percent (Dortmund) and 221.2 percent (county of Wesel) - Cologne's cumulated percentage value sums up to 193.0 percent - and therefore roughly around 200 percent. To perform an approximation about the necessary number of public charging stations in the analysed areas, the percentage values are therefore divided by two, as each user has on average given two answers but is not likely to recharge an electric vehicle more than one time a day, given the average driving distance of about 43 km per day. Therefore about 25 percent of the questioned citizens are likely to use a public charging station on a regular basis (assuming that until 2030 most electric vehicles will be sold and used in urban areas). As it is likely that some users who would not use public charging stations on a regular level would still use public charging stations on the weekend or on a non-regular basis (e.g. when visiting friends in other cities) it is assumed that on average 30 percent of all electric vehicles would be recharged at public charging stations on a normal day. It is assumed, that this number is representative for the whole European Union.

Using the number of electric vehicles that have been calculated for the European Union, this would mean, that by 2020 public charging stations for roughly 284,000 electric vehicles (BEVs) with 25 KW, for 0.33 million Range Extenders (15 KW) and for 0.78 million Plug-In-Hybrids (6 KW) would have to be installed in the European Union. By 2030 this number will have grown to about 3.3 million BEVs, 0.83 million REEVs and 6 million PHEVs.

From today's perspective it is very difficult to estimate how long an average charging process of an electric vehicle at a public charging station will take, as it cannot be predicted with any certainty which technology will prevail in the long run and when those technologies will prevail. Therefore it is assumed, that the wider roll-out of the first generation of public charging stations will take place at a time, when the average charging process to recharge the battery of a BEV (25 KW) at a public charging station will take about 2 hours to perform. For 2020 this time is the basis for the calculation of the necessary number of public charging points. For 2030 it is estimated, that the time to recharge a battery will have decreased significantly and the batteries of the new generation of electric vehicles will be able to cope with superfast charging technology (this technology will be further explained in the following Section 4.4.4.2). As charging stations with the "old" technology will still be in use by 2030, the average time to recharge an electric vehicle (BEV, 25KW) at public charging points is assumed to be about 1 hour.

As by 2020 the recharging process of a 25 KW battery will take about 2 hours, the recharge of a 15 KW battery (REEV) will take about 1.25 hours and the recharge of a 6 KW battery (PHEV) will take about 0.5 hours. This leads to an average charging time of 59 minutes for the 1.394 million electric vehicles, which are likely to use public charging stations in 2020.

A public charging station is not likely to be in use 24 hours a day but will be unoccupied for a certain time period per day. Today, there is no legitimate data about the use of public charging stations available, as electric vehicles are still very rare. To calculate the number of public charging stations necessary to satisfy demand, it is assumed, that in the time between 8 a.m. and 10 p.m. a public charging station faces an unoccupied time of 15 minutes between the charging processes. At night, between 10 p.m. and 8 a.m. an average of only 2 users is estimated to use the possibility to recharge their vehicle. These assumptions would lead to 8.2 users a day per public charging station and to 170,000 public charging stations in the European Union by 2020.

By 2030 the average time to recharge an electric vehicle will have decreased significantly to 31 minutes. Using the same assumptions as before for the time between 8 a.m. and 10 p.m. and assuming five instead of two users for the time between 10 p.m. and 8 a.m., the number of users per public charging station can be calculated to 23.6 users a day. This would lead to a demand of about 429,000 public charging stations in the European Union by that time. The presented numbers are to be seen as a very rough approximation and are strongly correlated to the technological and user behaviour development concerning the charging technology.

The roll-out of an area covering public charging infrastructure is rather hard to perform, as it holds a high economical risk and is insecure in relation to its technological implementation. While users can charge their cars at home without facing major problems or costs and may also be able to charge their car at their company's or at semi-public charging stations (e.g. supermarkets) in the near future, users who live in inner cities and therefore – in most cases – do not possess their own parking place are dependent on the availability of public charging stations. An example of a company which has already started the installation of public charging stations is the RWE AG (see Box 20).

Box 20: Charging Stations, Example of RWE

As of today RWE has already installed about 700 public charging stations in Europe, most of these in Germany. RWE, being one of Germany's largest energy providers uses its know-how in the energy field to access new fields of business. RWE only installs and operates the charging stations when they are produced by a supplier (Rohde & Schwarz) and therefore concentrates on its core competences.

(Source: RWE 2012b; Rohde & Schwarz 2009)

One possibility to avoid the installation of a great number of public charging stations (as it has been described in Section 4.4.4.1) would be the instalment of superfast (or high-power) charging points at existing petrol-stations. To recharge a battery of 25 KW in 6 minutes, the chargers would have to be able to provide about 250 KW. The main technological problem concerning superfast charging stations is the ability of the battery and the vehicle to handle the high degree of energy flow in such a short duration. While batteries that are able to cope with such high energy flows have already been tested at the laboratory level and it is also believed that vehicles could handle the extreme influx of heat through the installation of cooling and protection systems (costs: about 2,000 Euro), it is not believed, that superfast charging infrastructure will be available in the next 5 to 10 years. However, in the years after 2015-2020 a wider roll-out of superfast charging stations seems possible and is very attractive, especially due to the long driving distances which become – given reasonable recharging times – possible with the installation of these charging devices.[496] Before such a roll-out of superfast charging stations can be realised, many technological hurdles have to be conquered. The main problem today is that the lifetime of batteries from electric vehicles is reduced significantly if those batteries are frequently recharged by superfast charging devices.[497] Therefore the research in this field is strongly correlated with the research in the field of battery development which has already been described in detail previously.

The interviewed experts (72 percent) judged the development and installation of charging infrastructure as an important future business model with a rising market share of electric vehicles. Furthermore 65 percent of the interviewed experts think that the main focus of the monetary promotions given by the several governments, as well as by the EU itself, to promote the transition to electromobility in the EU, should be to invest in infrastructure development. In comparison, 37 percent of the interviewed experts think that the focus of the monetary promotions should be on the production, and only 32 percent on the development of new propulsion concepts.

The majority of the experts interviewed emphasised that the charging infrastructure will be an important business model in the future. Korean experts underline: "Charging infrastructure will definitely succeed; that´s clear!" or "Many Korean business companies (e.g. SK) plan to go into this business in the future, government should support building infrastructure first!" Across boundaries, most of the experts expect a high market potential. The market potential is also evaluated positively by the European experts, in whose answers are noticeably less euphoric in comparison to the Asian experts, especially by the European manufacturers: "That´s a very interesting question, but presently most of the energy providers consider this business as unattractive!" or "Until now, we have not identified an attractive business model!" Nevertheless, an expert from the United States emphasises that infrastructure will make or break electromobility, since it gives the consumer a spatial independence.

[496] Roland Berger (2009a)
[497] Hohberg, et.al. (2010)

4.3.4 Recycling of Batteries from Electric Vehicles

After 2020 a technological breakthrough in battery-technology can be expected. Zinc-air, lithium-sulphur and lithium-air batteries are the main field of research, concerning the electrode materials of future generations of batteries for electric vehicles.[498] Nevertheless the new, more efficient batteries share common raw materials with today's BEV batteries which are therefore of strategic relevance for the transition to electromobility. Another aspect is that the batteries currently used in electric vehicles can be used in the electricity grid to e.g. store energy of wind power plants. Fact is, is that the car-makers of current electric vehicles such as Nissan or Renault provide a warranty of 5 years for a maximum driving range of 100,000km. As these batteries have a longer service life then 100,000km (experts state a battery lifetime from 350,000km to 500,000km), they can be used as energy storage in the electricity grid after their use in electric vehicles.

Box 21: Second Life Use of Electric Vehicles Batteries

In the US the companies Nissan, ABB, 4R Energy and Sumitomo Corporation are evaluating and testing the propulsion battery of the Nissan LEAF for a second life use as energy storage in the electricity grid.

Furthermore, Honda developed a method for the extraction of rare earths from used products. The aim of Honda is recycling of valuable resources. Firstly, the method will be used in nickel-metal hydrid batteries that come from used Honda hybrid vehicles which are taken back from dealers. It is planned to expand the process to other used parts. Honda had previously handled used nickel-metal hydride batteries with heat treatment in order to recycle nickel-containing waste as a raw material for use in stainless steel. With the new procedure, the extracted rare earths are now as pure as newly mined raw metals. The newly developed method series allows the extraction of about 80 percent of the rare earth elements, which are contained in used nickel-metal hydride batteries. The recycled metals will not only be used in new nickel-metal hydride batteries, but also in other products.

(Source: Smartgridnews 2012; Honda 2012d)

The German "Nationale Plattform Mobilität" believes that by 2020 the most important technological solutions towards the development of an area covering battery collection and recycling systems will have been developed and implemented. By this time the upscaling of recycling facilities on an industrial level will have also taken place and will operate economically.[499]

This development will help to secure the supply of the rare materials to participants in the European Union. The German environmental ministry in co-operation with experts from the Lithorec and the Libri-project analysed that in the near future the percentage of recaptured material from electric vehicle batteries will be about 60 percent for lithium and about 85 percent for cobalt. The realised collection quota of discharged batteries from electric vehicles is assumed to be at a level of 95 percent (assuming that only about 5 percent of electric vehicles which were newly registered in the Europe will be recycled in countries which are not part of Europe). This study, assuming these applications, estimates that by 2050 about 17 to 23 percent of the European market demand for lithium will be satisfied by recycled material. For cobalt this number is even higher, expectations are assumed to reach about 33 percent by that time. In this context it has to be mentioned that this number does not only refer to the automotive industry's demand, but to the total demand.[500]

In addition to the technological developments, other challenges will have to be met in order to secure the economic feasibility of the roll-out of an EU wide battery collection and recycling system as well as to the supply the automotive industry with the necessary raw materials.One of these challenges is the implementation of regulations concerning the export of vehicles to non-EU countries. Today about 30 percent of all vehicles newly registered are not recycled in inner-European markets.[501]However, it is believed that this number will not apply for electric vehicles in the close future, due to the fact that

[498] Nationale Plattform Elektromobilität (2010)
[499] Nationale Plattform Elektromobilität (2010)
[500] Umbrella (2011)
[501] Umbrella (2011)

most vehicles are exported to developing countries and regions (e.g. Africa), in the long run this development could be a threat to the security of secondary material supply in the EU.

Due to the described technological breakthrough after 2020, agreements on the technological development and the used raw materials in batteries will also become necessary in the upcoming years. R&D concerning the improvement of the recovery rates in recycling processes as well as the degree of capacity utilisation will especially become more effective and economic if suppliers and OEMs can agree on a similar type of battery. The recycling and disposal of batteries is believed to be one of the most important new business fields in the transition to electromobility. 85 percent of the interviewed experts judge the development of recycling processes as a key challenge in the next few years. They believe this development to be even more important than the developments in the fields of infrastructure, car sharing, or maintenance.

Services like recycling and disposal are considered as very important by the European and U.S. experts interviewed. Due to the dependency on raw materials (see Chapter 3.2.5.1) most of the experts interviewed emphasise a great market potential in the field of recycling. Furthermore, second life applications of batteries are expected to become very relevant. For example, an Asian public policy maker stated: “Disposal and recycling will become an attractive independent business model!” While the U.S. and Asian experts interviewed consider that services associated with infrastructure will gain importance, the European experts rather assume the areas of recycling/disposal will become more relevant.

4.4 Forecast on the Evolution of the Value Added in the EU Automotive Service Market

The following chapter analyses the evolution of the value added in the EU automotive service market until 2030 (see Figure 57). The service sector does not only include the services which have already been discussed such as:

- Maintenance and repair (as part of the “After Sales Market”),
- Car sharing (as an important “Mobility Service”) and
- Charging infrastructure and recycling as additional services especially linked to electromobility.

Furthermore, the following services exist, but they are less influenced by electromobility:

- Services in the after sales market like trade of motor vehicle parts and accessories
- Mobility services like car rental and
- Trade of motor vehicles (which accounts for the majority of both total turnover and value added in the service sector)

In the sector “trade of motor vehicles” we assume that the revenues will increase by 2020. Since the EU new vehicle registrations will remain stable until 2020 (see Chapter 2.3.1.1), we expect a moderate increase in the total turnover to 825 billion Euro. The value added in trade of motor vehicles will decrease until 2020 amounting 65 billion Euro.[502] Due to saturation in the EU-27 new vehicle market, we expect a decline in the profits concerning new vehicle sales trade. The profit margins are expected to continue to decrease from 3 to 4 percent in 2011 to less than 1 percent in 2030, while the personnel costs are expected to remain stable from 2020 to 2030. Altogether, we expect a decrease of value added in 2030 to 52 billion Euro (see Figure 57).In 2030, a small and hardly calculable part of this value added will be contributed by the trade of electric vehicles.

In 2011, the automotive aftermarket[503] realised a total turnover of approximately 169 billion Euro (see Chapter 4.3.1). **In 2011, the EU automotive industry generated value added at factor costs amounting 42 billion Euro in the aftermarket.** The forecast on value added at factor cost aftermarket in 2020 and 2030 is based on the total turnover, which has been projected in chapter 4.3.1.

[502] The value added at factor cost is calculated in the same way as the value added in manufacturing of motor vehicles, see Appendix II [methodology]

[503] Including maintenance and repair and sale of motor vehicle parts and accessories

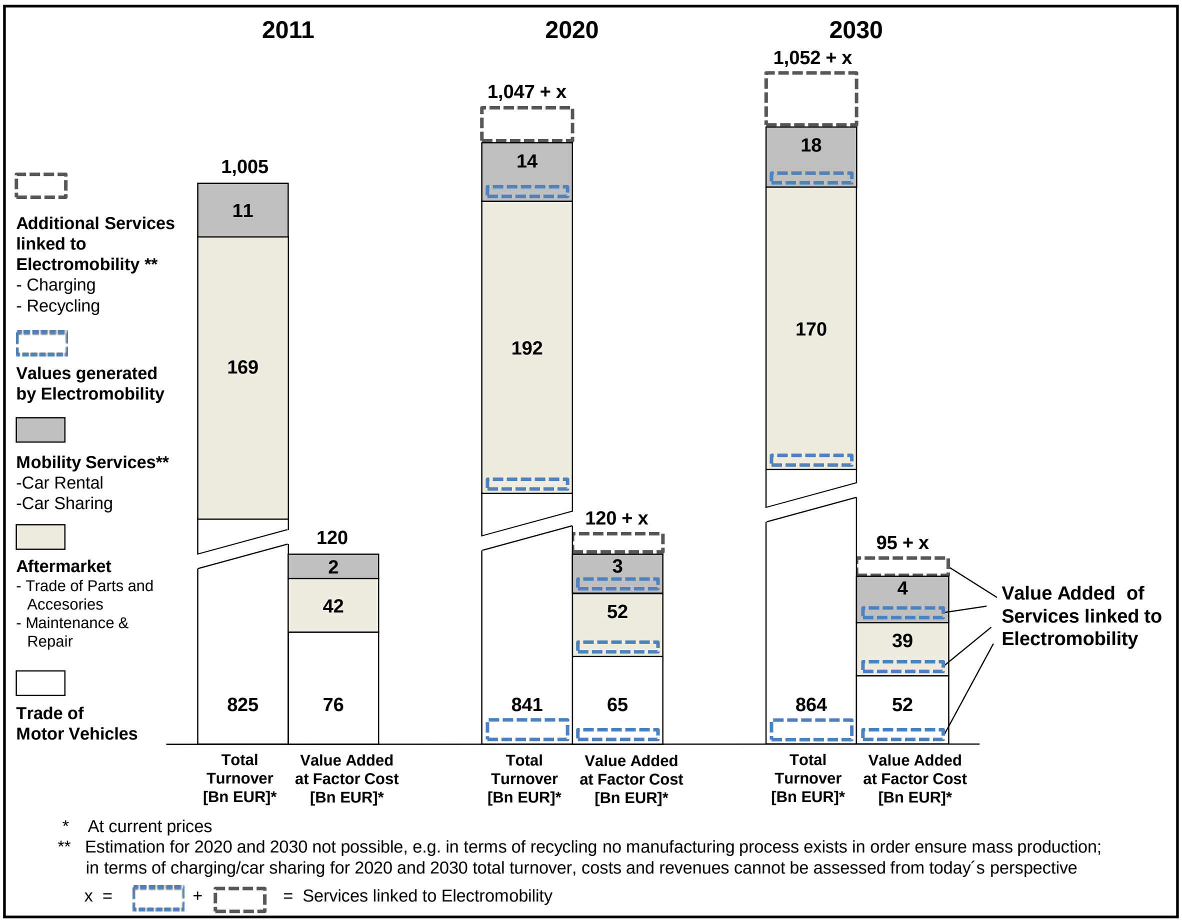
In 2020 a total turnover of approximately 192 billion Euro can be generated in the EU aftermarket. Due to education, training, and an increasing complexity[504] in the field of maintenance and repair in the short and medium term, the personnel costs will rise until 2020. **Overall, a value added at factor cost of 52 billion Euro can be achieved in 2020. Due to decreasing revenues in the aftermarket from 2020 until 2030, we expect that the value added of factor cost will fall from 2020 to 2030. Due to less employment in the field of maintenance repair, the personnel costs are expected to fall. Altogether, a value added at factor cost of 39 billion Euro can be expected in 2030** (see Figure 57).A small, but hardly calculable part of the future value added in 2020 and 2030 will be contributed by electric vehicles, particularly in the field of maintenance and repair, but the trade of parts and accessories for electric vehicles will also make a contribution.

Presently, mobility services mainly cover car rental and car sharing. Since car sharing has recently been gaining in importance in most of the European countries, a forecast on the current value added of mobility services can only be made based on the available data of car rental services. Car rental services reached a total turnover of about 11 billion Euro in 2011. The value added at factor cost amounted to about 1 billion Euro in 2011.The total turnover in the field of mobility services is expected to increase to 14 billion Euro in 2020 and 18 billion Euro in 2030. The value added of mobility services is expected to increase to 3 billion Euro in 2020 and 4 billion Euro in 2030, particularly due to the increasing market potential of car sharing (see Chapter 4.3.2 and Figure 57).

Concerning further services linked to electromobility (e.g. charging and recycling), an assessment on the development of value added is not possible on an aggregated level (EU-27). In terms of recycling no manufacturing process exists to ensure mass production. Therefore, both costs and revenues cannot be estimated reliably. Concerning charging infrastructure, an estimation of future revenues is not possible from today´s perspective. Experts interviewed confirmed that these markets will develop very differently in the EU. Therefore, both future revenues and costs cannot be estimated on an aggregated level (EU-27).

[504] In the short and medium term both electric vehicles and traditional vehicle concepts need services in the field of maintenance and repair. The staff must be properly trained to provide additional tasks. In the short and medium term, the redundant services in terms of maintenance and repair of electric vehicles will not be able to compensate for the additional tasks, because the market share of these vehicles will be slight (see Chapter 2.3.2).

Figure 57: Forecast on Value Added at Factor Cost in Automotive Services



(Source: Own Calculation)

Altogether we assume that the value added in trade and repair & maintenance will decrease, while the value added in terms of mobility services, including car sharing and the additional services linked to electromobility (car sharing services and recycling), will contribute to additional value added in the long term. This trend is also shown in Figure 57.

4.5 Services linked to Electromobility – Conclusion

It can be concluded, that the overall market volume of the automotive service sector is likely to rise in the coming years, as the two automotive powertrains (traditional engine and electric battery) will develop and exist in parallel, making the installation of charging and service infrastructure for electric vehicles necessary, while still having to maintain the traditional petrol, gas and service stations. Other developments like the rising number of car sharers (benefiting from small electric vehicles to be used in city centres will increase this trend even further.

Basically, business models, like car sharing, will arise irrespective of a certain vehicle technology. In the field of electric vehicles, however, **new business models in car sharing services can be expected independently from existing providers (e.g. car sharing solutions offered by manufacturers or transport associations).** According to many studies, the market potential of car sharing will increase, especially in mega cities. Nevertheless, it should be emphasised, that the majorityof the Japanese and Korean experts, who have been surveyed in this study, do not expect that car sharing services will have success in their countries in the medium term, because Japanese and Korean consumers do not like to share their vehicles.

In terms of the **maintenance and repair** field, the majority of experts interviewed expect that in electromobility this field **will remain in the hands of manufacturers and their trade organizations, particularly due to their expertise, safety reasons, and specific guarantee regulations**. However, due to the decreasing complexity of maintenance and repair volumes, the majority of experts believe that the market potential and the resulting profits will decrease in the long term. In terms of achievable revenue and profits, maintenance and repair are very important business segments in the downstream area of the traditional automotive value chain. The profit margins of maintenance and repair are currently higher than the sales of new and used vehicles.

The recycling of electric vehicles will also be an important business model in the upcoming years. Experts interviewed judge the development of recycling processes for BEV batteries to recapture the several strategic relevant materials as being the highest priority of all developments in the transition to electromobility. As of today, services are the major profit pool in the automotive industry, it is of high importance – in addition to technological developments in the battery, powertrain and the power electronics field – to focus on the development of new business models in the service sector.

Regarding the new services linked to electromobility such as recycling, car sharing, and charging services, a market potential can be expected in the long term. This assessment has been confirmed by the expertsinterviewed for this study. We assume that the value added in trade and repair & maintenance will decrease, while "new services linked to electromobility" will contribute to an additional value added in the long term.

5 Public Policy Framework

It has been quite clear from the beginning of electromobility that public policies will play a key role in order to accelerate the market penetration of electric vehicles, particularly due to the high initial investment costs and related public policy issues such as e.g. emission regulations in urban areas.

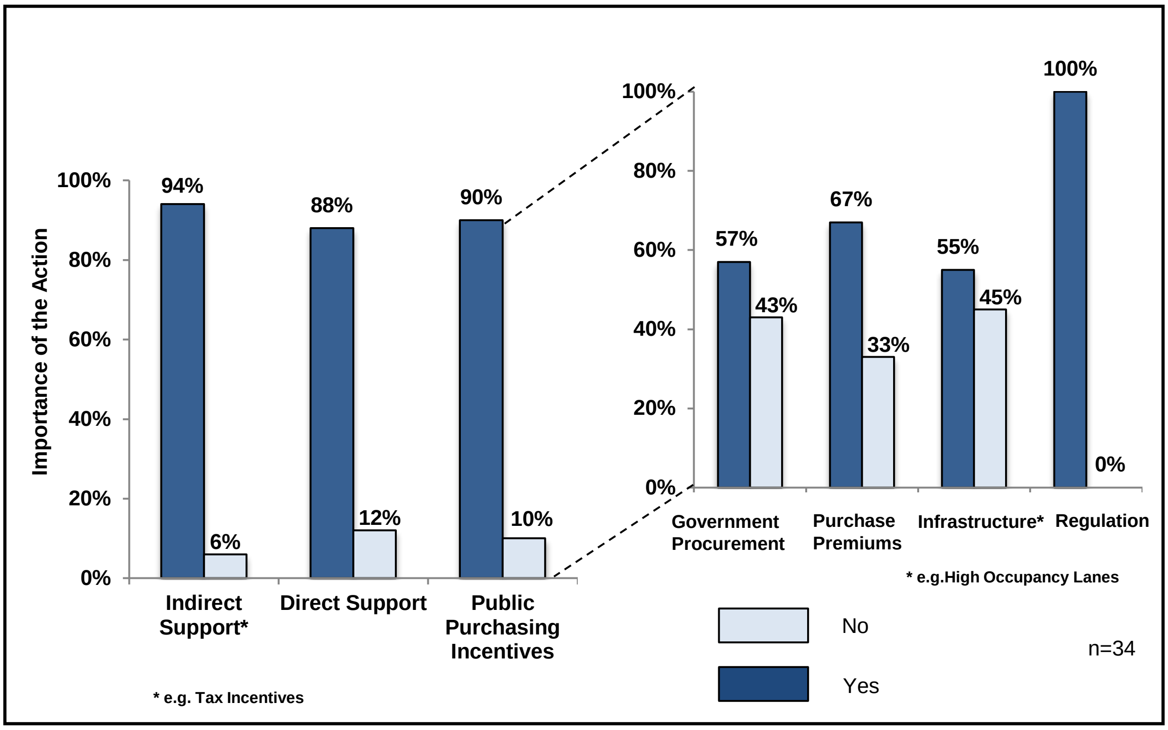
Depending on the objectives and time horizon, public policy can put different measures in place in order to promote a disruptive technological change, such as electromobility:

- indirect technology support (e.g. tax incentives)
- direct technology support (e.g. grants)
- public purchasing incentives

Apart from direct and indirect support, public policy makers can stimulate the market by offering public purchasing incentives, e.g. in terms of public procurement, purchase premiums for private customers,non-financial incentives (e.g. use of high occupancy lanes in the inner cities) and regulations.

Chapter 5.1 provides an overview on the current public policy framework in the EU compared to the U.S. and the Asian countries of Japan, Korea, and China. Figure 58 shows the results of our survey concerning the desired future tasks for public policy by experts interviewed. It becomes obvious, that the majority of experts consider all forms of public policy as relevant and that all these forms of support need to represent a consistent strategy. More specifically, future regulatory needs are discussed in chapter 5.2.

Figure 58: Future Tasks of Public Policy in Transition to Electromobility



(Source: Own Compilation according to Expert Interviews)

Finally, experts interviewed agreed that electromobility is a technological development which required further effort on awareness raising especially for potential consumers. There is a need to inform consumers in order to obtain acceptance and to stimulate customers' interest (see Chapter 3.2.5.5).

5.1 Current Public Policy Framework
5.1.1 Public Policy Framework of the EU Member States

The **German** government provided 500 million Euro (2009-2011) out of the second rescue package for initial research to academia, industry, associations, and local authorities. A joint consortium, the National Electric Mobility Platform, aims to promote electromobility, related technology requirements, infrastructure and raise public consciousness. The German government decided to provide an additional 1 billion Euro to the program until the end of the legislative period. Initial infrastructure is building up in eight metropolitan model regions. There is no buyers' incentives planned for the purchase of EVs but the vehicle tax will be waived for a period of 10 years and many disadvantages for EV company cars were abolished.

The **French**government provides consumers with a 5,000 Euro discount for purchasing low-emission vehicles. Electric and hybrid company cars are not subject to tax. Loans for innovative R&D projects are provided by the Fonds Stratégique d'Investissement (FSI). Between 2009 and 2010 funds for initial R&D (107 million Euro) were provided. By 2020 4 million private and 400,000 public charging points are planned to be installed (compare Table 36).

Table 36: EV-related Public Activities of selected Countries of the European Union (1/2)

Item	Germany	France
Financial incentives & taxation	No buyers' premium planned for the purchase of an EV.[3] 2009-2011: 500 million Euro provided to promote electromobility (out of the second rescue package).[2] Introduction of a vehicle tax waiver for the period of 10 years for vehicles producing ≤ 50g of CO2. Taxation disadvantages for EV company cars will be abolished.[3]	Consumers receive a 5,000 Euro-check by the French government for buying a vehicle producing ≤ 60g of CO2. In 2011 the French Ministry of Environment coordinated the delivery of 50,000 electric vehicles to 20 large private and public companies.[1] No company car tax applies for EVs and Hybrids.[9]
Research financing	Additional R&D funds of 1 billion Euro provided until the end of the legislative period.[3]	The program of research, experimentation and innovation in land transport (PREDIT) of the Environment and Energy Management Agency (ADEME) financed EV research projects worth ca. 107 million Euro (2009-2010). The state controlled Fonds Stratégique d'Investissement (FSI) provides loans for innovative R&D projects.[1]
Infrastructure	Eight metropolitan model regions are established, financed through the second rescue package. Demand for *public* charging stations is considered low in the (current) first phase of market ramp up. Most consumers are expected to charge their EVs at home. The German government supports R&D activities for inductive and quick charging technologies and encourages local authorities to establish charging infrastructure. The build-up of charging stations is seen a task of the private economy. Harmonised Smart-Grid standards on EU level are required.[4]	Short term plan: 1250 public charging stations to be installed by 2012 in 20 cities, investments: 60 million Euro Mid- and long term 900,000 private and 75,000 public charging points shall be installed (by 2015); 4 million private and 400,000 public charging points by 2020. Local administrations are involved in EV infrastructure projects, stimulating sales by increasing the EV share of their fleets and initiating car-sharing projects.[1]
Financial support of public authorities	In order to coordinate the interests of different stakeholders the government set up the National Platform for Electric Mobility (NPE) to establish Germany as a lead market for eMobility by 2020.The German government plans to buy EVs for their official fleet.[3]Close cooperation with	The Ministry for Ecology, Sustainable Development and Spatial Planning subsidises buying EVs, sets legal standards, and formulates technical recommendations for infrastructures. The Environment and Energy Management Agency (ADEME) executes EV projects through calls for bids.[1]

	the Chinese government in the area of norms and standardisation, as well as between research institutes, firms, and local governments was initiated.[3]	
Consumer perception	High perception about EV and hybrids but low knowledge about battery duration and recharging time. Majority can imagine buying an EV, natural gas or fuel cell powered vehicle in the future at the price of conventional vehicles. Most favour recharging at home.[a]	Approx. 30% of French consumers show interest and consider purchasing an electric or hybrid vehicle driven by the environmental friendliness of these vehicles. Every fifth state lowers running cost as purchase motivation. On the contrary, the majority knows little about EVs or hybrids. The willingness to pay a premium is low[b]

(Source: Colling et al. 2010[1]; Koskue 2010[2]; BMWI 2012[3]; Bundesregierung 2011[4]; Proff/ Fojcik 2010 [a]; EurotaxGlass 2011 [b]; ACEA 2011c[9])

Since January 2011 hybrid and EV buyers in the **United Kingdom (UK)** receive a discount of 2,400-6,000 Euro. Vehicles taxes were recalculated based on CO2 emissions, thus for EVs and hybrids they are rather low. 170 million Euro are provided by the government for EV-related R&D activities. Initial infrastructure is established in three metropolitan areas, so-called “EV hubs”, supported by ca. 36 million Euro of governmental funds, featuring 11,000 recharging points.

The **Italian** government approved to co-finance EV-related R&D projects of up to 50 percent. EV buyers pay no ownership tax for the first five years after registration. Afterwards, the tax is reduced by 75 percent compared to conventional vehicles. Electromobility pilot projects operate in bigger cities but large scale infrastructure development has not started yet. Funds of 380 million Euro are provided to local authorities to engage in and promote projects relating to infrastructure and eco-friendly mobility.

In **Spain**, local government grant a 2,000-7,000 Euro discount on the purchase of an EV. Municipals buying EVs receive a 20 percent subsidy. The government initiated and financially supports the “Movele” program (2008-2011) to assist in initial infrastructure and promoting sales of EVs in three selected cities (Barcelona, Madrid, and Seville). By 2014 charging points will be installed in homes, for company fleets, at public parking places and at road sides (compare Table 37).

Table 37: EV-related Public Activities of selected Countries of the European Union (2/2)

Item	UK	Italy	Spain
Financial incentives & taxation	Point-of-purchase grants of 2,400-6,000 Euro for private and business fleet buyers from January 2011 onwards.[5] Several vehicle taxes for new cars are calculated based on CO2 emissions (in g/km), resulting in low taxes for EVs.[7]	No annual ownership tax for five years from the date of first registration. After five years, 75% reduction of the tax applied to comparable petrol vehicles.[9]	Several local governments grant tax incentives of 2,000-7,000 Euro for the purchase of EVs and other eco-friendly vehicles.[9]
Research financing	The UK Government provides 480 million Euro in total, of which 170 million are provided to market player for R&D activities into “low carbon vehicles”.[5,6]	The Italian government approved support and co-finance of up to 50% of projects promoting electromobility.[8]	140 million Euro for industrialization support and R&D; 173 million Euro to priority R&D lines.[10]
Infrastructure	Charging infrastructure is not a core activity at present. [5,6] However, the Office for Low	Pilot projects are operated in bigger cities. Recharging infrastructure build-up has not started	The government initiated Movele program (2008-2011, investments ca. 10 million

	Emission Vehicles (OLEV) provides 36 million Euro for three EV hubs (in Milton Keynes, London, and the North East),and plan to install 11,000 recharging points. Those three locations shall provide experience for future developments.[5]	yet.[8]	Euro) targeted the ramp up of infrastructure and dispersion of EVs in Barcelona, Madrid, and Seville. Amount of charging points to be achieved by 2014: 62,000 in homes, 263,000 for company fleets, 12,150 public parking and 6,200 public road-side charging points.[10] 35 million Euro investment in electric grid-related communication systems.[10]
Financial support of public authorities	The UK government is supporting several initiatives such as setting up three EV hubs in the UK, or working with the Energy Technologies Institute (ETI), private businesses, and local governments on standards and infrastructure projects.[5]	380 million Euro are made available by the Italian government for local bodies to spend on projects relating to infrastructure and eco-friendly mobility.[8]	For municipalities with ≥ 50000 inhabitants (= 145 cities) 20% subvention for the purchase of EVs (6000 Euro max/ unit), i.e. 240 million Euro in sum.[10]
Consumer perception	Consumers may be hesitant to buy EVs because of: high purchase price, lack of charging facilities, concerns towards the battery.[5]	As Italians drive on average 37km/ day with an average speed below 50 km/h, consumer behaviour suits well for EV use. Italians are enthusiastic about EVs compared to other countries. The strongest factor against EV acceptance is a yet underdeveloped charging infrastructure.[8]	Private consumer interest in EVs is currently low, due to high purchasing cost, low vehicle autonomy, recharging models and battery issues. Fleets are seen as an initial market driver.One handicap of Spain is that all car producers have their decision-making headquarters outside of Spain.[10]

(Source: Kontio-Blunt/ Salonen 2010[5]; Agentshap NL 2011[6]; Directgov 2011[7]; Olivieri 2010[8]; ACEA 2011c[9]; Finpro 2010[10])

It is clear that both the EU as whole[505] and individual Member States already engage in wide-ranging policy initiatives in support for electric vehicles. In the field of direct technology support, all five major EU member countries support research activities. The EU as such has also engaged in major research projects. As for indirect support, it is also noteworthy that the countries offer incentive mechanisms one way or another. In the EU-level European Green Car Initiative, for instance, public-private partnerships are encouraged. In the field of public purchasing incentives, a similar range of activities can be noted. Regulatory activities to achieve standardisation and interoperability on the European level are particularly noteworthy, and further action on this is being recommended or prepared. For instance, all five Member States studied offer “infrastructure” (e.g. use of high occupancy lanes) support. There are somewhat more notable differences in terms of purchase premiums or support. France and the United Kingdom in particular support consumers with large purchase discounts ranging up to 6,000 Euro per vehicle, whereas Germany is not planning to offer such a discount. The EU itself also does not support consumers through purchase related instruments. An important element for the EU-level is to provide regulatory type-approval framework guaranteeing safety of vehicles.

[505] European strategy for clean and energy efficient vehicles from 2010 and CARS 2020 Action Plan from 2012.

The overall picture is can be considered as fairly heterogeneous when considered in detail. While some similarities or even overlaps of direct and indirect research support between countries and between the EU level and Member States cannot be excluded, there are also some stark differences; for instance in terms of public purchasing incentives..

5.1.2 Public Policy Framework of the U.S.

Following the rapid increase of the oil price in the years preceding the world financial crisis, the United States has begun to initiate support policies for electric vehicles. While consumer preferences were in favour of large vehicles and the three large automakers vigorously lobbied against stricter emission standards, the federal government was slow to enact legislation that would create sufficient incentives for manufacturers to devote serious resources to the development and commercialisation of electric vehicles. While high fuel prices had depressed the demand for less economic vehicles, it was the global financial crisis that brought an opportunity to promote electric vehicles. When car sales dropped substantially in 2008 and again 2009, the "big three" were at the brink of collapse. In a departure from past practice, the Obama administration sought to increase fuel efficiency and reduce greenhouse gas emissions of road vehicles by raising standards.

As in the European Union, the Public Policy Framework of the U.S. is rather complex when it comes to federal programs as well as individual state-level programs.

Ad 1: Federal Programs

On the federal level the government passed a series of economic stimulus measures to put 1 million PHEVs and EVs on U.S. roads by 2015. In this context, 14.4 billion dollars have been dedicated to the development and commercialisation of PHEVs which were considered the optimal solution to achieve emission reductions under prevailing technical and financial constraints (see Table 38 for details). [506]

Table 38: Support for Electric Vehicles contained in the American Recovery and Reinvestment Act

	Million USD
Innovative Technology Loan Guarantee Program	6,000
Advanced Battery Manufacturing Grant	2,000
Plug-in Vehicle Tax Credits	2,000
Advanced Energy Investment Manufacturing Tax Credits	1,700
Automobile Purchase Sales Tax Credits	1,700
Infrastructure/Vehicle Deployment	400
Federal Purchase of High Efficiency Vehicles	300
Clean Cities Program	300
Total	14,400

(Source: Based on Zhang, F./Cooke, P. 2011)

In order to stimulate the consumption of electric cars, the federal government has initiated various schemes that provide **tax credits** to businesses and private consumers who purchase electric cars.

The American Recovery and Reinvestment Act (ARRA) of 2009 introduced federal government tax credits for sales of PHEVs – defined as "a vehicle which draws propulsion energy from a traction battery with at least 4 kWh of capacity and uses an offboard source of energy to recharge such battery".[507] Pursuant to ARRA, buyers of passenger or light duty vehicles with a gross weight of up to 14,000 pounds became eligible for tax credits worth $ 2,500. Additional deductions of $ 417 for every kWh of battery capacity that exceeded the minimum threshold of 4 kWh were introduced as well. The

[506] Zhang/Cooke (2011), p. 14.
[507] Internal Revenue Service (2009)

maximum tax credit per vehicle was set at $7,500 which implied that the initiative did not provide purchasing incentives for vehicles with batteries of more than 16 kWh. Based on these conditions, the Chevrolet Volt and the Nissan Leaf both qualify for the maximum tax credit of $7,500. Under the auspices of this program, which aimed at PHEVs sold after December 31st, 2009, a minimum volume of at least 200,000 units per manufacturer is to be sold before incentives will be phased out.[508] Until the end of 2011, the federal government also offered a 10% income tax credit to support the conversion of conventional vehicles to PHEVs and BEVs. Before the program ended up to $4,000 of federal funds were provided for every conversion.[509]

The Environmental Protection Agency supports the use of on-board idle reduction devices by exempting them from the federal excise tax imposed on the retail sale of heavy-duty highway trucks and trailers. The same exemption applies to vehicles that had already been in use prior to the installation of such technology. To be eligible, related equipment must have been sold after October 4th, 2008 and needs to be approved by the EPA.[510] In order to promote the development and commercialisation of FCEVs, Washington has introduced tax credits for both FCEVs and liquefied hydrogen fuel. Buyers of light-duty FCEVs may benefit from a tax credit of up to $4,000. While purchases of medium-duty and heavy-duty FCEVs are supported as well, tax credits available are based on vehicle weight and are lower for these categories. This program is scheduled to expire on December 31, 2014.[511] In addition to sales incentives for vehicles, liquefied hydrogen fuel is subject to preferential tax arrangements as well. Buyers can claim a tax credit worth $0.5 per gallon, however they are liable for reporting it and must pay the federal excise tax on the sale or use of the fuel. The tax credits must first be taken as a credit against alternative fuel tax liability while remaining credits will be paid out by the IRS. Tax credits for liquefied hydrogen will be abolished on September 30, 2014.[512]

The Department of Energy has launched several initiatives and programs **to promote R&D related to vehicle electrification.** Initiated in 2010, the Batteries for Electrical Energy Storage in Transportation project (BEEST) conducts advanced research on battery technologies for BEVs and PHEVs. The project has ten focal areas which are aimed at increasing the performance and lowering the cost of rechargeable batteries to “enable EV/PHEVs to meet or beat the price and performance of gasoline-powered cars, and enable mass production of electric vehicles that people will be excited to drive”. Endowed with 36.3 million dollars of funds, BEEST is pursuing a bottom-up approach, gauging the optimisation potential of all major battery components to improve battery capacity, size, weight, rechargeability and cost.[513] Furthermore, several research institutes run or affiliated by the U.S. government are conducting research activities on electric drive technologies which will accelerate their commercialisation (see Table 39).

[508] Ibid.
[509] Plug In America (n. d.).
[510] United States Environmental Protection Agency (n. d.)
[511] Internal Revenue Service (2008)
[512] United States Department of Energy (n.d.1)
[513] Advanced Research Projects Agency (2010)

Table 39: National Laboratories and Research Institutes conducting Electric Drive Technology Research

Research Institute	Research Focus
Argonne National Laboratory	PHEV Technology Simulation, laboratory assessment and validation of PHEVs and related technologies Cost reduction, battery size and performance, durability, safety (Source: http://www.transportation.anl.gov/phev/index.html)
Idaho National Laboratory	PHEV charging Infrastructure Comparative assessment of energy consumed per kilometer/mile Support for the U.S. Department of Energy Advanced Vehicle Testing Activities (Source: https://inlportal.inl.gov/portal/server.pt/community/home/255)
National Renewable Energy Laboratory	Costs and benefits in comparison with PHEV technology Thermal management of batteries and enhanced power electronics Infrastructure planning and calculating for Plug-In vehicles Second-use research for batteries after usage in Plug-In vehicles (Source: http://www.nrel.gov/vehiclesandfuels/hev/)
Oak Ridge National Laboratory	Safety and reliability issues research on EVs Overcoming the initial premium price barrier as one of the major goals Domestic production of EVs in the U.S. Reduction of storage and charging equipment prices (Source: http://www.ornl.gov/sci/ees/transportation/)
Pacific Northwest National Laboratory	Integration of PHEVs including smart-recharging solutions Impact of EVs on the U.S. Power System in general Discovering special time windows for recharging (off-peak day times) Research on power grid outlets (charging stations) and their distribution (Source: http://eioc.pnnl.gov/)
Sandia National Laboratories	Batteries in various forms (double layer capacitors, thermal batteries, etc.) Power source research (Source:http://www.sandia.gov/bus-ops/partnerships/tech-access/facilities/battery.html)

(Souce: Own Compilation)

In the wake of the world financial crisis, the Department of Energy launched the **Advanced Technology Vehicle Manufacturing (ATVM) loan program** in November 2008 to support the development and production of fuel efficient high performance cars inside the U.S. The term ATV refers to light-duty vehicles or ultra-efficient vehicles with conventional internal combustion engines, as HVs and BEVs. The program was created to help auto manufacturers and component suppliers to finance up to 30 percent of the cost for "reequipping, expanding or establishing manufacturing facilities in the United States to produce ATVs or qualifying components or engineering integration performed in the United States for ATVs or qualifying components."[514] Since its inception, the program has closed loan arrangements with four automakers, in total worth more than 8.3 billion dollars, and has supported the construction of the first two manufacturing facilities for pure electric vehicles in the U.S. Its first project was the provision of 5.9 billion dollars in loans to the Ford Motor Company for upgrading its factories

[514] United States Department of Energy Loan Programs Office (n.d.)

across the U.S. and introducing fuel efficient technologies, including hybrid electric drive systems.[515] Fisker Automotive obtained 529 million dollars in loans for the development and production of two lines of PHEVs. Nissan North America received 1.4 billion dollars for manufacturing BEVs and constructing a battery production plant.[516]Tesla Motors benefited from a 465 million dollar loan arrangement enabling the company to reopen a plant for EVs and PHEVs production and to set up manufacturing facilities for battery packs, electric motors, and other powertrain components.[517]

Under the umbrella of the American Recovery and Reinvestment Act, passed in early 2009, the Department of Energy together with other government organisations, initated financial assistance programs that aimed for the development of electric vehicles and their commercialisation. Two individual schemes are particularly important, the Transportation Electrification Initiative and the Electric Drive Vehicle Battery and Component Manufacturing Initiative, released in March and May 2009 respectively.

The Transportation Electrification Initiative supported EV projects of companies, research institutes, and other organizations aiming for a timely market introduction and subsequent high volume production of electric cars and related technologies. It provided funding support to auto manufacturers (or teams led by automakers) for the development and production of small fleets counting at least 100 concept vehicles - BEVs, PHEVs or FCEVs. These cars had to be produced inside the U.S., meet vehicle safety standards and undergo extensive testing in real world operational scenarios in order to demonstrate a cost-performance ratio suitable for mass market penetration.[518] Overall, projects were expected to accelerate usage learning curves and production schedules to help the accomplishment of national electric vehicle goals for 2015. The Department of Energy planned to support 2 to10 projects with individual funding volumes ranging between \$20 and \$100 million. Once approved, projects were required to present their vehicles one year after being adopted into the program. Two years were scheduled for extensive performance evaluation with data becoming available through testing being fed back into the development process of the next generation of electric vehicles.[519]

The second program, dubbed Electric Drive Vehicle Battery and Component Manufacturing Initiative, provides grants supporting companies to build new or increase existing production capacities of advanced batteries and electric drive components as well as the components thereof. All companies are required to already possess advanced know-how in the area in which they apply for funding support and prove the existence of customers committed to purchasing their additional output volumes. Furthermore, companies have to demonstrate that they can meet customer requirements both in terms of output volume and technical specifications and ensure that production takes place inside the U.S.[520] Importantly, the program stipulates that capacity additions are realised in accordance with actual demand conditions from downstream industries. This is supported by encouraging teaming with established automakers, battery makers and electric drive component manufacturers. Furthermore, the program highlights the significance of large production volumes to help operations increase performance and reduce costs as they move through the learning curve. Output supplied in all five areas covered has to reach the quantities necessary for making 20,000 to 100,000 PHEVs annually. In total, \$2 billion in federal funds were made available to support capacity expansions in these five key areas.[521]The Transit Investments for the Greenhouse Gas and Energy Reduction (TIGGER) program initiated by the Department of Energy aims to reduce greenhouse gas emissions of public transit operations. The program encourages electric drive projects in the field of on-board vehicle energy management such as energy storage, regenerative braking, and fuel cells.[522]

The National Fuel Cell Bus Program, also administered by the Department of Energy, goes one step further and seeks “to facilitate the development of commercially viable fuel cell bus technologies and related infrastructure with funding awarded through a competitive grant process.” This program is targeting transit operators with expertise in managing hydrogen and fuel cell public transportation. [523]

[515] United States Department of Energy Loan Programs Office (n.d.)
[516] Id.
[517] Id.
[518] United States Department of Energy and National Energy and Technology Laboratory (2009a)
[519] Id.
[520] United States Department of Energy and National Energy and Technology Laboratory (2009b)
[521] Id.
[522] United States Department of Transportation Federal Transit Administration (n.d.)
[523] United States Department of Energy (n.d.2)

In order to **promote the construction of charging infrastructure**, the federal government has provided tax credits to private consumer and commercial car owners. Until early 2009, the construction of charging stations was rewarded with tax credits worth 10 percent (max. $1,000) of the related cost for private consumers and 30 percent (max. $30,000) for businesses. Following the approval of the stimulus bill in the spring of 2009, threshold levels were raised, allowing both private and commercial EV holders to deduct 50 percent (max. $2,000 and $50,000 respectively) of the costs for installing charging equipment. The program, which was originally due to expire by the end of 2010, was extended for another year but was eventually abolished effective December 31st, 2011. From January 1st, 2012, the government has reinstated the original values that were in force prior to the stimulus bill introduced in 2009.

The federal government especially supports the dissemination of hydrogen fuelling equipment with tax credits. Buyers can deduct up to 30 percent of the cost incurred (up to 30,000 dollars). Petrol station operators who install fuelling equipment at multiple sites may use the credit individually for every location. Private individuals who buy hydrogen fuelling equipment for residential use can benefit from tax credits of up to 1,000 dollars. This program is slated to be abolished by the end of 2014.[524]The Transport Electrification Initiative mentioned earlier offers funding support to projects engaged in the development and improvement of infrastructure required for the operation of electric vehicles. Infrastructure technologies covered by the program include “the integration of vehicles into an intelligent transportation system, optimisation of the vehicle and electric charging infrastructure, and establishing smart charging and grid interaction.”[525] The Department of Energy planned to support 2-4 projects with individual funding volumes ranging between 10 million and 75 million dollars. Projects were required to deploy their infrastructure technology one year after being adopted into the program. Following initial deployment, two years were scheduled for extensive performance evaluation in real world environments, including different geographical and climatic settings, to demonstrate that the technology is mature enough to meet actual demand conditions. In order to highlight the practical relevance and market orientation of the advanced infrastructure technologies developed under the program, participating companies have to demonstrate that they can either achieve commercialisation within five years of initiation or volume production within one year after the project’s end.[526]

Ad 2: Individual State-level programs

A small but growing number of individual states use public purchasing incentives via purchase premiums for electric automobiles. In most cases, state governments have agreed to cover a certain share of the sticker price up to a fixed ceiling. However, the maximum subsidies provided are not sufficient to compensate for the price premium of electric vehicles over conventional vehicles of the same performance type. It is important to note that in some jurisdictions, authorities do not practice differential treatment for purchases of new and used cars. While this move supports the second hand market and protects initial owners from a drop in resale prices, the likely shift in demand towards used vehicles might undermine incentives to buy new cars and negatively affect the sales prospects of carmakers. Furthermore, it should be pointed out that state governments have moved to support the installation of supply equipment and charging infrastructure under the same conditions available for car purchases. Interestingly, the measures described here are not exclusive to BEVs and PHEVs. Many state governments, such as in Illinois, offer the same degree of support to all alternative fuel vehicles, a category which is defined in much broader terms and includes gas powered cars and other non-electric drive technologies. Table 40 provides a detailed overview.

Table 40: Financial Incentives of Individual States

California	Purchase subsidies of $2,500 for BEVs and PHEVs and $1,500 for electric motorcycles and NEVs. The city of Riverside provides local residents with purchase subsidies for both new and used hybrid vehicles worth $2,000 and $1,000 respectively
Hawaii	Purchase subsidies covering 20% of the vehicle price (max. $4,500)
Illinois	Purchase subsidies of 80% (max. $4,000) of the price for alternative fuel vehicles
Maryland	Purchase subsidies $20,000 for all electric trucks

[524] United States Department of Energy (n.d.3)
[525] United States Department of Energy and National Energy and Technology Laboratory (2009a), p. 12.
[526] United States Department of Energy and National Energy and Technology Laboratory (2009a)

Ohio	Subsidies covering 80% of the cost of purchasing EVs
Oklahoma	Subsidies covering 50% of either the price premium of EVs and PHEVs or the conversion costs of conventional vehicles.
Pennsylvania	Purchase subsidies of $3,500 for PHEVs (battery 10 kWh or more) and BEVs (battery under 10 kWh) for the first 500 applicants Purchase subsidies of $1,000 for PHEVs or BEV (battery 10 kWh or less)
Tennessee	Purchase subsidies of $25,000 for the first 1000 EVs sold in the state

(Source: Based on Plug In America n. d.)

On the **state level, tax incentives** are the most common form of support for electric vehicles. A large and growing number of jurisdictions offer preferential tax arrangements for buyers and/or owners of electric vehicles (see Table 41). While states in the western United States have been the front runners in the past, the following table illustrates that jurisdictions located in the central and eastern parts of the country have caught up in recent years. Typically, the amount deductible is defined as a fixed share of the purchase price with a maximum amount fixing a ceiling.

Table 41: Tax Incentives Provided by Individual States

Colorado	Income tax credit of 75% (max. $6,000) of the price premium of BEVs or PHEVs
Georgia	Income tax credit of 10% (max. $2,500) of the cost for purchasing, leasing or converting to alternative fuel vehicles Income tax credit of 20% (max. $5,000) of the cost for purchasing, leasing or converting to zero emission vehicles
Hawaii	Income tax credit of up to 20% (max. $4,500) of the vehicle purchase price
Louisiana	Income tax credit covering 50% of the cost of purchasing or converting to a hybrid electric vehicle
New Jersey	Exemption from sales tax for zero emission vehicles
Michigan	Exemption from personal property taxes for EVs and PHEVs
Montana	Income tax credit of 50% (max. $500) of the costs for converting conventional vehicles to run on alternative fuels
Oregon	Income tax credit of 25% (max. $750) of purchase price BEV or conversion costs
South Carolina	Income tax credit of 20% of federal tax credits for PHEVs and BEVs
Utah	Income tax credit of up to $750 of the purchase price of BEVs and PHEVs. Income tax credit of up to $2,500 of the cost of converting conventional vehicles to BEVs and PHEVs
Washington D.C.	Exemption from excise tax for alternative fuel and fuel efficient vehicles Reduction of vehicle registration fees. Exemption from time-of-day and day-of-week restrictions and commercial vehicle bans
Washington	Exemption from the 6.5% sales tax for BEVs Exemption from the 0.3% motor vehicle sales tax for PHEVs
West Virginia	Income tax credit of 35% of the purchase price of BEVs and PHEVs. Income tax credit of 50% of the costs incurred for conversions to BEVs and PHEVs.

(Source: Based on Plug In America, n. d.)

Many states have introduced or passed legislation to institute non-monetary incentives for electric vehicle ownership. The most common form is access to dedicated **high occupancy vehicle lanes** (lanes reserved for vehicles transporting at least two passengers) on public roads. A total of eleven states have so far moved to allow HOVL usage (Arizona, California, Florida, Illinois, Maryland, New Jersey, New York, North Carolina, Tennessee, Utah, and Virginia). Similarly, a smaller number of states have approved electric cars to use **carpool lanes** and designated parking lots (Arizona, California, Florida, New Jersey, and Georgia).[527] As far as parking in public spaces is concerned, Connecticut, Hawaii, and Nevada have so far waived parking fees for electric vehicles. In order to increase the convenience for owners of electric cars, a number of states (incl. Idaho, Maryland, Michigan, Missouri, Nevada, North Carolina, and Washington) have exempted such vehicles from mandatory **motor vehicle inspections and emission inspections**. In isolated initiatives, only Florida has passed legislation exempting electric vehicles from most insurance surcharges while Arizona and Illinois have either lowered or waived vehicle registration fees for electric cars. Nebraska is offering buyers of EVs and PHEVs preferential **access to car loans** at subsidised interest rates of 5 percent or less in the context of its Dollar and Energy Saving Loan Program.[528]

While some states, such as Arizona offer preferential treatment to the larger group of alternative fuel vehicles, others, such as California have restricted benefits to battery electric vehicles even excluding plug-in hybrids.

The installation of **supporting equipment, such as charging stations**, is promoted by relatively few individual states (see Table 42). Incentives take the form of tax credits or purchase subsidies and are available to both private individuals and companies.

Table 42: Promotional Measures for Charging Infrastructure Construction of Individual States

Arizona	Income tax credit of $75 for the installation of private EV charging outlets
Georgia	Income tax credit covering 10% (max. $2,500) of the cost for constructing EV charging infrastructure
Hawaii	Subsidies covering 20% of the cost of supply equipment (max. $4,500)
Louisiana	Income tax credit covering 50% of the cost of constructing alternative fuelling stations
Ohio	Subsidies covering 80% of the cost of installing charging stations
Washington	Tax exemptions for charging station parts and labour costs
West Virginia	Income tax credit of 50% of the costs incurred for installing charging infrastructure. Up to $10,000 for residential, $250,000 for commercial and up to $312,500 for publicly accessible charging stations.

(Source: Based on Plug In America, n. d.)

To conclude, the public policy framework in the U.S. shows a wide range of measures at the federal level and at the individual state level. Measures between 2008 and 2009 should certainly help to overcome the economic crisis. This chapter shows that in the U.S. indirect support, direct support, and public purchasing incentives are granted in all facets.

5.1.3 Public Policy Framework of Asia

5.1.3.1 Public Policy Framework of Japan and Korea

As early as 1998 the Japanese government set targets based on emission reduction commitments in the frame of the Kyoto protocol to be achieved by 2010. Those included the dispersion of 100,000 EVs and 2 million hybrid vehicles, promoted by a budget of ca. 75 million Euro annually. Japanese consumers are said to receive the highest discount for buying electric vehicles. Price reductions of up to 12,000 Euro have been reported. No acquisition and weight tax apply until March 2013. Road taxes are reduced for EV owners. The Japanese government heavily subsidises R&D of high performance

[527] Plug In America (n. d.)
[528] Plug In America (n. d.)

batteries, such as for advanced- and post-lithium-ion (about 330 million Euro until 2015). Infrastructure installation is supported by 124 million Euro. Selected pilot regions, the so-called “EV/PHV-Towns”, are established as test grounds for EV infrastructure. They serve to create demand, establish infrastructure and educate the public. The EV/PHV Towns are an initiative of the government, jointly run in co-operation with local governments and the private sector. So far, there are few charging points in Japan. By 2020 the Ministry of Economy, Trade and Industry (METI) plans to have 2 million normal chargers (residentially) and 5,000 quick chargers. In addition, private firms plan to install charging facilities at vending machines. 10,000 chargers are planned for the first year of operation. Testing fast charging of taxis is another example of a co-operation project between the Ministry of the Environment, Better Place, Subaru, and Mitsubishi.

The “Green New Deal” package from the **Korean** government (2009 to 2012) targeted the revival of the economy. A 1.4 billion Euro share was allocated to the promotion of low carbon vehicles. The government launched joined programs with academia and private business to speed up dispersion of eco-friendly cars and to improve co-operation among firms. EV related traffic laws were introduced benefitting EV owners. R&D supports concentrates firstly on battery performance and related systems. 253 million Euro are planned to be invested in battery technology and charging infrastructure R&D (until 2014), and 35 million Euro for R&D for battery producers. Consumers receive a tax discount for purchasing an EV of 800 to 3,000 Euro. By 2020 2.2 million charging points are planned, supported by governmental investment of 111 million Euro (compare Table 43).

Table 43: EV-related Public Activities in Japan and Korea

Item	Japan	Korea
Financial incentives & taxation	Purchase price reductions of up to 16000 dollars (ca 12000 Euro) off the retail price of electric vehicles.[18]No acquisition and weight tax accruement until March 2013,[16] reduction on road tax.[18]	2009-2012: Government initiative “Green New Deal” (30 billion Euro) to reduce CO2 emissions. Share allocated to the promotion of low carbon vehicles is 1.4 billion Euro.[11,12] Tax reduction for purchasing an EV: 5% reduced consumption tax, 7% reduced acquisition tax, discount of up to 20% on governmental automobile bond purchases. In absolute terms: ca. 800-3000 Euro.[13,14]
Research financing	Japan supported most R&D activities in the area of battery technology. For the development of advanced- and post-lithium-ion ca. 330 million Euro until 2015. Infrastructure installation ca.124 million Euro. [22,23]	253 million Euro for battery technology and charging infrastructure R&D (until 2014), 35 million Euro for R&D for battery producers.[6] Heavy investments in smart grid projects are planned.[15]
Infrastructure	Currently 155 EV charging stations (as of March 2010).[19] Plan by the Ministry of Economy, Trade and Industry (METI): 2 million normal chargers (mostly for home usage), 5,000 quick chargers by 2020.[20] First phase infrastructure is established in so-called “EV/PHV-Towns” (i.e. pilot test regions) – a cooperation initiative with local governments and private sector. Goal: Create demand, establish infrastructure, educate the public.[24] Private firms cooperate in order to install charging facilities at	The Korean government plans to mass produce EVs from 2011 is decelerated due to the lack of charging facilities. Only 16 EV charging facilities in 9 cities exist. Plan: 2.2 million charging points by 2020 based in the 2011 roadmap supported by governmental investments of 111 million Euro. Support to local governments for establishing charging facilities (until 2012) and private businesses (from 2013). Public use of EVs will be developed. They shall be used in e.g. national parks, eco parks, as airport shuttles, etc.[15]

	vending machines (there are approx. 2.5 million vending machines in Japan). 10,000 chargers are planned in the first year of operation.[19] The Ministry of the Environment, Better Place, Subaru, and Mitsubishi cooperate to test fast charging in taxis.[21]	
Public support	Based on CO2 emission reduction targets agreed to in the Kyoto protocol, the Japanese government set targets in 1998 to be achieved by 2010 including the dispersion of 100,000 EVs and 2 million hybrid vehicles. A budget of ca.75 million Euro was invested annually. The program was managed by the Japanese Ministry for Economy, Trade and Industry (METI) and the Ministry for Land, Infrastructure and Transport. Support measurements included subsidies for establishing recharging stations, fleet usage, and a purchase subsidy of up to 50% of the incremental cost of a vehicle for EVs and hybrids.[18]	The Ministry of Knowledge Economy is in charge to execute the governments “Green Growth” strategy. It launched the “Green Car Forum” joined by academia and private businesses to speed up commercialisation of eco-friendly cars. EV related traffic laws were introduced so EVs can drive on designated roads, existing ICEs can be legally converted. R&D support concentrates on battery performance and related systems. Public organisations receive subsidies for buying EVs. The “Green Network” was introduced in order to improve cooperation among local parts firms.[15]
Consumer perception	EV pricing and the availability of recharging stations are considered barriers to a higher penetration rate.[17,19]	Factors considered as slowing down the dispersion of EVs: lack of recharging points and convenient access to power sources, high price of EVs, in particular: high price of batteries, safety measures: some EVs caught on fire during tests.[15]

(Source: Agentshap NL 2011[6]; UNEP 2010[11];Robins et al. 2009[12]; AHK Korea 2011[13]; Korea Herald 2011[14];Virtanen/Lee 2010[15]; JAMA 2011b[16];Kageyama 2010[17]; AEA 2009[18]; Hayes 2011[19]; METI 2010a[20]; Narich et al. 2011[21]; Tsujimoto 2010[22]; Ishitani 2007[23]; METI 2010b[24])

The Japanese and the Korean governments both strongly support R&D activities in the area of electromobility in order to accomplish their technology diffusion goals, using a wide range of direct and indirect support. Both are actively initiating infrastructure-related projects, but, in order to maintain industry leadership in key components, a large portion of technology-related financial support goes into furthering the development of lithium-ion batteries. In terms of public purchasing incentives, the amount of purchase discounts for electric vehicles in Japan ranks among the highest worldwide and can reach levels of up to 12,000 Euro per car. As mass marketization in Korea has not yet gained drive, purchase discounts currently do not exist. However, based on expert interviews it is very likely that Korea will grant purchase discounts in the future. While Japan is considered the world’s leading country in the area of electromobility today, Korea also occupies a leadership position in battery manufacturing, so it is interesting that consumer awareness for eco-friendly products is still generally low. Several experts in Japan as well as in Korea do rather see purchasing price reductions and tax incentives as major, necessary incentives for spreading enthusiasm for electric vehicles among consumers. The key strength of Japan and Korea seems to be in battery technology, and the governments are actively supporting the drive to create sustainable comparative advantages in this field. According to experts interviewed, even today the leadership is quite remarkable, and given additional government support, the differences with the rest of the world could increase further.

5.1.3.2 Current Public Policy Framework of China

The Chinese government expects the national number of motor vehicles to increase dramatically in the future – projections indicate a near doubling in size to 150 million units until 2020. Estimates for 2030 put the number of vehicles on Chinese roads at 250 million.[529] This scenario confronts government authorities with the formidable challenge of how to accommodate the growing mobility needs that both enable and result from protracted economic growth and, at the same time, accomplish the transition to a more sustainable, eco-friendly development pattern.

A series of interviews conducted with industry experts in China and Europe left no doubt that a broad consensus exists among automakers, component suppliers, research institutes and other stakeholders in the Chinese EV sector that the government has to play a leading role in the transition towards electric mobility. It is well accepted that forceful government intervention is a conditio-sine-qua-non the build-up of charging infrastructure and the formulation of technical standards. Furthermore, government organizations are expected to bridge the gap between the cost of an EV and a corresponding conventional vehicle with a gasoline engine through the provision of buying incentives, tax privileges, preferential financing and other means - either until technological progress has caught up or consumer preferences have turned sufficiently “green”. This mindset is reinforced by the designation of the automotive industry as a pillar industry throughout the reform era. As such, automaking has always been heavily regulated and tightly controlled by central government organizations - first and foremost the National Development and Reform Commission (NDRC)[530]. As far as the new energy vehicle sector is concerned, several central ministries are involved in the creation of a favourable development environment. The Ministry of Industry and Information Technology (MIIT) is in charge of drafting industrial policy guidelines and working out technical standards in conjunction with the industry. The Ministry of Science and Technology (MOST) has the mission to support the development of new technologies and is heavily involved in R&D promotion measures as well as demonstration projects. The Ministry of Finance (MOF) is administering special funding facilities and tasked with disbursing money based on policy guidelines. Finally, the Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) conducts product testing and verifies that imported and domestic vehicles can meet mandatory standards. Below the central government level, provincial and municipal authorities are primarily tasked with the implementation of plans and programmes. In addition, they typically work out their own supporting policies within (and oftentimes beyond) the limited policy space they command.

Although this brief introduction may create the impression that the Chinese government is a major driver of the transition towards electric mobility and (pro)actively draws up ambitious roadmaps into hitherto uncharted territory, any evaluation of the government’s role has to be done with caution.

Over the past ten years, Chinese authorities have published over 20 major policy documents regulating and promoting the new energy vehicle industry. The frequency of releases has increased notably since 2007 with new documents introducing optimistic forecasts as well as ambitious development targets, i. e. China should lead the global automotive industry in the development, production and commercialization of EVs. However, Chinese policy makers have consistently proven too optimistic about the development of China’s new energy vehicle market. The capacity and sales targets put forth in the Adjustment and Revitalization Programme for the automotive industry from 2009 are a case in point. Emphasizing the importance to expand production to generate economies of scale, the document urged auto companies to establish capacities for manufacturing 500,000 units per year until 2011. Furthermore, it demanded that electric cars should then represent 5 percent of total sales. Considering that more than 10.1 million sedans were sold during that year, the number of newly launched electric cars should have reached 506,000 – well in line with the capacity goal. However, only 8,159 units were actually sold in 2011.[531] The Energy-saving and new energy vehicle industry development plan (2012-2020) released in July 2012, extended the deadline for an annual sales volume of 500,000 EVs by another four years. But even that date appears not to be set in stone as comments of Wang Binggang, the leader of the expert group heading the Energy-saving and new energy vehicle pro-

[529] METI (2012)

[530] The Commission reviews and approves foreign investments into the automotive industry as well as other sectors of the economy. It is engaged in the selection of domestic joint venture partners and has far reaching decision making authority concerning the establishment and normal operations of foreign invested enterprises in the auto industry. One expert interviewed for this report stated that the Commission had intervened in the selection of plant equipment to be installed at certain facilities and mandated from which local supplier this particular equipment would have to be procured.

[531] State Council (2009) at2.3.6.

gramme under the national 863 research plan, created fresh doubts. He pointed out that the number of 500,000 units were but an approximate target and cautioned that precise estimates were not possible.[532]

According to the **Special Projects for Science and Technology Development Related to Electric Vehicles during the 12th Five-Year Programme**[533]released in April 2012 and the **Development Programme for the Energy-saving and New-energy Vehicle Industry (2012-2020)**[534] released in July 2012, the two most authoritative and recent policy documents available by the time of writing in August 2012, the Chinese government had divided the future development of EVs into three phases.

Phase I (2008 – 2010)

- Launch EV pilot projects in public services of large and medium-sized cities.
- Completion of a large-scale pilot project involving 595 battery electric vehicles during the 2008 Olympic Games in Beijing.
- Initiation of the 10 Cities 1000 Vehicle Programme in 2009 as a large-scale pilot promotion project in urban centres across the country.

Phase II (2010 – 2015)

- Realize the production of hybrid vehicles on an industrial scale.
- Put a cumulative combined total of 500,000 BEVs and PHEVs on the road until 2015.
- Launch large-scale pilot projects for the commercialization of small-size BEV
- Initiate small-scale pilot projects for the evaluation of FCV in public services.
- Conduct research and development activities with regard to FCV as the next generation of electric vehicles and establish a research and development platform in this area.
- Provide support to science and development activities in order to facilitate the increase of the proportion of pure electric vehicles to all vehicle sales to level of 1 percent.
- Promote comprehensive research and development efforts focusing on Lithium Ion batteries.
- Intensify technology support for the modularization of vehicle batteries as cornerstone of indigenous innovation efforts.
- Reach a breakthrough in the mass production of vehicle batteries.
- Set up 400,000 charging posts and 2,000 stations for battery charging and replacement in over 20 pilot cities and border areas.

Phase III (2015 – 2020)

- Continue to promote the large scale industrial production of pure electric and commence work on the next generation of pure electric vehicles.
- Increase the combined BEV and PHEV population to 5 million units until 2020.
- Achieve a combined production capacity for BEVs and PHEVs of 2 million units by 2020.
- Launch the production of the next generation of vehicle batteries on an industrial scale.
- Optimize the basic support infrastructure for electric vehicles.
- Enhance vehicle – network integration.
- Continue to provide technology support to promote the popularization of all types of electric vehicles until 2020.

Several industry insiders interviewed for the compilation of this report have cited government in-fighting, local protectionism and a failure to force through a unified set of technical norms and standards as major problems that have offset some of the beneficial aspects of industrial policy guidance. Some experts interviewed held the opinion that Chinese authorities have taken a wait-and-see attitude towards the further development of the new energy vehicle sector, a perception confirmed by UK Trade & Investment.[535]

Frustrated about the failure to accomplish major development objectives in spite of sizable investments and comprehensive nurturing activities, the Chinese have started to seek out international co-operation on issues such as definition of common standards. As far as the development direction is concerned, industry experts expressed disappointment that authorities were crafting industrial policy

[532] Caijing (2012)
[533] METI (2012)
[534] State Council (2012)
[535] UK Trade & Investment (2010)

guidelines based on research trends and commercialization projects of other countries instead of independently working out a Chinese approach.[536]

Another issue that needs to be addressed in the context of China's industrial policy framework for EVs is the pressure created on automakers to engage themselves in this new area, where they do not have any expertise. The ambitious push by Beijing to accelerate the development and commercialization of electric powertrain technologies has not been met by the same degree of enthusiasm on the part of domestic OEMs. Having just established themselves as new and rapidly expanding players in the international auto industry[537], they serve established customer bases while addressing the dual challenge of improving technology levels and building up brands. While the prospects of assuming a leading position in a new market is certainly attractive for Chery, Geely and other companies, industry experts consulted for the compilation of this study have voiced doubt that these companies possess the expertise, particularly in the area of vehicle integration, to deliver what the government is demanding from them. This argument is supported by the observation that only a fraction of the large number of concept vehicles presented at auto shows are ever followed by actual market introductions.

Major Project for the Popularization and Commercialisation of Electric Vehicles

Chinese leaders have long held the conviction that the tremendous growth in mobility needs, which stems from the two megatrends of industrialization and urbanization, has to be met by means other than conventional gasoline vehicles. In the 1990s, when the domestic auto industry was still in its infancy, central authorities started to improve the environmental performance of road traffic, i. e. by instituting mandatory emission limits and promoting less polluting public busses.[538] Although the development of EVs was first mentioned as a national objective in the 8th Five-Year Plan (1991-1995), subsequent Five-Year Plans (FYP) have made little or no reference to this task, limiting themselves to calls for more efficient, less polluting cars. The 12th FYP (2011-2015), however, has marked a breakthrough in that it designates EVs as one of seven "strategic emerging industries" to be energetically developed into "leading pillar industries".[539] In this context, it puts emphasis on developing PHEV, BEV and FCEV technologies. According to the outline document, the state reserves itself a leading role through its key science and technology projects which are envisioned to support the development of core technologies, the formulation of standards, and the implementation of demonstration projects. More concretely, central authorities announced the initiation of a special industrial investment fund to promote R&D activities as well as new business models related to new energy vehicles (NEV)[540]. In order to increase access to vital investment capital, financial institutions were urged to step up loan support. A revamping of taxation policies was promised to encourage innovation and stimulate investment as well as consumption in the new energy vehicle sector. Furthermore, the government promised to accelerate the definition of standards and support the construction of necessary infrastructure to "create an excellent environment for nurturing and expanding market demands".[541]

In 2009, the MOF and the MOST jointly launched the **10 Cities, 1000 Vehicles Programme**, arguably the largest and most important scheme targeting the commercialization of EVs in China to date.[542] The main objective was to make use of large scale demonstration projects in urban centres to stimulate the development of EVs and gain valuable insights for further technology improvement.[543] Ten large and medium sized cities[544] were chosen for pilot projects and tasked to put at least 1,000 EVs on the road before 2012. Due to an initial lack of charging infrastructure the programme focused on fleet operators, i.e. taxi companies, and the public service sector, i. e. transportation, sanitation or postal services. On the one hand, it was expected that this approach could guarantee a high level of compliance, as all partners were more or less directly controlled by government authorities. On the other, the choice of target groups reflects the technical necessity to start with vehicles that had predictable driving patterns since charging networks had yet to be installed. The program was expanded twice to in-

[536] Ibid.
[537] The development lag in engine technology has not kept Chinese OEMs from improving quality levels, reducing costs and expanding their global reach through exports and investments in developing and emerging markets.
[538] Sun (2012)
[539] State Council (2011) at 10.1
[540] The term New Energy Vehicle is commonly used by Chinese authorities to refer to BEVs and PHEVs. Non-plug-in hybrids are categorized as Energy-saving vehicles.
[541] Ibid. at 10.3
[542] Worldbank (2011)
[543] Ministry of Finance and Ministry of Science and Technology (2009)
[544] Beijing, Shenzhen, Shanghai, Jinan, Chongqing, Wuhan, Changchun, Hefei, Dalian, and Hangzhou

clude the current number of 25 cities.[545] Until the end of 2010, the most recent date for which information is available, a total of 12,846 new energy vehicles had been launched under the project. With two years (little more than half of the project duration) still ahead, the prospects for overall success may appear dim, however, industry experts consulted for this report hold the opinion that municipal governments have greatly intensified their efforts in 2011 and expect ample activity in 2012, the last year of the program. Beijing and Shanghai are leading the other cities in project implementation. Beijing has added roughly 1,200 new energy vehicles in both 2010 and 2011. For 2012, the city plans to launch over 5,000 units. Data collected by Fourin[546] suggests that more than half of the vehicles introduced nationwide are busses.[547] Only one third of the EVs procured under the auspices of the 10 Cities, 1000 Vehicle Programme are passenger cars, mostly used as fleet vehicles of government agencies or operated by taxi companies while the rest represented were special purpose vehicles, i.e. sanitation trucks.

Dividing EVs by powertrain technology, it is striking that over 60 percent of the new vehicles are non-plug-in hybrids while BEVs make up 33 percent. FCEVs account for about 5 percent while the share of PHEVs is minimal.[548] The fact that all pilot cities had been slow to adopt EVs and implement the other promotion measures stipulated by the project greatly frustrated the progress of the central government's EV promotion initiatives. As it became increasingly likely that several cities would miss their respective targets, the MOF announced in May 2012 that pilot cities which make slow progress, achieve no visible results or fail to meet their objectives would be excluded from the programme.[549]

Box 22: A failed Attempt at Technology Leapfrogging

As Chinese automakers are lagging behind the international competition in the field of advanced combustion engines, policies were initially aimed at developing electric drive technology to move ahead of the international competition. Instead of devoting resources to master gasoline-electric hybrid engine technology, the Chinese government strongly favoured BEVs, PHEVs and FCEVs. In this regard, it initially pursued a policy orientation strikingly different from the two-pronged European strategy that simultaneously focused on optimizing existing ICE-based vehicles to successfully compete in the current market environment and developing EVs as a strategic new product to win over the market in the future.

Although China has started the development of EVs some 20 years ago and in spite of the substantial resources devoted to EV related research, Chinese companies continue to depend on imports of powertrain control electronics and other key components. The expected breakthroughs have failed to materialize. Attractive (and affordable) vehicles are still not available from Chinese manufacturers. Slow infrastructure construction did not create an environment suitable for EV popularization. Muted consumer interest, further rattled by media reports about fatal accidents involving EVs, reflected in disappointing sales.[550] It thus became clear that the leapfrogging approach needed to be replaced by a more practical policy strategy, a point unanimously supported by all experts interviewed for this report. Following this realization, the Chinese government has scaled back its ambitious targets and brought its development strategy more or more in line with the two pronged approach followed by European countries. Policy documents and statements by leading administrators whom had illustrated a definitive preference for full EVs gradually accepted hybrid electric drive technology, which had previously been rejected as a transitory development stage, as a necessary step on the way to vehicle electrification.

[545] Changsha, Kunming and Nanchang were added in May 2010. Tianjin, Haikou, Zhengzhou, Xiamen, Suzhou, Tangshan and Guangzhou were added in September 2010.

[546] Fourin (2012c)

[547] The strong performance in this area is due to generous subsidies of up to RMB 500,000 per unit as well as the relatively convenient charging procedure for vehicles with predictable driving patterns and convenient access to battery swapping or overnight charging facilities. Pressure from the central government also plays a major role in the process. In late May 2012, the MOF disclosed that all medium-sized and large cities across the country should promote the adoption of hybrid electric busses.

[548] Fourin (2012c)

[549] JinRongJie (2012)

[550] Combined sales of BEVs and PHEVs in 2011 totalled 8159 units and estimates put the total EV population at 16,000 see JinRongJie (2012a)

1. Financial Incentives

The provision of buying incentives is one of the most important tools used by the Chinese government to stimulate the popularization and commercialization of EVs. However, the degree of subsidization differs between powertrain technologies. As hybrid electric drive technology was long regarded as an intermediate step without much future development potential, financial incentives in this category are less generous compared to pure EVs. Consequently, support schemes follow a hierarchy topped by BEVs as the most preferred vehicle type. Next in line are PHEVs which can claim less generous support, followed by pure hybrid vehicles and efficient ICE powered cars which receive minor amounts.

In May 2010, the Chinese government initiated a buying subsidy scheme to support private purchases of BEVs and PHEVs in six cities[551] participating in the 10 Cities 1000 Vehicles Programme. A special fund was created as part of the central government budget to provide one-time funding support for buying or renting new energy vehicles (either complete vehicles or batteries only) from 2010 until 2012. Subsidies are not disbursed to consumers but paid to the manufacturers in order to lower the sales price. The exact amount of the subsidy depends on the battery capacity (RMB 3,000 are paid per kWh) and the drive technology (maximum subsidies for PHEVs and BEVs amounting to RMB 50,000 and RMB 60,000 respectively). In anticipation of a fairly strong consumer interest, the subsidies are available in full only for the first 50,000 PHEV/BEV units sold by each producer and will subsequently be scaled back as commercialization progresses.[552]

The six municipal governments were required to promote EV sales on a large scale and promote the commercialization of either the car or the battery rental business. Furthermore, they were tasked to draw up their own fiscal support measures, provide electricity at subsidized rates and put in place the necessary infrastructure, such as charging stations, dedicated parking lots and battery recycling systems. BEVs are required to have a battery capacity of no less than 15 kWh while PHEVs have to have a battery capacity of at least 10 kWh, a range of no less than 50 kilometres in electric mode. [553]

A growing number of cities throughout the country have initiated their own buying subsidy programs to complement those administered by central authorities. Local subsidies are granted on top of money received from the central government and are typically disbursed to producers instead of consumers. The exact amounts awarded for EV purchases vary from city to city. While the municipal government of Beijing matches the financial incentives of central authorities with equal payments (max. RMB 60,000 for BEVs / RMB 50,000 PHEVs), the city of Hefei offers significantly lower benefits to EV buyers (RMB 20,000 for BEVs / RMB 15,000 for PHEVs).[554]

Since during its first 18 months government organizations on all levels initiated financial incentives, the scheme was not met with much success. Until the end of 2011, the combined sales of PHEVs and BEVs to private persons stood at just 1,500 units. Considering that the initial plan envisioned a total combined PHEV/BEV population of 132,100 at the end of the pilot project in 2012, this number is particularly disappointing. The dismal performance can be attributed to two main problems. Firstly, even though the combined subsidies significantly reduce the sales price of approved vehicles, they still cannot cover the total price difference between an electrically powered vehicle and its comparable ICE based version.

The following example will illustrate this problem. The regular price of BYD's top-selling PHEV model, the F3DM, is RMB 169,000 which is reduced to an actual RMB 89,000 thanks to combined purchase incentives provided by the central government and the Shenzhen government. However, this is still 34 percent higher than the price for the F3, the equivalent version of the vehicle which is powered by an internal combustion engine which sells at only RMB 67,000.[555]

While purchasing subsidies are provided by both central and local government authorities, all eligible vehicles have to be included in the **Catalogue of Energy Saving and New Energy Vehicles Recommended for Pilot Popularization Projects** which covered about 417 vehicle models of different manufacturers by the time of writing in August 2012.[556] Since 2010, the catalogue has been gradually

[551] Beijing, Changchun, Hangzhou, Hefei, Shanghai and Shenzhen
[552] Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology and National Development and Reform Commission (2010)
[553] Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology and National Development and Reform Commission (2010)
[554] Cars 21 (2011b)
[555] Fourin (2012c)
[556] China Vehicle Technology Service Center (n.d.)

expanded as new vehicles were added through 32 batches released by the central government. In terms of powertrain technology, two thirds of the models contained are pure energy vehicles while hybrids account for the rest. Sorted by vehicle type, roughly half the electric cars featured in the catalogue are busses while passenger vehicles only make up a quarter.[557] Since numerous EVs are expected to be introduced in 2012, based on a large showing of marketable models presented at this year's China Auto Show in April, the catalogue is likely to be expanded significantly in the near future.

The provision of financial incentives to encourage private purchases of electric cars has a major flaw. Since the promotional measures are concentrated on the large cities taking part in the 10 Cities, 1000 Vehicles Programme, they are not targeting the areas where the most dynamic demand growth is expected.[558]While tier 1 und tier 2 cities have the advantage of more advanced infrastructure and higher disposable incomes, they already have large vehicle populations often causing serious congestion problems. With opportunities for further construction of roads and parking lots limited, the addition of further cars as envisioned in the financial incentive is less attractive for both consumers and urban planners. Provided economic growth will continue in China over the medium term, it stands to expect that vehicle demand in smaller (tier 3 and tier 4) cities will grow disproportionately. Furthermore, due to the generally lower income levels in the economically less developed urbanities, the stimulus effect of fiscal incentives will arguably be stronger than in the large metropolises.

2. Taxation

The Chinese government has made ample use of tax regulations to stimulate the development and sales of EVs enabling both producers and consumers to benefit from a large variety of preferential measures. The first part of this chapter will introduce fiscal support measures targeting companies while the latter half will outline consumer-oriented policies.

A host of incentives is available to support companies that engage in the production of EVs or components thereof. Furthermore, enterprises that provide support services, such as research and consulting are qualified to take advantage of preferential policies as well. Fiscal policy is employed to achieve several key objectives, such as industrial restructuring, energy conservation, sustainable development and technological upgrading. It takes a major role in the Chinese public policy framework since the Energy Conservation Law, promulgated in October 2007, established the Catalogue of energy-saving technologies and energy-saving products to be promoted.[559] The law ruled that both the production and use items contained in the catalogue will be supported by tax benefits.[560] Other preferential arrangements relate to the promotion of imports of equipment and technologies conducive to energy conservation.

The new Enterprise Income Tax Law (EITL) which came into effect on January 1st, 2008 reiterated the government's intention to provide tax incentives for products and technologies related to energy efficiency and conservation. It rules that corporate income tax could be partially or even completely waived for projects related to environmental protection, energy or water conservation. [561] Concretely, the law established a practice, according to which profits from energy conservation or emissions reduction projects are exempted from corporate income tax for a period of three years, starting with the first year of profitable operations. For the fourth, fifth and sixth year, profits will be taxed at half the regular rate. Enterprises engaged in the development and production of new energy vehicles are qualified to take advantage from this incentive scheme since their products are in line with the national objective of energy conservation and environmental protection. [562]

Furthermore, the EITL introduced regulation in support of indigenous innovation and technological progress. Companies found to meet relevant criteria can have their income tax waived or reduced to a preferential rate of 15 percent (instead of the regular 25 percent). Moreover, companies may take advantage of accelerated asset depreciation (the depreciation period is shortened to allow for higher annual deductions) and over-proportional depreciation (the depreciation amount deducted from taxable income is a multiple of the actual purchasing value). Since automakers and suppliers active in the EV sector typically engage in R&D and technology-intensive production, they have been approved as innovative, high technology enterprises which qualifies them to benefit from one or more of the above

[557] China Vehicle Technology Service Center (n.d.)
[558] Cars 21 (2011c)
[559] National Development and Reform Commission (2008)
[560] Standing Committee of the National People's Congress (2007) at 61-63
[561] Ibid.
[562] Ibid.

incentive measures.[563] Additionally, individuals and enterprises that generate income from the provision of technology development, transfer, consulting, contracting, training or other services related to new energy vehicles are entitled to have their income tax partially or completely waived depending on the individual circumstances.[564]

Buyers of EVs can benefit from various tax privileges as well. In order to stimulate EV sales, the Vehicle and Vessel Tax Law[565] has been adjusted. Under the revised law, which came into effect on January 1st, 2012, BEVs, FCEVs and PHEVs are exempted from vehicle tax while various types of HVs will be taxed at only 50 percent of the regular rate. China's annual vehicle tax, which previously took the form of a flat rate amounting to RMB 300 to RMB540 per unit[566], has been amended to take into account engine sizes as an indicator of fuel efficiency and environmental performance. In this regard, the law introduced seven tax brackets - the highest is set for vehicles with more than 4 litres of engine displacement at RMB 3,600 to RMB 5,400 while the lowest of only RMB 60 to RMB 360 is reserved for vehicles with engines below 1 litre.[567] While the orientation towards greener vehicles is apparent, it is striking that the benefits reserved for EV owners are not significantly superior to those that can be claimed for conventional low-motorized vehicles of comparable performance. According to the consensus of industry experts consulted for this report, even though the highest and lowest tax charges differ by the factor 90, it does not stand to expect that consumers aspiring to purchase luxury cars, SUVs or sports cars with large engines can be sufficiently motivated to choose EVs based on annual savings of RMB 5,400 alone. This implies that the more affluent car buyers who are the target group for EVs will be little moved by the new legislation. The less wealthy, on the other hand, might also shy away from buying EVs due to the higher sticker price and the relatively low annual tax savings.

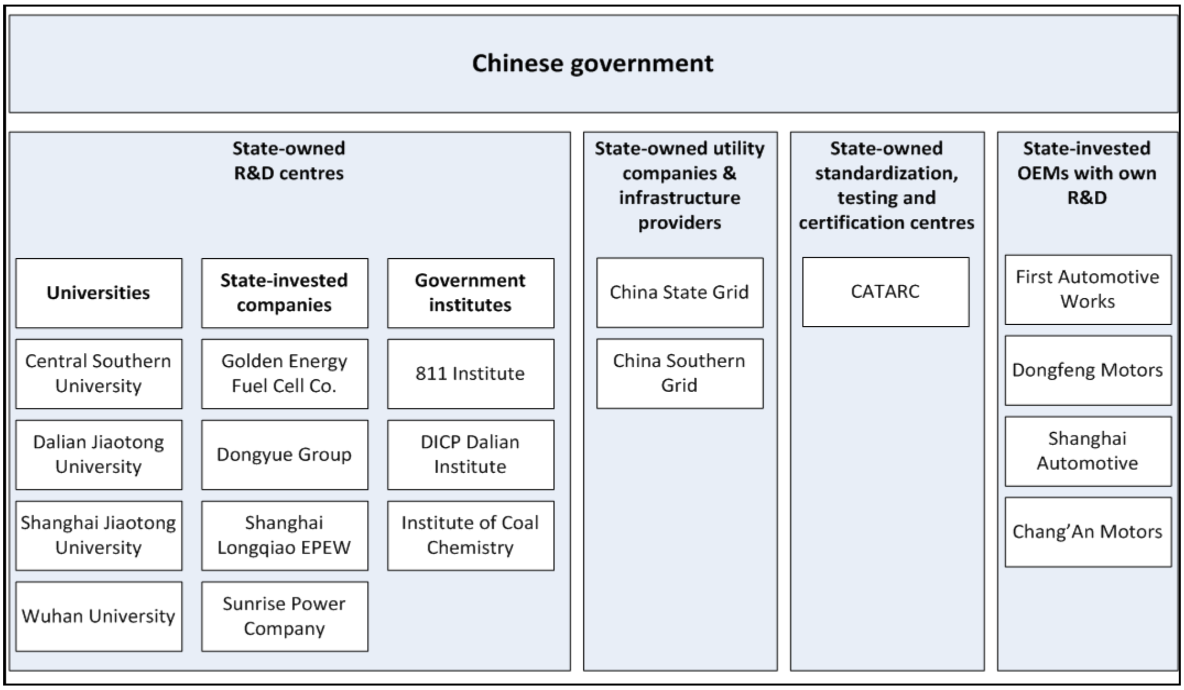
Furthermore, a growing number of municipal governments, i.e. Beijing, have decided to waive locally administered taxes and fees for EVs.[568]

3. Research Financing

The Chinese government itself is heavily involved in R&D activities in the area of EVs. Through state-run universities and research institutes, state-owned utility companies, standardization bodies, testing and certification centres as well as state-invested automobile companies the state transcends the EV industry (see Figure 59). Considering the pronounced influence of state organizations on the auto industry and related industries, such as power generation and transmission or electrical engineering Chinese authorities appear to be uniquely positioned to drive technology development and drive progress in the commercialization of electric cars.

563 Standing Committee of the National People's Congress (2007)
564 Ibid.
565 Standing Committee of the National People's Congress (2011)
566 GreenProspectsAsia (2012)
567 Standing Committee of the National People's Congress (2011)
568 Cars21 (2011b)

Figure 59: Government Involvement in EV related R&D



(Source: Own Illustration based on expert interviews and Finpro 2010)

Indeed, the Chinese government has been the initiator and driving force behind China's strategy to become the world leader in electric mobility.[569] Subsequently, the past development can be described as a top-down approach in which state authorities have defined the transition to electric mobility as a priority objective. Different from other countries, the Chinese automotive industry initially did not take an interest in developing electric cars and was reluctant to venture into this new field. By nudging or pressuring companies to engage themselves, government authorities aimed to jump start EV development. To sweeten the pie, it provided generous R&D funding and shared technology developed in its own research institutes. Accurate data on research financing is hard to come by as government authorities rarely disclose precise numbers. However, China Daily had reported earlier that the MOST has spent RMB 2 billion to support the development of technologies related to FCEVs, PHEVs and BEVs at more than 200 universities, research institutes and companies.[570] For a compilation of the information reasonably available by the time of writing in August 2012, please refer to Table 44.

Table 44: Research Support Programmes and related Investments

2001	863 Electric Fuel Cell Vehicles Project (Ministry of Science and Technology)	RMB 800 million
2006	863 Energy-Saving and New Energy Vehicles Project (Ministry of Science and Technology)	RMB 1,100 million
2008	10 Cities, 1000 Vehicles Programme (Ministry of Science and Technology, Ministry of Finance, National Development and Reform Commission, Ministry of Industry and Information Technology)	
2009	Adjustment and Revitalization Programme for the Automotive Industry (State Council)	RMB 3,000 million
2010	Subsidies for private purchases of new energy vehicles (Ministry of Science and Technology, Ministry of Industry and Information Technology, Ministry of Finance)	RMB 60,000 BEV and RMB 50,000 PHEV per unit sold
2010	863 Key Technology and System Integration Project for Electric Vehicles (Ministry of Science and Technology)	RMB 738 million

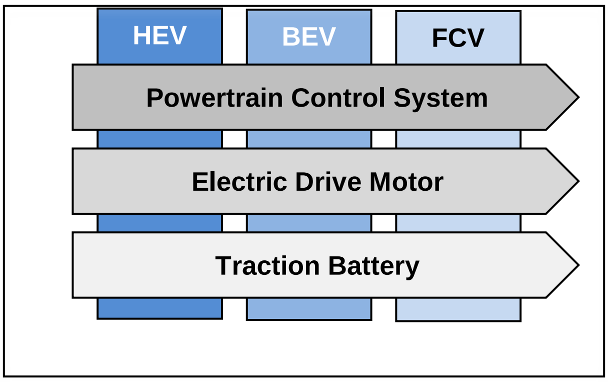
[569] State Council (2009)
[570] China Daily (2012b)

The roots of government support for the development of EVs reach back two decades into the early 1990s. The **8th FYP** (1991-1995) marked the beginning of official support for the development of new energy vehicles[571] while the first comprehensive industrial policy guideline for the automotive sector, released in 1994, announces government assistance to the development and production of energy efficient, environmentally friendly vehicles with alternative propulsion systems.[572]

Government-sponsored research is organized under the umbrella of the National High Technology Research and Development Plan, funded and administered by the MOST. With the institution of the plan in March 1986 (hence its name 863) the government aimed to promote cutting edge research across various fields of science and technology in the domestic context. In 2001, the initiation of the **863 Electric Drive Fuel Cell Vehicle Project** marked the adoption of EV related research into the plan, as well as the beginning of meaningful research support for this field. With a funding of RMB 800 million, the project was large when compared to other research priorities at the time.[573]

In 2002, the Chinese government had introduced the **Three Horizontals and Three Verticals Framework** in order to organize and coordinate research and development efforts. The three horizontals represent three major electric drive technologies (BEV, PHEV and FCEV) while the three verticals refer to three core component technologies (traction batteries, electric motors and powertrain electronics). This framework served as the basis for R&D initiatives under the national 863 science and development programme during the 10th FYP (see Figure 60).

Figure 60: The 3 Horizontals and 3 Verticals Framework during the 10th FYP

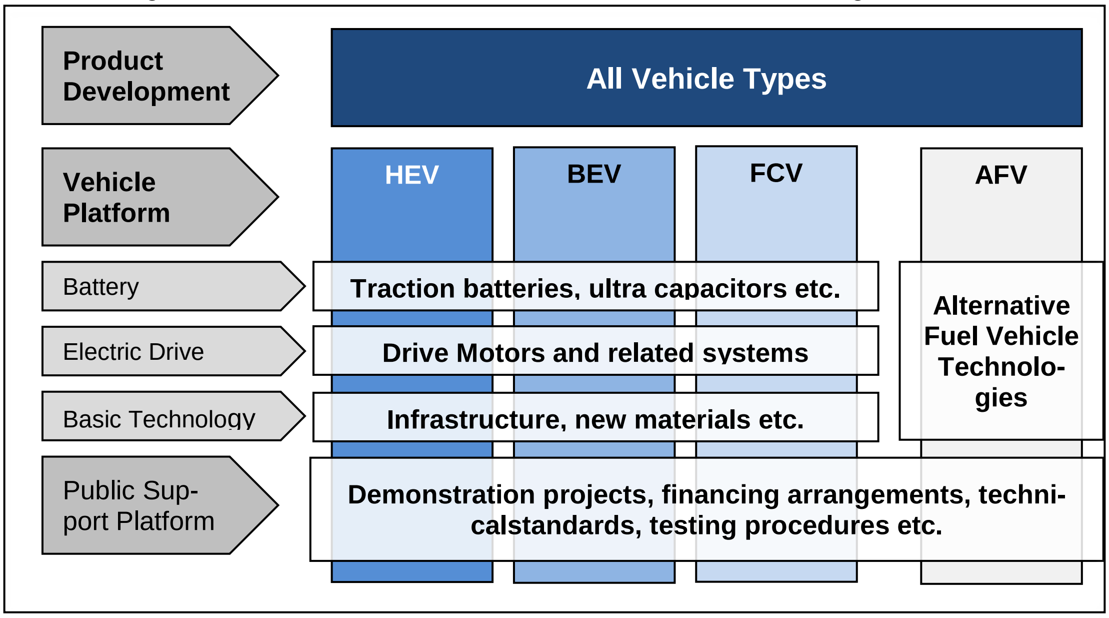


(Source: Own illustration adapted from MOST information)

With the beginning of the 11^{th} FYP, the MOST invested another RMB 1.1 billion to stimulate research and work out a technology roadmap through its **863 Energy-Saving and New-Energy Vehicle Project** which focussed on PHEVs, BEVs and FCEVs.[574] The original Three Horizontals and Three Verticals Framework underwent an adjustment which increased both specificity and comprehensiveness of the concept (see Figure 61). Importantly, non-electric innovative propulsion platforms, such as CNG and bio diesel were included to extend the scope to the whole array of alternative power train platforms. Furthermore, the addition of a support platform which integrates technical, legal, economic and political issues into the R&D framework is expected to improve coordination between different stakeholders and avoid parallel investments or conflicting interests which would lead to a waste of resources. More precise, the organization of product testing, intellectual property rights, demonstration projects, industry finance, standardization, industrial policy and technology information on a common platform for all alternative powertrain types is to ensure the compatibility and coherence of activities.

[571] State Council (1991) at 5.1
[572] State Planning Commission (1994)
[573] Early, Robert et al. (2012)
[574] Sun (2012)

Figure 61: The 3 Horizontals and 3 Verticals Framework during the 11th FYP



(Source: Own illustration adapted from MOST information)

Besides the 863 Plan, a number of other policy initiatives have influenced development objectives and R&D funding. The revision of the **automotive industry policy guidelines** in 2004 brought about a stronger focus on new energy vehicles calling for an intensification of research and development efforts for electric cars and traction batteries. The central government pledged its support in scientific research as well as technology upgrading and provided a favourable industrial policy framework to stimulate the production and use of hybrid vehicles. [575] In 2009, under the influence of the world financial crisis, the Chinese government released the **Adjustment and Revitalization Programme for the Automotive Industry** which was intended to stabilize and stimulate the industry in the face of slowing growth. More forcefully than earlier government documents, the Programme puts the focus on independent innovation and the popularization of new-energy autos. It called for the intensification of technical renovation efforts and the improvement of research and development of new-energy autos to reach advanced international levels.[576] Furthermore, it demanded the acceleration of product upgrades and the establishment of independent brands to actively develop new-energy vehicles.[577]

The programme indicated the government's intention to stimulate the industrialization of BEVs, PHEVs and core components thereof. Companies should utilize optimal engineering technologies, mass production techniques and cost control technologies for three core components (traction batteries, electric motors and control electronics) of new-energy autos. A production capacity amounting to 1 billion Ah of high performance batteries was planned along with the development of key components of HVs and FCEVS. [578] It was announced that a special fund set up by the central government would provide a total of RMB 10 billion to the domestic automotive industry for investments in R&D and production technology upgrades and the development of new-energy autos as well as their three key components.[579]

The **Development Programme for the Energy-saving and New-energy Vehicle Industry (2012-2020)**, which was finally released in July 2012 after two years of preparation and discussion behind closed doors, distinguishes between energy-saving vehicles (ICEs and non-plug-in hybrids) and new energy vehicles (plug-in hybrids, BEVs and FCEVs). This division is highly relevant as it signifies the readiness of Chinese authorities to pursue a two-pronged approach, similar to the one practiced in Europe where parallel development paths are defined to make conventional vehicles greener and promote the development of pure-electric ones. Thus, it marks a departure from the previous bias in

[575] National Development and Reform Commission (2004)
[576] State Council (2009) at 2.3.7
[577] Ibid. at 2.2
[578] State Council (2009) at 4.5
[579] State Council (2009) at 4.9

favour of all-electric power trains and recognizes the optimization potential for ICEs as well as the important role for pure-hybrids for reducing the environmental footprint of road vehicles.

However, the Programme does not give any indication on the amount of funds government authorities are willing to devote to research financing.[580] While publicly available draft versions of the document and information leaked during the formulation process have suggested a research funding volume of more than RMB 100 billion to be spent over the ten year period between 2011 and 2020, the final document does not contain any such reference.[581] After several weeks of uncertainty following the release of the final version of the Development Programme for Energy-saving and New-energy Vehicles, Vice-Finance Minister Zhang Shaochun revealed in late May 2012 that the central government would allocate RMB 1-2 billion annually for supporting R&D activities and for strengthening the industry value chain related to EVs. He emphasized, that EV manufacturers with the capacity for volume production would be at the centre of state of financial promotion measures.[582]

1. Non-monetary incentives

A recent development in the promotion of EVs has been the introduction of various non-monetary incentives. These are instituted to favour EV buyers relative to the owners of other cars without the need to devote public funds in the process. In a comparative study on the popularization of electric two-wheelers (e2w) in Taiwan and mainland China, Yang has found the reverse subsidy concept to be a very effective instrument for promoting and accelerating the technology transitions. His review of the two episodes illustrates that even though Taiwanese authorities had devoted substantial funds (as purchasing subsidies) to establish price parity between conventional motor scooters and electric ones, the effect had been modest as most buyers remained unimpressed by the new technology. On the mainland, however, many cities had simply banned gasoline powered scooters from city centres while granting access for e2w's. The effectiveness of this measure was striking especially because no financial incentives had been offered. Interestingly, Yang notes that the success of e2w's in Chinese cities had been more of a side-effect rather than the stated aim of government measures to remove the noisy and polluting scooters from the streets.[583]

Most experts consulted for this study have pointed out that the Chinese government possess stronger regulatory powers than found in other countries and suggested that Chinese authorities will eventually capitalize on their influence to force the transition towards EVs - beginning in urban centres. Asked why this had not yet happened, experts agreed that technology was still immature and production capacities were still insufficient. A wholesale switch to EVs initiated by administrative fiat was considered a very likely scenario with many experts citing the e2w case. Interestingly, municipal authorities have long employed auto market regulation as an instrument for urban planning without taking much account of consumer preferences. In the following section, it will be illustrated how city governments have used their administrative powers to address escalating traffic problems and how this may present valuable opportunities for the promotion of EVs.

Thanks to rapid urbanization and a rise in disposable incomes, vehicle ownership in China has increased fourfold between 2001 and 2010. Consequently, cities have come under pressure to expand urban infrastructures in order to accommodate a quickly rising number of vehicles. Municipal authorities have reacted quickly and invested heavily in new roads, tunnels, bridges and parking lots as well as the general improvement of traffic management systems. However, the addition of 18 million new cars, busses and trucks to Chinese roads per year has shown the limits of urban infrastructure expansion. After years of claiming new ground and putting down asphalt, the marginal costs of urban road expansions have risen substantially. In order to address chronic traffic congestion, municipal government have come to regulate annual sales and implement ownership restrictions. In 1994, Shanghai was the first city in China to set up an auction system that awards license plates to the highest bidders.[584] Considering that new car demand greatly exceeded the available number of new registrations, the bidding prices surged over the years to reach RMB 64,000 in May 2012.[585] This mechanism did not only serve to curb the stream of new cars but also created additional revenues for the government. In 2011 the government of Beijing has capped the number of new private vehicles at 240,000 and

[580] State Council (2012)
[581] People's Daily Online (2011b)
[582] JinRongJie (2012)
[583] Yang (2010)
[584] Fourin (2012c)
[585] China Scope (2012)

implemented a lottery system to allocate much wanted license plates. As a consequence, the number of new cars on the city's roads has dropped to 173,000 in 2011 from 792,000 in 2010.[586] Other cities following suit are Guiyang which adopted the Beijing-model in July 2011 and Guangzhou which chose to introduce both a free license plate lottery as well as an auction in August 2012.[587] Most experts consulted on this matter agreed that more and more cities are going to follow these examples in the coming years.

Further municipal regulation imposes restrictions on driving and parking. Several cities limit vehicle usage based on the last digit of the license plate, allowing only vehicles with certain numbers to drive on designated days of the week while banning others from public roads. Many cities prohibit cars registered in other jurisdictions from entering the city centre completely or at certain times of the day. Yet others reserve designated roads exclusively for local cars. Similarly, vehicle parking has become subject to extensive regulation with many cities introducing parking fees adjusted by time and location and implement fines for rule violations. Overall, municipal regulation governing vehicle use has become more and more specific and imposed increasing limitation on ownership rights.

After the kick-off of the two flagship programmes aimed at popularizing EVs, it was found that ownership, driving and parking restrictions hindered the progress of promotion measures. This appears reasonable as it stands to assume that the preferences of auto buyers in Shanghai and other cities administering license place auctions, are in favour of larger, more expensive and representative premium vehicles. Considering the additional costs of auction bids, few consumers can be expected to opt for small economy models or EVs that are inferior to conventional cars in terms of range, speed and aspirational value. Consequently, all 25 municipalities participating in the 10 Cities, 1000 Vehicles Programme were ordered by the central government in November 2011 to exempt EVs from license plate auctions, lotteries and other purchasing restrictions. Furthermore, cities were urged to repeal driving restrictions and other measures limiting the usage of EVs. Simultaneously, the 25 municipalities carrying out demonstration projects have to institute reduced parking fees, electricity rates and road tolls especially for EVs.[588] While this demand may appear self evident, even the city of Beijing had not implemented these rules at the time the document was released.[589] Another indication that implementation lagged is a statement from Zhang Shaochun, Vice-Minister of Finance, in May 2012 who demanded that all 25 pilot cities abolish ownership and driving restrictions.[590]

2. Infrastructure

China is a country of continental dimensions and has a very heterogeneous topography. Both factors severely complicate the establishment of a nationwide charging network and drive up costs. The situation is further complicated by the fact that transportation and electricity networks have not yet developed to the degree typically found in industrialized economies. Despite significant development efforts by government authorities over the past three decades, stark disparities still separate the "modern China" in coastal areas with advanced urban infrastructures, relatively high disposable incomes and easy access to EV service centres from the less developed regions in the large agriculturally oriented hinterland where incomes are low and infrastructure is poor. The idea of setting up one large unified network is hence complicated by the co-existence of customer groups with very different income levels, driving requirements and consumer preferences. A one-fits-all approach is likely to fail as it does not sufficiently take into account the diversity contained in the 151 million Chinese drivers of motor vehicles today.[591]

Considering the unprecedented speed with which China has expanded its infrastructure in recent years, with several thousand kilometres of new highways and railway lines built every year, the development pace of EV charging infrastructure is somewhat disappointing. Although the construction of supporting networks is making steady progress, its present status is insufficient to support a burgeoning EV population and must be considered a limiting factor for the commercialization of new energy vehicles. By the time of writing in April 2012, the availability of modern charging infrastructure was limited to 25 urban centres selected for participation in the 10 Cities, 1000 Vehicles Programme.

586 China Daily (2012c)
587 NewsGD (2012)
588 Ministry of Finance, Ministry of Science and Technology, Ministry of Industry and Information Technology and National Development and Reform Commission (2011)
589 Xinhua News (2011)
590 Jin Rong Jie (2012)
591 Bloomberg Data.

In early 2012, it was reported that China had set up 243 charging stations and 13,283 charging posts, making it the world leader in charging infrastructure.[592] The central government has indicated its intention to install a total of 2,351 charging stations and 220,000 charging outlets across the country until 2015, the final year of the current 12th FYP.[593] It should be pointed out that at present, charging infrastructure has predominantly been installed to serve the needs of government fleets, busses and taxis. The overall expansion of charging infrastructure thus does not necessarily translate into increased convenience for private users as they do not have access to bus depots and government compounds. The expansion of public charging infrastructure is lagging behind initial projections. Since the range of current BEVs is limited to about 150 kilometres, the availability and convenient accessibility of charging facilities is a key factor influencing purchasing decisions. The situation is reflected by the fact that 84 percent of EVs in China are registered for the commercial sector.[594] Although a lot of progress has been made to provide sufficient supporting infrastructure for a rising number of electric drive public transportation vehicles, the situation for private cars is rather bleak. It was reported that of the nearly 800 charging poles planned in Shanghai's Jiading District, only 50 had actually been installed by November 2011.[595]

In order to address this problem, several local governments offer the installation of free recharging infrastructure or require real estate developers to reserve parking space for EVs in new residential compounds.[596] The municipal government of the capital, Beijing, has announced the installation of six large charging stations, 250 power charging and battery swapping stations and 210 smaller delivery stations.[597]

While it stands beyond a doubt that the Chinese government is taking the leading role in the promotion of EVs related infrastructure, it has become subject to some debate whether or not it is positioned to successfully build up a nationwide charging network. Since government organizations throughout the country have improved governance standards, harbour a strong growth orientation and are unified under the rule of the Communist Party, conditions certainly appear very favourable. Investigating the stakeholders of vehicle electrification, it can be found that utility companies, grid operators, automakers, banks, research institutes and standardization authorities are largely owned and controlled by the government. Without major interference from private business, environmental groups, political opposition or social movements, it is easy to conclude that the Chinese government can devise the concerted effort necessary for a rapid expansion of smart grids and EV charging infrastructure. This image, however, has been found to be fundamentally flawed as recent disputes about basic technology standards have illustrated.

Within the state sector alone, two major problems blocking any quick expansion of EV support infrastructure can be identified: (1) regional governments contending with each other to protect local companies and (2) very large state-owned enterprises fighting over commercial interests. Firstly, regional governments are contending to establish themselves as major centres for the fledgling EV industry and aggressively support local OEMs to become industry leaders. Beyond other means of industrial policy discussed elsewhere in this paper, provincial and municipal authorities have seized the opportunity to define local norms and standards as a means to promote local players and keep the competition out. This situation was made possible by the central government's long hesitation to establish uniform communication protocols binding for all automakers across the country and comprehensively regulating all major aspects of charging technology has opened the door for regional governments and individual automakers to define their own standards. Municipal governments of Hefei (home to Jianghuai Auto), Shenzhen (home to BYD) and other cities have readily set local standards to accommodate local OEMs and protect their home market.[598] The multitude of coexisting standards has greatly complicated the expansion of a nationwide infrastructure and discouraged consumers from buying EVs. In a nutshell, the blooming patchwork of standards has effectively broken down China's potentially large EV market into small, locally centred parcels.

[592] Cars21 (2012d)
[593] Cars21 (2011d)
[594] Reuters (2012c)
[595] Fourin (2012c)
[596] China Automotive Review (2011)
[597] Cars21 (2012b)
[598] Cars21 (2012d)

In a long awaited move, the central government has released a unified framework of standards and norms in early 2012.[599] Unification of the various standards used by the time of writing in April 2012 will undoubtedly become a formidable challenge for government authorities on all levels consuming a significant amount of time for adjustment negotiations and further delaying the realization of China's potentially large market potential for EVs. The EV charging station at Gao'antun, located in Beijing's Chaoyang District, illustrates the current problems. During a visit of the facility in April 2012, it was confirmed that over ten different power charging and battery swapping standards are supported. However, the station, heralded as one of China's largest and most modern of its kind, also showcases the determination for massive investments in the improvement of supporting infrastructure for EVs. Equipped with a total of more than a thousand chargers and several battery swapping machines, the installation can service up to 400 vehicles (mainly sanitation trucks) on a daily basis.[600]

Secondly, a struggle has erupted between two groups of enterprises to capture the future business expected to come from the wholesale transition to electric mobility. These companies represent an important part of the Chinese economy, are highly profitable and equipped with strong political influence since they are all directly owned and controlled by the central government. The dispute centres on the question, whether power charging or battery swapping should be chosen for nationwide implementation. One group, mainly consisting of automakers and petroleum companies, favours the charging approach: Sinopec, PetroChina and China National Offshore Oil Co. (CNOOC) all operate large networks of fuelling stations and intend to upgrade these with power charging facilities to capture new business opportunities and prevent existing installations from becoming obsolete in the future. [601] In order to get footholds in the power charging market, CNOOC partnered with state-owned Potevio, an IT and telecom company, to set up Potevio-CNOOC New Energy Power Co. Established in 2009, the joint venture company has constructed several charging stations in Shenzhen and strives to expand operations to other parts of the country. Sinopec's Beijing Oil branch has announced a plan to construct or refurbish a total of 275 installations to serve as integrated refuelling and recharging stations during the 12th FYP period. To this end, the company has teamed up with Beijing Capital Group to found Beijing Sinopec Xinke Energy Technology which is tasked with converting Sinopec's existing filling stations into integrated refuelling and recharging installations. In November 2011, the joint venture launched trial operations at the first such facility located in Beijing's Daxing Caiyu Economic Development Zone.[602]

The opposing group is predominantly made up of the two grid operators State Grid and Southern Grid which push for the adoption of the battery swapping model made famous by the Israeli company Betterplace. Tasked with upgrading and expanding the national electricity network, these companies are heavily engaged in setting up smart grids, ensuring the transmission of power generated from renewable energy sources and creating the backbone infrastructure required for a large EV population. Grid companies posit that battery swapping constitutes a superior alternative to power charging as current technology does not allow for fast DC charging without damaging vehicle batteries and regular AC charging is too slow and unpractical to be implemented on a large scale. [603] According to experts consulted for the preparation of this report, State Grid has started to set up large battery swapping centres in a few large cities. Initially, these centres serve to replace batteries powering public transit vehicles but State Grid has plans to expand their operational scope to support battery swapping for smaller vehicles in the future as well. In the context of China's national energy policy that seeks to raise the share of renewables in the overall energy mix,; large, centralized battery storage facilities can serve to consume excess energy generated at off-peak times for use in the transportation sector. Following a number of pilot projects tied to the 2008 Olympic Games in Beijing and the 2010 World Expo in Shanghai, a small number of swapping centres have entered regular operation until 2012.

Car manufacturers, confronted with the daunting task of redesigning their vehicles to accommodate battery swapping, have voiced strong opposition according to industry representatives. While the development of EV models that support both battery swapping and power charging significantly increases production costs, OEMs fear the weakening of their bargaining position both vis-à-vis battery manufacturers and within the automotive value chain in general. As battery designs are likely to be unified for the sake of cost cutting as well as complexity reduction and time saving, OEMs' business may be reduced to building vehicles around a standardized battery.

[599] China Daily (2011b)
[600] Cars21 (2012b)
[601] SGT Research (2012)
[602] EcoBusiness (2012)
[603] Ibid.

According to data collected by Fourin in December 2011, except for Tibet, each of the 31 provinces, autonomous regions and cities directly under the central government have already installed both conventional as well as fast charging infrastructure – albeit in differing numbers. A further 17 sub-central jurisdictions had also set up battery swapping stations with the lagging 14 provinces predominantly located in sparsely populated and economically less developed areas, such as Yunnan, Qinghai and Xinjiang.[604]

Experts interviewed for this report were divided in their opinions concerning the underlying reasons for the coexistence of multiple charging standards. While some maintained that this situation resulted from a weak position of the central governments vis-à-vis regional authorities, others have interpreted the situation in the context of past Chinese development strategy which has traditionally emphasized local pilot projects for testing new economic approaches.

With regard to joint initiatives on the international level for a harmonization of norms and standards, experts reported that initially, Chinese government organizations had shown little interest. It was perceived that Chinese policymakers were set on pursuing a leapfrogging approach and singlehandedly define standards for EVs and supporting infrastructure. As the ambitious development goals put forth in earlier government plans increasingly proved unattainable due to a slower than expected progress in advancing key technologies, reducing costs and capturing consumer interest, the Chinese side has assumed a more accommodative and co-operative stance toward joint initiatives. This process has culminated in China not only participating in the working group meetings of the international standardization organizations in Geneva, but accepting the invitation to take the helm in these proceedings.

3. State support

Unfortunately, it was not possible to gauge the amount of public funds channelled to manufacturers of new energy vehicles due to a lack of information publicly available. However, a combination of tax privileges and subsidized loans are considered to be the prime elements of direct funding support. Furthermore, it should be noted that as OEMs receive the purchase subsidies paid for domestically produced electric cars, they have exclusive access to a revenue stream unavailable to international competitors who import their vehicles into the Chinese market. Considering the rather small number of EV sales today, this source of funding probably does not constitute a major advantage. Should sales pick up in the future, for example thanks to technical breakthroughs that reduce the price gap between conventional and electric vehicles, this support mechanism may well gain in importance.

4. Consumer Information Needs

Government authorities and manufacturers have joined hands to showcase new energy vehicles to the public. Urban residents are likely to get in to contact with EVs with increasing frequency as the number of public busses and taxis with electric drive technology is growing. While car rental and car sharing businesses are still in their early stages of development, these too, have started to make an impression.[605]

Furthermore, authorities and companies have successfully capitalized on high profile events to showcase electric cars and advertise them to the general public. Electric shuttle busses and free test driving opportunities were commonly used to raise awareness at events, such as the 2008 Beijing Olympics, the 2010 World Expo in Shanghai, the Asia Games in Guangzhou in the same years or the 2011 Universiade in Shenzhen, in 2011.[606]

A notable approach is the establishment of EV pilot zones, such as the Jiading International EV Pilot City in Shanghai's Jiading District, which is also home to Shanghai Automotive Industry Co. The zone, which was visited during an information gathering trip to China in April 2012, concentrates dealerships, services centres and a test drive centre in one place, making it convenient for potential buyers to familiarize themselves with electric cars. Since the zone also hosts related government departments and provides convenient charging opportunities, it is laid out as a one-stop-shop.

[604] Fourin (2012b)
[605] Cars21 (2011e)
[606] UK Trade & Investment (2010)

Most experts interviewed for this report agree that Chinese consumers are reasonably well informed about major characteristics of EVs and have a basic understanding of their advantages and disadvantages. Besides the joint initiatives by companies and authorities outlined above, the exposure to electric transportation technology has been strong thanks to two forms of electric mobility which have already gained increasing popularity in recent years. Firstly, electric scooters have made rapid inroads to establish themselves as an important means of urban transport. The transition from gasoline powered scooters has been rapid – a result of sweeping regulation banning their use in city centres. With China being the world's largest producer and consumer of electric two-wheelers, the total vehicle population has grown to about 120 million units in 2012. This serves to indicate a general acceptance of battery powered vehicles among the urban public. Secondly, in rural areas, low-speed EVs have become a common sight as they are reasonably cheap with prices starting at RMB 30,000.[607]Developed by producers of agricultural machinery in Shandong Province, LSEVs are intended to address increasing mobility needs in China's less developed rural areas. These vehicles use lead-acid batteries as an energy source, are made of fiber-reinforced plastic and generally lack the extras which make the ride in a conventional modern car a comfortable experience. In spite of a top speed below 60 km/h and a maximum range per charge of no more than 100 km, LSEVs have become very popular throughout the country.[608] As opposed to electric two-wheelers, authorities have denied official recognition of these vehicles due to the low technology content and safety concerns. Although annual production volumes have exceeded 50,000 units in 2011 (more than six times the combined production volume of regular BEVs and PHEVs) authorities continue to deny official registration of these vehicles for use on public roads and do not include them in the catalogue of certified new energy vehicles.

Overall, it can be found that electric mobility solutions have been adapted to meet demand conditions in both rural and urban areas. The rising popularity, as expressed in surging sales, demonstrates that Chinese consumers are prepared and willing to make the transition from conventional ICE powered vehicles to electric drive technology. The role of government authorities has been ambivalent, since they did not encourage electric mobility per se but acted selectively to seek out the solutions that were either most critical for addressing urgent needs (improve the air quality in city centres by banning gasoline scooters) or promised to yield the most development potential through use of high technologies (promotion of BEVs and PHEVs).

This finding is confirmed by a BCG survey from 2011 which suggests that Chinese consumers are better informed and more curious about alternative vehicle propulsion systems as compared to their peers in the U.S. and the EU. At the same time, the survey also indicates that consumers in China hold more favourable attitudes towards four key propulsion technologies[609] than those in the two other regions. While Chinese car buyers were the least likely to accept higher sticker prices for EVs, they proved to be the group most willing to choose an electric car if higher upfront costs could be compensated by lower operating costs over the vehicle's useful lifespan.[610] A separate survey confirms that consumer interest in EVs in China is extremely high but suggests that while potential buyers were willing to pay a price premium, they expected unit prices to be rather low.[611] To what extent these favourable consumer attitudes are the result of government messaging and demonstration projects, as suggested by BCG[612] or have to be explained otherwise cannot be verified here due to time and space constraints.

However, it may be important for the government to push ahead with information and education campaigns as Chinese consumers were found to harbour a preference for representative cars that may serve to illustrate their social status or individual success. KPMG (2011) quotes a senior Volkswagen manager as saying "People in China want to be seen driving imported premium cars, including SUVs, even though high duties make them far more expensive."[613] Given that the relatively wealthy consumers who can afford the comparatively expensive EVs are very conscious of their personal image and the ways in which their choice of private vehicle may reflect on it[614], government campaigns have already sought to improve brand recognition and increase the social appeal of EVs.

[607] Zhou, Lei et al. (2010)
[608] Ibid.
[609] Clean diesel, compressed natural gas, biofuels/ethanol, hybrid and electric/plug-in electric vehicles
[610] BCG (2011)
[611] Deloitte (2011)
[612] BCG (2011)
[613] KPMG (2011) p. 10
[614] CNN Money (2010)

5. Government procurement

EV procurement by government authorities has been particularly strong in areas such as public busses, sanitation trucks and other commercial vehicle types. In 2009, the first year of the 10 Cities 1000 Vehicles project, the MOF allocated RMB 1 billion for purchasing electric city busses. Municipal governments have been quick to seize the opportunity, as they could claim up to RMB 500,000 in subsidies for every EV they bought.[615] However, with 26 companies manufacturing pure electric or plug-in hybrid busses, production activities are spread across the country. It was reported that local governments favour producers located within their jurisdiction during the procurement process. An industry insider was quoted as saying that municipal authorities im Changsha, the capital city of Hunan Province, were determined to purchase the first 200 electric busses from BYD and did not consider any other suppliers even though procurement was based on a public bidding process.[616]

Regarding passenger cars and light commercial vehicles, the Chinese government had released a catalogue of models approved for government purchase in February 2012. The list contained a total of 412 car models, including five PHEV and BEV models[617] but restricts the choice of government officials to Chinese brands exclusively presumably to improve the image and recognition of domestic automobile brands.[618] Since most trips made by public officials only cover short distances and take place within urban centres where recharging facilities are becoming more common, EVs have been dubbed a suitable addition to government fleets.[619] While it is notable that NEVs have finally been included in government procurement programs outside of pilot areas this does not imply a rapid shift towards green vehicles as the newly released catalogue also contains 78 different SUV models.

6. The role of local governments

Due to space restraints, the diverse role of sub-central government organizations in the transition to electric mobility in China cannot be discussed in detail. It should be stated, however, that local authorities across China are providing substantial resources to both the development of electric cars and the creation of suitable environments for their operation. The readiness to support the development and popularization of electric drive technology typically stems from the need to maintain economic growth, attract investment, create jobs and upgrade the local industrial structure. Supporting the development and production of complete vehicles or major components thereof presents an opportunity to build up high technology bases which may bring significant development potential and constitute a cornerstone for future growth. Since the personal careers of government officials in China are controlled by an elaborate performance evaluation system that draws heavily on economic factors, cadres have an intrinsic interest to promote growth opportunities coming from industries which promise future growth.

While contributing to a pro-growth mindset, this system has significant negative side effects. Since most EV promotion programmes organized by the central government depend on local authorities for project implementation and subsidy disbursements, provincial, municipal and town governments have significant policy space. One of the downsides of this situation is market fragmentation and local protectionism, which may take the form of preferring local companies in official procurement procedures, the formulation of local standards intended to keep “imports” from rivalling localities out of the local market, the establishment of buying subsidies restricted to local products or the direct subsidization of local companies by way of cash grants, low-interest loans and/or tax privileges.[620] Statistics comparing the performance levels of 25 cities participating in the 10 Cities, 1000 Vehicles Programme reveal that municipalities with an automaker inside their jurisdiction have launched far more EVs than those without a local automotive industry.[621]

In Summary, the Public Policy Program currently implemented in China appears to be very comprehensive, combining a broad range of instruments with a clear focus. All of the categories highlighted by the interviewed experts as important and desirable instruments in the fields of public policy can be identified in their Program,: namely direct and indirect support, as well as public purchasing incentives and specifically a facilitating set of regulations, the provision of adequate infrastructure, government procurement initiatives and purchase premiums. As the Worldbank pointed out in 2011, “China has

[615] Electric Vehicle Times (2012)
[616] Ibid.
[617] Jianghuai Auto: PEV, BYD: F3DM, Chery: M1-EV, Chang’An: MINI EV and Jiangnan: E300.
[618] Cars21 (2012a)
[619] Cars21 (2011f)
[620] Electric Vehicle Times (2012)
[621] Fourin (2012b)

launched possibly the world's most aggressive program to transition its public and private vehicle fleet to fully electric and electric-gas hybrid vehicles."[622]

This highly potent public policy approach, however, seems to be seriously inhibited, appearing unable to yield its full potential due to frictions between the players involved. Local governments, while in principle subordinated to central government policies, are still invested with sufficient autonomy and room to manoeuvre enough to follow their own interests and implement (hidden) agendas. By protecting and/or promoting their specific local enterprises at the expense of a unified national thrust towards electromobility, China's local governments are therefore substantially weakening the, in principle, very well designed central public policy approach. Another issue, still open for debate is the question of whether Chinese governments at all levels are not asking too much from their enterprise sector, which appears to lack the necessary human capital and skills to fully respond to the incentives and strategic goals spelled out in China's political drive towards electromobility.

BYD – a company with roots in electronics, battery and automobile manufacturing – appears uniquely positioned and seriously committed to pushing EV development forward. Facing the same wary consumers as its peers, the company has turned to become a supplier of commercial passenger vehicles, e. g. taxis and buses. While this strategy seems well suited to the current market environment, it has to be questioned if excitement for EVs can be created among Chinese car buyers with vehicles they only know as taxis. Will private auto purchases - which typically have a strong emotional component - be swayed this way? Without further research, the question cannot be answered with any degree of certainty, but serious doubts remain that this approach will succeed in a market trending towards larger and more representative premium vehicles.

As many local government agencies - even those selected for participation in demonstration projects - have defied pressure from Beijing to adopt EVs into their fleets, it appears highly questionable if government procurement may constitute a means to create sufficient production volumes to generate economies of scope and scale – let alone incentivize the general public to follow its lead.
As the overwhelming success of the e2w popularization has illustrated, the implementation of non-monetary incentives in the form of reverse subsidies may hold the key to success. By exempting EVs from newly instituted license plate auctions, authorities have increased the market value of these cars and allocated measurable monetary benefits to its buyers. At the same time, it lowered the market value of conventional vehicles and reduced the de facto price gap between the two buying options. Remarkably, this has been achieved without the disbursement of public funds.

In fact, the Chinese government has created a market for the rights of vehicle ownership and usage, both of which used to be public goods. It has assigned prices to these rights and eventually employed this setting to reward EV purchases. Similarly, Chinese authorities have created monetary value for buyers, owners and users by exempting EVs from mandatory inspections, reducing parking fees and lowering electricity rates. Some privileges granted to EVs have no measurable monetary value but still have the potential to significantly improve their usability, i. e. exemption from license plate lotteries or parking permits in prime locations. These scarce goods for which no market price exists may well provide a powerful purchasing incentive. The basic idea is to couple (costly) e-vehicles with exclusive access to goods and services, which can be provided by government agencies (regulators) at no or little costs to themselves. Such instruments may become a corner stone of public purchasing incentives targeting private households as, with little public outlays and hardly any tax revenue losses, they come at little cost for government budgets.

All major countries studied have already initiated a considerable range of policies in various fields, including direct and indirect support as well as public purchasing incentives. In research promotion efforts, key components like battery technology are particularly noteworthy. For Japan and Korea, such support seems to create considerable comparative advantages. Public purchasing incentives in terms of designing and testing an infrastructure framework also play a role in both countries. With respect to supporting the purchase of cars, Japan is leading the field, but it can be expected that Korea will soon use similar measures to support sales.

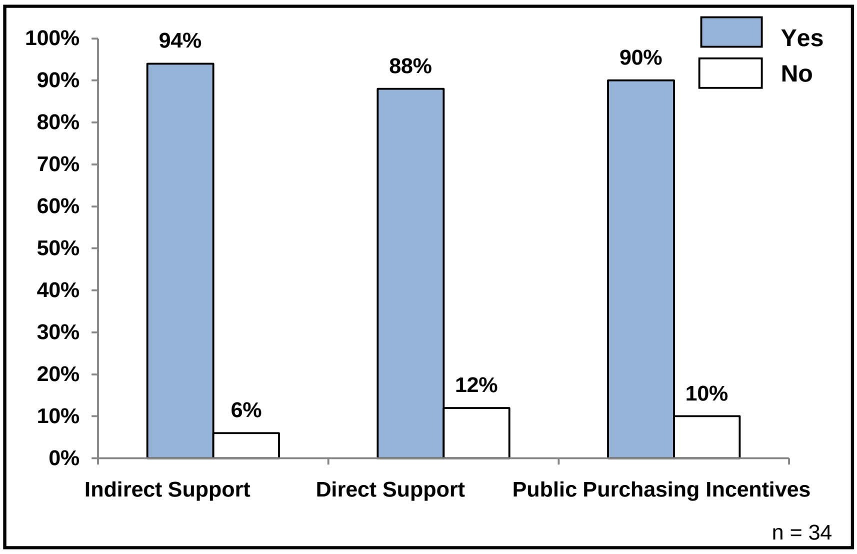
[622] Worldbank (2011): This view is shared by private sector representatives such as Kevin Wale, head of GM China Group who states that "China's government is supporting electric-car technology more than any other country on earth" (CNN Money (2010).

5.2 Future Regulatory Needs

The majority of the experts interviewed consider direct and indirect support technology as very important and indispensable in transition to electromobility. Particularly the OEM experts emphasise, that basic research cannot be taken over by the market and their players. In this case, the European experts have stressed, that technology support should not focus on a special power train technology (e.g. the Korean focus on battery electric vehicles). Funding should enable long-term planning. The players benefit from certainty and continuity.

The following figure presents an overview on the future tasks of public policy in transition to electromobility rated by experts.

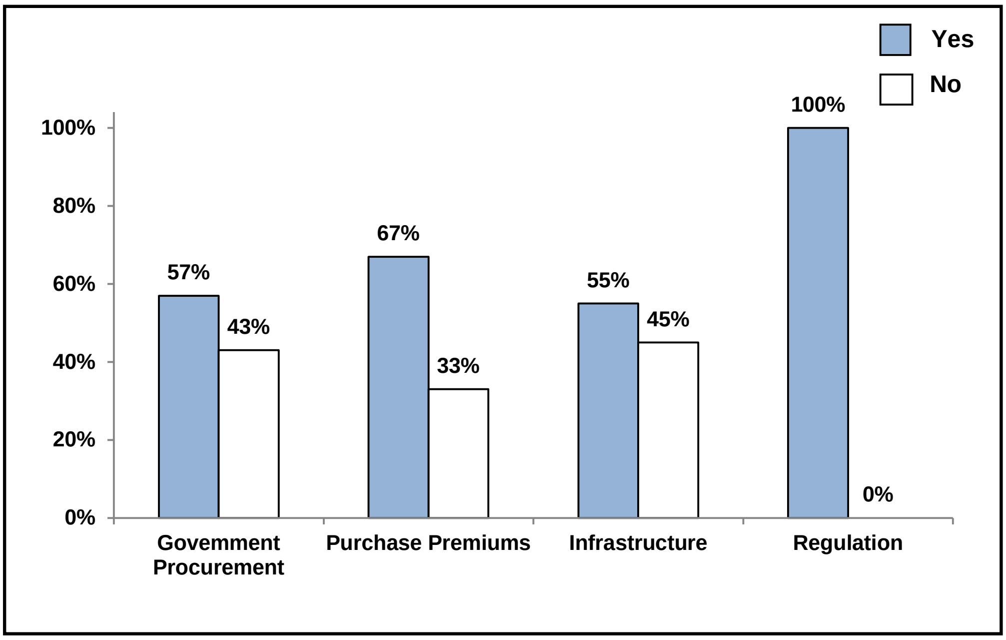
Figure 62: Results of the Expert Survey concerning Future Tasks of Public Policy in Transition to Electromobility



(Source: Own Compilation according to Expert Interviews)

In terms of the future tasks of public purchasing incentives the responses were very heterogeneous among the experts interviewed (see Figure 63). All of them agree that regulation is a very important non-monetary instrument (100 percent approval), but their responses varied in their evaluation concerning government procurement, purchase premiums, and “infrastructure” incentives.

Figure 63: Results of the Expert Survey concerning Future Tasks of Public Purchasing Incentives in Transition to Electromobility



(Source: Own Compilation according to Expert Interviews)

While the majority of experts from industry argue in favour of the implementation/extension of purchase premiums, scientists and policy makers are rather sceptical. However, purchasing premiums can boost sales. Nevertheless, our market model shows that purchase premiums will result in no significant improvement of the utility-cost index in the short term, because even with an offer of purchase premiums with an amount of 5,000 Euro the threshold will not be exceeded. In principle, purchase premiums should be used in a limited timeframe, they should not favour certain technologies, but all ecological friendly vehicles. In this case, emission limits could be a helpful assessment basis. Purchase premiums must not lead to a distortion of competition.

Furthermore the majority of the surveyed experts consider public procurement as a “drop in the ocean”. With the exception of China (almost 1 million registered vehicles by public authorities per year), public procurement will likely not contribute to any significant market development in most of the countries. Nevertheless, public procurement has an exemplary role. In the EU, France has currently taken a leading position. Originally, a public procurement of 50,000 vehicles was announced. The consortium of buyers (ADP, Air France, Areva, Bouygues, EDF, Eiffage, ERDF, France Télécom Orange, GDF Suez, Suez Environnement, GRT Gaz, GrDF, La Poste, RATP, le consortium d'aide aux collectivités SAUR, la SNCF, le groupe SPIE, l'Ugap, Veolia et Vinci) were driven by the purchase plans of La Poste. CEO Jean-Paul Bailly has committed to purchase 10,000 Renault Kangoo ZE in 2011, which should be delivered up until 2015.In October 2011, the ambitious goals of the purchase plans were reduced, because Renault could not deliver fast enough. The state fund FSI withdrew from the battery production by the mid of last year, and thus reduced the certainty of investment. Altogether, about 23,000 vehicles have been actually ordered as of today.[623]

The influence of a preferred use of infrastructure (e.g. high occupancy lanes), is rated rather low by the experts, because these benefits "... will not lead to an increasing amount of registrations!" Instead, regulation is considered as especially helpful to promote the market penetration (and technological development) of electric vehicles. Emission limits, entry restrictions (e.g. downtown) or regulations concerning the taxation of company cars represent reasonable non-monetary measures in the view of many experts interviewed.

The majority of the experts interviewed stated that the promotion of R&D (especially basic research) and the development of infrastructure are most important, while the development of manufacturing operations is predominantly done by the market. According to the manufacturers, the promotion of

[623] Ugap (2011); Challenges (2011)

efficient production technologies could be more helpful than a promotion of component manufacturing in the EU (e.g. industrial subsidies).

Most of the Asian experts consider the promotion of infrastructure as necessary in order to build up a market for electric vehicles. Presently, most of the countries (even in the EU) have different structural and local conditions. Among the European experts particularly the Italians, regard the build-up of infrastructure as very important:

"Only if the customers know where they can charge their vehicles, will they acquire an electric vehicle. Only a few people in this country have a garage! In the small alleys of Rome there is limited space to implement an infrastructure for electric vehicles."

The Chinese experts also consider the development of infrastructure as a key driver in the transition to electromobility, followed by standardisation. The compatibility of components will result in cost savings and increase competition. Furthermore, the Korean and Japanese experts evaluate the development of infrastructure as very important, followed by the support of R&D. Japan is currently the advanced economy with the highest public indebtedness. Its gross public debt is twice the size of its yearly output in terms of gross domestic product. From that perspective, asking about a shortage of funds for electromobility support and about alternative scenarios is a highly sensitive issue. Raising taxes is a highly controversial issue in Japan. In early 2012, the government tried to defend a raise in the consumption tax from modest levels of 5% by earmarking the additional revenues for social security. Even such a programme finds difficult acceptance by voters. It is hard to imagine that voters would accept higher taxes for an even less “emotional” target like technology. From a different perspective, supporting new technologies has always been a prime priority of Japanese governments, even throughout the difficult so-called “lost decades” since the 1990s. One can thus assume that the government, in case of serious funding shortages, would rather look for cuts elsewhere than to undermine strategic technology fields.

As for Korea, public debt is much more manageable, although even there the public is concerned about fiscal exuberance and is much more conservative than elsewhere about seemingly “spendthrift” government programmes. Public policy very much depends on the initiatives of new presidents of the republic. A new president will be elected (for one term only) in late 2012, and it will very much depend on his/her priorities how technology support will fare. Currently, there is a disposition to strengthen social policy issues in the future. In case of funding shortages, this could mean a tough period for an ambitious electromobility program. For the current but outgoing government, electromobility related measures were packaged inside the Green Growth initiative introduced during the global financial crisis, but this project is so associated with the current president, that it is an open question as to what extent a future government, particularly if under pressure, will keep its commitment to ambitious electromobility programs. From a different perspective, though, supporting new technologies is usually seen in the Korean public as a huge success story of having raised South Korea from the ashes of the Korean War to advanced economy status, so pressure in light of certain continuity can be expected.

Interestingly, a reduction in EU tax revenues from fuel sale resulting from the use of electric vehicles is considered as less problematic in the near term according to most of the experts interviewed. Since the market share of electric vehicles will be small in the medium term, the additional loss of fuel tax is expected to be small as well. According to most of the experts, effects on fiscal revenues are not expected before 2025 or 2030. However, by 2025/2030 it will certainly be politically difficult to enforce tax increases. Therefore it makes sense to think about alternative ways of obtaining revenues from the automotive sector beforehand.

5.3 Public Policy Framework – Conclusion

All major economies studied in this chapter have already been using a wide spectrum of direct and indirect support as well as public purchasing incentives (see Table 45). This corresponds to results of the expert interviews undertaken for this study (see Figure 62).

The Public Policy Framework implemented in **China** appears to be the **most comprehensive and ‘aggressive’ of all electromobility programs** discussed in this study. However, in how far it will eventually lead to desired successes is doubted. These doubts are based on the insight that China’s national drive towards electromobility is facing substantial **resistance at local levels, where particu-**

laristic interests are incapacitating central government initiatives. Furthermore, recent developments in China seem to prove once again, that technological leapfrogging is very difficult for companies in emerging economies if the gap is very large. China's industrial sector appears to be overchallenged by the targets outlined in policy documents by all levels of government and still rely on support by established foreign players to tackle more complex problems. Once the major technological problems are solved, the mobilisation of demand appears to be only a minor challenge. Nevertheless, leapfrogging is often the only option if competencies are missing in an industry - and can only work, if the government is supporting it, as the examples of Japan and Korea after World War II indicate. Furthermore, it is out of the question, given the massive concentrations of pollutants in Chinese mega cities, for solutions within conventional engine technology to be made; China must move beyond the internal combustion engine technology into the new frontier of electromobility. China´s comprehensive Public Policy Framework comprises e.g. financial incentives to buy BEVs and PHEVs in six cities as one measure public purchasing incentives, indirect support through new enterprise income tax laws and research financing as well as direct support for companies that engage in the production of EVs.

China's policymakers have shown remarkable determination in their efforts to promote electromobility and related technologies. Driven by (1) the desire to open a technology field in which Chinese enterprises can command global leadership, (2) the need to reduce the environmental footprint of the transportation industry, (3) the imperative to reduce the consumption and import dependence of oil as well as (4) the necessity to find creative solutions for accommodating increasing mobility demands; electromobility has been understood to constitute a perfect driver for China's economic advancement in the coming decades. As a consequence, the Chinese government has invested heavily in various promotion and subsidization activities at the corporate as well as the private household level.

However, the results of massive public policy programs have been disappointing. The various policy initiatives have proven unfit to trigger substantial innovation dynamics or create even a minimum of free market acceptance. There is little in these programs that can be recommended to EU policy makers as best practice. Probably the most important lesson to be learned from the Chinese experience is that (without strong intrinsic motivation at the corporate and household level) cash injections alone are insufficient to bring about the desired transition to greener forms of mobility. Although a market buy down strategy could achieve price parity between conventional and electric vehicles, any such attempt would run up prohibitively high costs for the Chinese government and – by extension – Chinese taxpayers. Furthermore, as the example of the introduction of e2w's has shown, it is far from certain that consumers who are not yet fully convinced of the performance, reliability and quality of the new technology (and have been rattled by media reports of tragic accidents involving EVs) can be won as buyers. Despite large investments, the hen and egg dilemma, which has crippled development and sales of EVs, has not been resolved. The corporate sector will not commit itself to a significant re-orientation of its R&D and production activities as long as private households will continue to buy traditional ICE technology and vice versa.

Next to the world-class competence Japanese automobile makers possess in relation to the development and production of vehicles, coordinated efforts between the private and public sector can be regarded a key factor of success. Public policy in Japan contributed to the country's leading position in terms of electrically-powered vehicles today. Vehicle dispersion targets to be fulfilled by 2010 were formulated and agreed on early as consequence of emission reduction commitments made in the frame of the Kyoto protocol. The development of key components, i.e. lithium-ion batteries, crucial to occupy the first-mover position, was supported by governmental R&D subsidies. The most effective measurement can be seen in the promotion of vehicles sales. Next to tax reductions for purchasing electrically-powered vehicles, the Japanese consumer receives a discount of approximately one-third of the original sales price of the vehicle.

For transferring policy lessons to other circumstances, in particular "lessons learned" for the EU, different institutional characteristics of countries and regions should be kept in mind. As for consumer-related measures, Japanese consumers are known for being particularly attracted to novel products, and they may be tempted to pay premium prices even if the performance of an innovative product in terms of classic performance criteria is still in doubt. Purchasing subsidies in such circumstances may be successful in lowering the critical price threshold for such pioneer consumers, whereas in the EU, consumers tend to be more conservative, giving more weight to conventional price-performance considerations, so even a hefty subsidy may not convince too many consumers.

As for industry-government co-operation, for instance in terms of effective R&D subsidies, it has to be kept in mind that in Japan, such industrial policy for strategic industries has to be quite successfully isolated from capture by laggard companies or regions. Certainly, the Japanese state hasits own issues of misspent government subsidies in the past, but such subsidies were primarily distributed by other agencies in charge of regional matters under political influence, for instance, whereas the Ministry of Economy, Trade, and Industry (METI, formerly MITI) has been rather free from such capture, due to its relatively high status. For such mechanisms to work in different circumstances, like the EU, it has to be ascertained that subsidy-giving or coordinating agencies are effectively isolated from lobby pressure, in order to provide support to such companies that deliver the best results for industry development, not wasting critical support on laggard companies and regions, risking not only the success of electromobility support, but compromising the whole concept of strategic industry support.

Marketization of electric-vehicles just started in Korea. The goal to become the fourth largest market for electric vehicles by 2015 is promoted by R&D subsidies, mainly for the development of lithium-ion batteries. The role of the government in formulating industry development targets, executed by the private sector (the *Chaebol*), is a traditional Korean approach. As of today, the Korean government offers tax incentives for the purchase of electric-vehicles. As the market is still young, development prospects are hard to forecast. In the near future, as mentioned by an industry insider, the Korean government plans purchase incentives comparable to the ones in Japan, i.e. one-third of the purchase price will likely be subsidised. Learning from Korea, basically the same considerations apply as for the case of Japan. For Korea in particular, the case can be made that successful state-industry cooperation relies on a particularly tight top-down decision-making that is informed by national strategic goals, made possible through traditionally tight control from the top of the President's Office through the relevant line ministries, presidential commissions, government think-tanks, etc.

As in the EU the Public Policy Framework in the U.S. is rather complex, with federal programs as well as individual state-level programs. These different programs do sometimes overlap. In the U.S. larger R&D Programs are financed by the government, significant public purchasing incentives are offered as well as direct support for companies producing EVs and parts. To conclude, the public policy framework in the U.S. shows a wide range of measures at the federal level and at the individual state level. Measures between 2008 and 2009 should certainly help to overcome the economic crisis. This chapter shows that in the U.S. indirect support, direct support, and public purchasing incentives are granted in all facets.

Table 45: Overview on Public Policy Frameworks in China, Japan, Korea and the U.S.

	Public Policy Measures			Practical Constraints	
	Indirect Support	Direct Support	Sales Promotion	Multi-level Consistency	Congruence in Fiscal Sources
China	research financing	supporting EV producers	incentives to purchase EVs	- local level particularist interests are incapacitating central government initiatives	+ supporting Chinese producers of EVs
Japan	R&D subsidiaries for central parts	government subsidiaries primarily given by other agencies	high incentives to purchase EVs	+ coordinated efforts between public and private sector	+ subsidizing Japanese producers of EVs
Korea	R&D subsidiaries for the Li-Ion batteries	subsidiary giving	promotion of EVs sales	+ top-down decision making informed by national strategic goals to-wards electromobiity	+ subsidizing Korean producers of EVs
USA	larger R&D programs	supporting producers of EVs and parts	promotion of EVs sales	- different federal and state-level programs that sometimes overlap	+ supporting American companies

(Source: Own Compilation)

Public Policy Frameworks are always embedded in the national/regional context, so that a comparison, which policy measures work best or which countries have the best working support are very difficult to pursue. E.g. it is impossible to create a METI-type innovation support in countries like the U.S. or in core European markets like UK, the Netherlands or Germany. These countries require country/region specific activities. Therefore, we proposed for example a "European Platform for Battery Technology" in chapter 3.2.1.1.1 - see also section 6.3).

What can be stated is, that the obvious necessity to use all types of Public Policy measures in all countries leads to a clear need for a consistent use of these policy measures. This consistency has two dimensions:

1. Between the supranational and nation level (i.e. the central government and regional government level) and
2. Between the three types of policy measures.

According to the results of this chapter and the summary provided in table 45, it is apparent that the Public Policy Framework in Japan and South Korea is much more consistent than that of China and the U.S., particularly in terms of the coordination of the different policy levels.

In transition to electromobility, a congruence of the fiscal sources of the financial support for EVs and the people/institutions that benefit from it is required. Table 45 demonstrates that all regarded countries try to achieve congruence in fiscal sources.

6 Conclusions
6.1 Main Results of the Study

The results of this study underline, that **the European automotive industry will play a major role in the transition to electromobility.** According to the results of our market model, about 7 percent of the EU 27 new vehicle registrations will be electric vehicles[624] in 2020, while a share of 31 percent can be expected in 2030, including passenger cars and light commercial vehicles.

We anticipate a phased transition analogous to the evolution of CO_2 emission limits: initially plug-in hybrid vehicles will capture the market, from 2030 battery electric vehicles will gain importance, and possibly after 2040 full cell electric vehicles will dominate the market.

In terms of the global market, we expect about 86 million new vehicle registrations in 2020, about 99 million vehicles in 2030, covering passenger cars and light commercial vehicles. According to the results of our market model, the global share of electric vehicle registration will be about 9 percent in 2020 and about 31 percent in 2030. The market development in Europe will proceed less rapidly compared to the global market development.

The utility-cost index of battery electric vehicles will change from 44 today to 65 in 2020 and 133 in 2030 compared to vehicles with an internal combustion engine. Furthermore, the utility-cost index of range extenders will decrease from 55 today to 78 in 2020 and 119 in 2030 compared to vehicles with internal combustion engines (100). Presently, the utilities of battery electric vehicles are perceived by customers as less than the costs compared to vehicles with internal combustion engines. Therefore, the utility-cost index is less than 100. The utility-cost index of plug-in hybrids will change from 67 today to 83 in 2020 and 128 in 2030. Apart from that, the utility-cost index of fuel cell electric vehicles will change from 1 today to 8 in 2020 and 54 in 2030 compared to vehicles with internal combustion engines. While the utility-cost relation of all electric vehicles will improve over time, the cost-utility relation of vehicles with internal combustion engines will deteriorate over time.

The industrial plans of the European automotive companies show that three strategic groups will emerge: first movers or innovators, which will develop new, independent vehicle concepts and architectures, then followers, which will focus on an integration of the new propulsion technologies into existing vehicle concepts and finally – in between those two strategic groups the fast followers, who are currently trying to integrate electric powertrains into existing vehicle concepts in particular, while observing the first movers very closely. By building up competencies in specific areas of technology the fast followers can come up with customer tailored, optimized new vehicle concepts only shortly after the first movers.

Despite increasing globalisation and outsourcing, the European value added at factor cost will decrease only slightly in the transition to electromobility. **Altogether, the decrease in value added will be compensated by new business opportunities, particularly downstream activities like new services** (e.g. the infrastructure build-up or energy production of renewable energy).**As a result, electromobility will not a have a detrimental effect on the value added in the EU industry in the long term in general, as there are new business opportunities for the European automotive industry.** For this reason a near constant employment level can be expected.
In terms of services, we expect a decline of value added from 2020 especially in the field maintenance and repair, because electric vehicles will not be as service intense as vehicles with internal combustion engines with higher complexity. However, in terms of new services linked to electromobility (e.g. car sharing, charging, and recycling), we assume, that additional potential of value added will emerge in the long term.

All experts interviewed are convinced, that the economic policy mix (indirect measures including research financing, direct measures like subsidies and public purchasing incentives) will play a major role in accelerating the transition to electric mobility on an EU-wide, national, regional and local level. There is a need for supporting the automotive industry by introducing consistent economically efficient policy measures. Concerning radical technological changes emerging in the upcoming period of 10 to 20 years, assessments are somewhat uncertain. The base case scenario, assuming business as usual without further business policy initiative, corresponds to the estimated average of all involved experts, both the project team and the experts interviewed in this study.

[624]Including Battery Electric Vehicles, Plug-In Hybrid Electric Vehicles and Range Extender

In conclusion, we developed an upper and lower scenario in order to reveal the range of possibilities. Finally, steps to accelerate the path to electromobility will be discussed, especially how the EU public policy can contribute to the development of the EU automotive industry which is both sustainable and competitive.

6.2 Scenarios

In this section two different scenarios will be considered in addition to the base case scenario: the upper scenario, “Accelerated Path to Electromobility” and the lower scenario, “Long Run to Electromobility”.

In order to estimate the upper and the lower scenarios, the main input factors of the market model have been adjusted, particularly the

- Development of fuel prices
- Development of technical costs
- Improvement[625] of electric vehicle and components, e.g. in terms of Range
- Market presence[626] of electric vehicles and
- Potential of ICE-technology in terms of fuel consumption.

In the **“Accelerated Path to Electromobility”** scenario fuel prices will rise by the year 2020 by at least 50 percent in each country market. Furthermore, fuel prices will double by 2030. Due to the increased demand (economies of scale, investment), technical costs will decrease faster than in the base case scenario (see Table 46). The increasing market penetration leads to higher investments in alternative drives. As soon as 2020, the average range of electric vehicles from the current 80-120 km will have been significantly improved. In the upper scenario electric vehicles become relevant for private customers earlier. Both the segments of "unfit Consumer" and "pragmatists" will enter the market earlier. In the medium-term, the technical features of the vehicle, such as range, will have already suited their driving patterns. Due to the improved benefits (reduced costs, coverage, etc.) and a rapid market penetration by 2020 (electric cars are "present" on the road) even the "late adopters" will include electric vehicles in their evoked set from 2025. Private consumers will appear generally more open minded towards electric vehicles. Due to the consistent responses of the majority of experts, the optimisation potential of internal combustion engines in terms of fuel efficiency (25 percent) is assumed to be similar to the base case scenario.

In the **“Long Run to Electromobility Scenario”** the fuel prices rise much more slowly in 2030 than in the base case scenario. Due to a very low demand (economies of scales, investments), the technical costs will fall more slowly than in the baseline scenario. Therefore, the utility-cost index of electric vehicles will not improve significantly. With the exception of a small group of "green enthusiasts" less private customers will buy electric cars. This lower end case scenario expects a global market development of 85 million vehicles until 2020 and approximately 95 million vehicles in 2030. Due to the consistent responses of the majority of experts, the optimisation potential of internal combustion engines in terms of fuel efficiency (25 %) is assumed to be similar to the base case scenario as well.

The following Table 46 provides an overview on the main characteristics of the three scenarios.

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[625] Leads to an earlier or later market penetration, e.g. “unfit user” will enter the market earlier/later
[626] Leads to an earlier or later market penetration, e.g. inclusion of electric vehicles in the evoked set by the ‘lateadopters‘

Table 46: Main Characteristics of the Three Scenarios

	Accelerated Path to Electromobility (Upper End Scenario)		Base Case Scenario		Long Run to Electromobility (Lower End Scenario)	
	2020	2030	2020	2030	2020	2030
Global Registrations (in million units)	98	120	86.4	99.2	85	95
Market share of Electric Vehicles (PHEV, REEV, BEV, FCV) Global	9%	36%	9%	31%	8%	23%
EU 27	8%	42%	7%	31%	9%	21%
Cost Developent of Additional Technical Components	-60%	-80%	-50%	-70%	-25%	-50%
Optimization Potential of Internal Combustion Engines in terms of Fuel Efficiency	25%		20-25%		25%	
Value Added at Factor Cost EU 27 (in billion EUR)	185	172	141	142	120	103

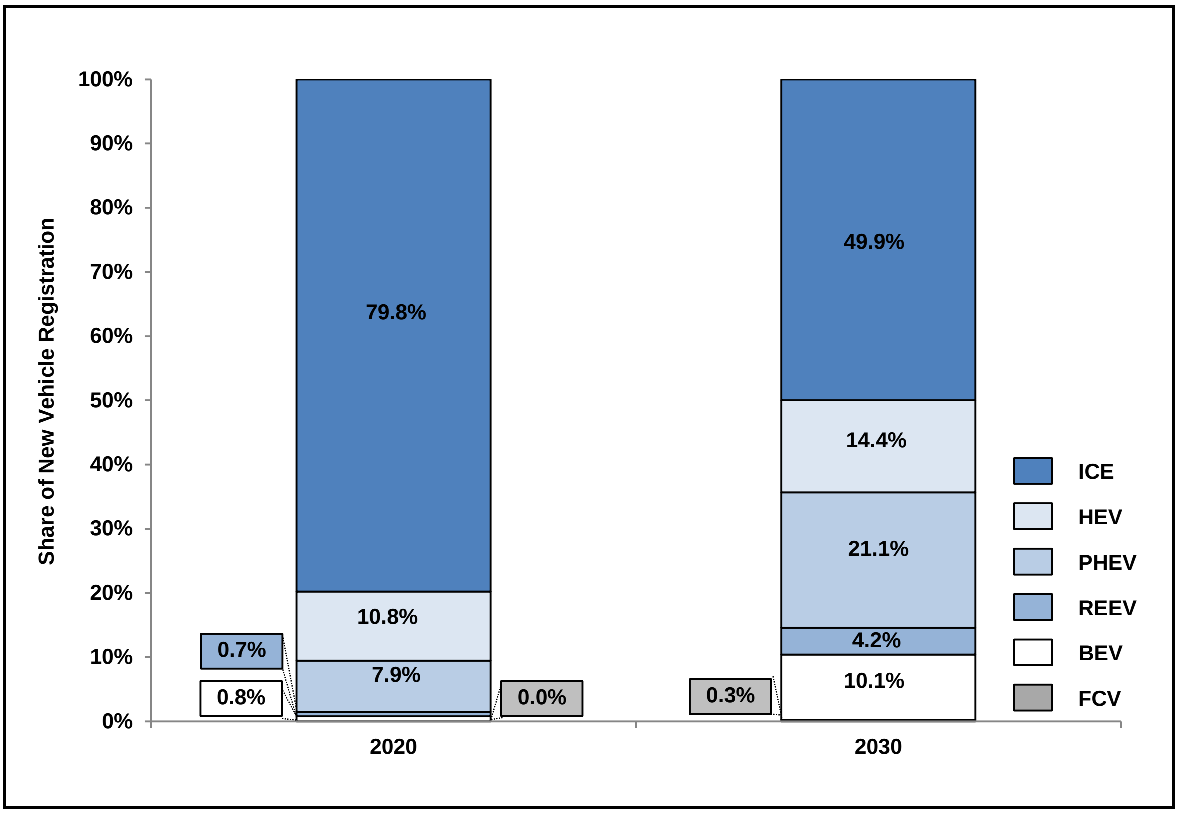
(Source: Own Calculation)

6.2.1 Upper Scenario: “Accelerated Path to Electromobility”

In this chapter, the scenario “Accelerated Path to Electromobility” will be illustrated. Initially, the global market development of electric vehicles will be presented, followed by the market development of electric vehicles in the EU 27 market. Finally, the impact on the value added at factor cost of the EU automotive industry will be calculated.

This upper scenario expects a global market development of 98 million vehicles until 2020 and approximately 120 million vehicles in 2030. The following Figure 64 represents an overview on the global market development of electric vehicles in the scenario, “Accelerated Path to Electromobility”. As Figure 64 summarises, the registrations of vehicles with traditional combustion engines will decline until 2030 (with a share of almost 80 percent in 2020 compared with a share of 50 percent in 2030) while the registrations of electric vehicles will increase rapidly (with 9.4 percent in 2020 compared with a share of about 36 percent in 2030).

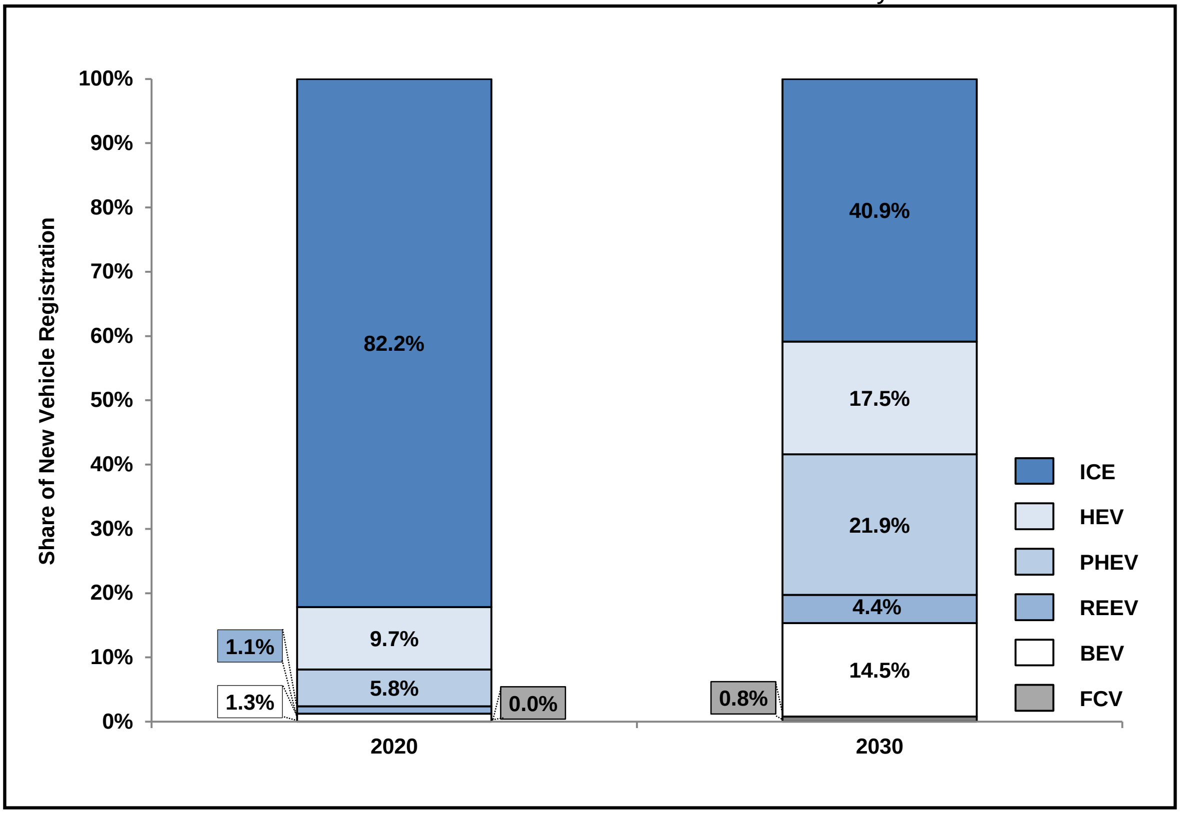
Figure 64: Shares of Global Electric Vehicle Registrations in Percent until 2030 in the Scenario "Accelerated Path to Electromobility"



(Source: Own Calculation)

Similar to the global market development, the **EU 27** market penetration of new electric vehicles based on the scenario "Long Run to Electromobility" will be faster than in the base case scenario as well. As Figure 65 summarises, the registrations of vehicles with traditional combustion engines will decline up to 2030 (with a share of almost 82 percent in 2020 compared with a share of 41 percent in 2030) while the registrations of electric vehicles will increase rapidly (with 8 percent in 2020 compared with a share of about 42 percent in 2030).

Figure 65: Shares of EU Electric Vehicle Registrations in Percent until 2030 in the Scenario “Accelerated Path to Electromobility”



(Source: Own Calculation)

In comparison to the base case scenario, it becomes obvious that both scenarios, “Accelerated Path to Electromobility” and the base case scenario demonstrate a similar market penetration of electric vehicles in the short term. In 2020 the global and European market of both scenarios show only slight differences. Even in a very optimistic scenario, a rapid increase of the market development would be limited by the offer of the manufacturers, especially in the short term. In 2020, a very strong increase in the demand of electric vehicles would probably not be able to be supplied by the market side. This is also reflected by the majority of experts, who have been surveyed in this study. Most of them do not expect a production capacity which is significantly higher than 20 percent in 2020, including both electric vehicles and full hybrids.

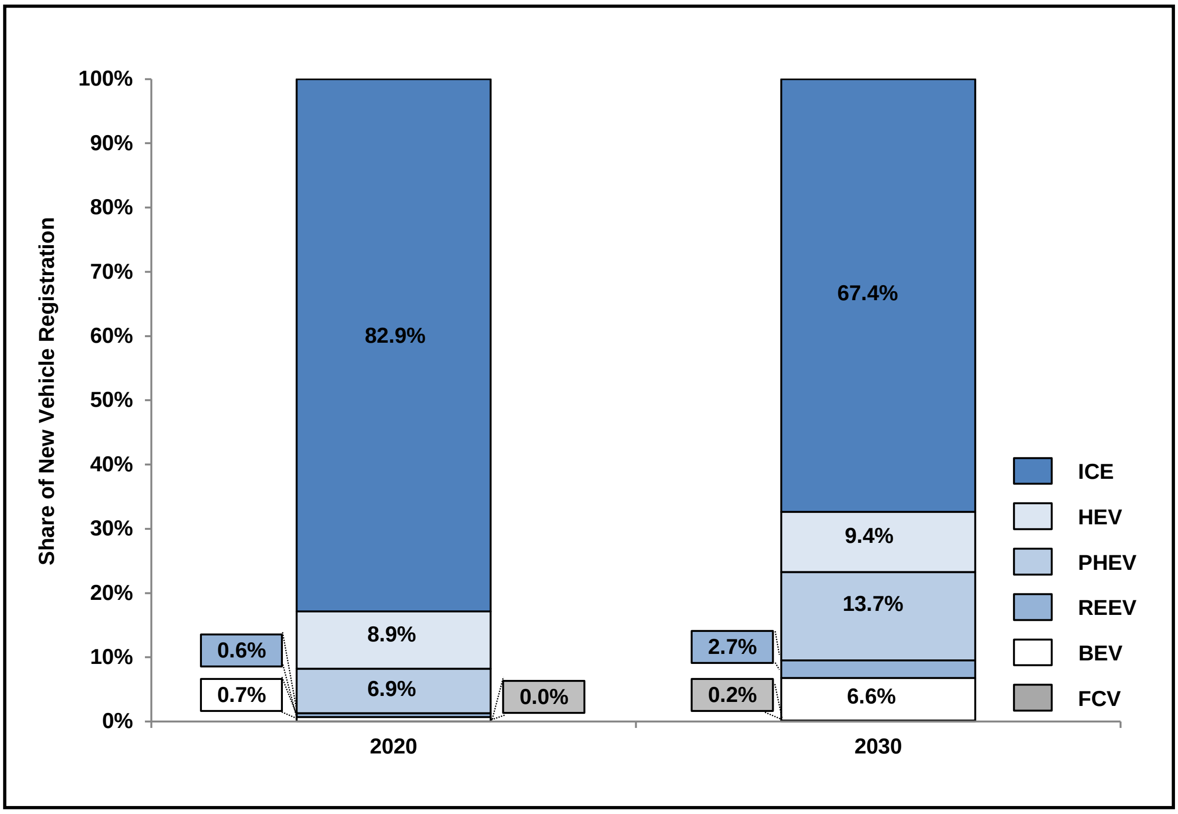
In 2030, the global market share of electric vehicles increases by an additional 6 percentage points, compared to the base case scenario. In the EU 27 market the market share of electric vehicles increases by an additional 11 percentage points compared to the base case scenario.

Similar to the global market development, the value added of the EU in the automotive industry will change. Based on the results of expert interviews, we expect in the “Accelerated Path to Electromobility” scenario an EU production volume of 20.5 million vehicles in 2020 and 22.5 million vehicles in 2030. The majority of experts, who have been surveyed in this study, consider these production volumes as an “optimistic” baseline. The increase of production would lead to a value added at factor cost of 185 billion Euro in 2020 and 172 billion Euro in 2030. Compared to the base case scenario the EU automotive industry would be able to generate an additional value added at factor cost of approximately 30 billion Euro and therefore be able to implement additional employment (see Section 6.3).

6.2.2 Lower Scenario: "Long Run to Electromobility"

In this section, the scenario "Long Run to Electromobility" will be illustrated. Initially, the global market development of electric vehicles will be presented, followed by the market development of electric vehicles in the EU 27 market. Finally, the impact on the value added at factor cost of the EU automotive industry will be calculated.

Figure 66: Shares of Global Electric Vehicle Registrations in Percent until 2030 in the Scenario "Long Run to Electromobility"



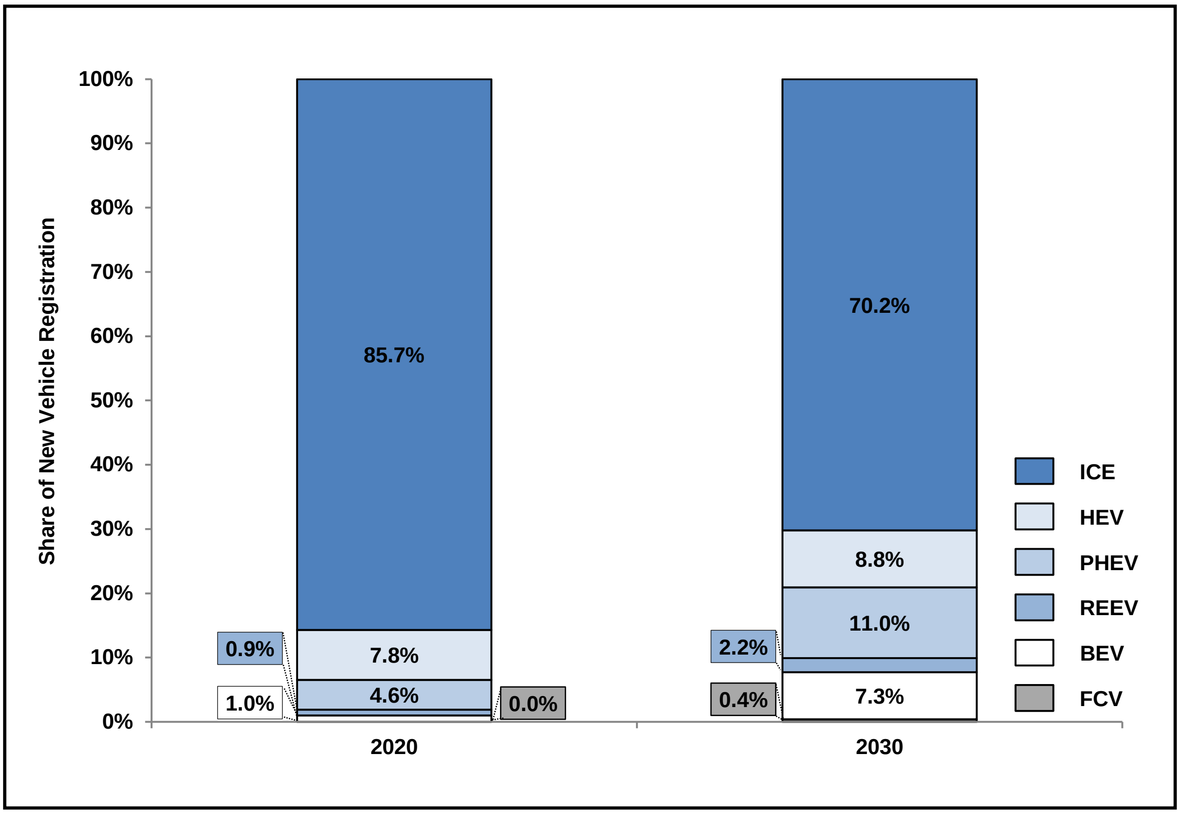
(Source: Own Calculation)

Figure66 summarises the market development of the scenario, "Long Run to Electromobility". The registrations of vehicles with traditional combustion engines will decline moderately (with a share of almost 83 percent in 2020 compared with a share of 67 percent in 2030)[627] while the registrations of electric vehicles will increase (8 percent in 2020 compared with a share of about 23 percent in 2030).

Similar to the global market development, the EU-27 market penetration of new electric vehicles will be more pessimistic in the scenario, "Long Run to Electromobility" as well. As Figure 67 summarises, the registrations of vehicles with traditional combustion engines will decline up to 2030 (with a share of almost 86 percent in 2020 compared with a share of 70 percent in 2030) while the registrations of electric vehicles will increase (9 percent in 2020 compared with a share of about 21 percent in 2030).

[627] Full hybrids vehicles are the calculated difference between the figures of ICE and Electric Vehicles.

Figure 67: Shares of EU Electric Vehicle Registrations in Percent until 2030
In the Scenario "Long Run to Electromobility"



(Source: Own Calculation)

Similar to the global market development, the value of the EU the automotive industry will change. Based on the results of expert interviews, we expect an EU production volume of 16.5 million vehicles in 2020 and 15 million vehicles in 2030. According to this assumption, the production capacity for vehicles manufactured in the EU, will continue to decrease. The majority of experts, who have been surveyed in this study, consider these production volumes as a "pessimistic" baseline.

In comparison to the base case scenario, it becomes obvious that both scenarios, "Long Run to Electromobility" and the base case scenario show a similar market penetration of electric vehicles in the short term. In 2020 the global and European market of both scenarios only show slight differences.In 2030, the global market share of electric vehicles decreases by 11 percentage points, compared to the base case scenario. In the EU 27 market the market share of electric vehicles increases by an additional 10 percentage points compared to the base case scenario.

These production volumes would lead to an increase of value added at factor cost of 120 billion Euro in 2020 and 103 billion Euro in 2030. Compared to the base case scenario the EU automotive industry's value added at factor cost will decrease by approximately 40 billion Euro, employment will also decrease (see Section 6.3). The calculation of the value added in the upper scenario is based on assumptions which have been discussed with experts in interviews. The EU automotive industry will invest less in electric vehicles. The limited market growth will lead to overcapacities. Prices will spiral down (e.g. component prices). The total turnover of EU automotive manufacturing will decrease.In this scenario the EU vehicle production is expected to continue to decline even in the long term, as production volumes migrate to lower wage countries. In the lower scenario the EU-27 production volume of new motor vehicles (passenger cars and light commercial vehicles) will decrease to 16.5 million units in 2020 and 15 million units in 2030. In this scenario, the revenues of EU automotive industry will decrease to 664.5 billion Euro in 2020 (base case scenario: 745 billion Euro) and to 575 billion Euro in 2030 (base case scenario: 751 billion Euro). Profits and employment in the EU automotive industry will decline. The value added will be less analogous.

6.3 Policy Recommendations

The results of the scenario analysis illustrate that policy-makers should make every effort to avoid any additional costs of electric vehicles since a stronger overall market development would contribute to a significant amount of additional value added. Comparing the base case scenario and the upper scenario (“Accelerated Path to Electromobility”), a difference between 44 billion Euro of value added by 2020 and 30 billion Euro by 2030 exists. Assuming that half of this additional value added derives from the labour market and assuming roughly 100,000 Euro total costs per employee (as an average of all employees), the upper scenario would create approximately 100,000 to 150,000 additional (direct) jobs in the EU automotive industry facilitating further jobs in upstream and downstream services. Conversely, in the lower scenario (“Long Run to Electromobility”), the EU automotive industry would generate 20 to 40 billion Euro less value added. This would lead to approximately 150,000 to 250,000 less direct jobs in the automotive industry since downward variations always have a stronger effect on the labour market than upward changes.

However, a realistic assessment of the development of electromobility is important. The scenario analysis shows that only small market shares can be assumed for electromobility by 2020 even in the realistic scenario. In some countries, such as Germany for example, market shares of 5 percent will be reached which is generally considered to be critical for a market breakthrough ("tipping point"). From this point onwards companies can be expected to focus their research and development funding on this technology.

In the face of the present disillusionment with the state of the electric vehicle market in general and the development in China in particular, **European public policy should not stop short of supporting electromobility in a timely and consequent manner**. Since China lacks alternatives to effectively address its pollution problems in urban centres, both government and business give their support to this technology.

The realistic figures of the scenarios show that the overall Chinese market in 2030 will be doubled compared to the EU-27. Thus, it is not to be expected that the technology will remain backwards in the long term. The commercial interests of international OEMs and suppliers from the EU, Japan and the U.S. will reinforce China’s process to electromobility. Even though this may imply a loss of intellectual property, these countries will continue to increase the production and technology development in China.

The European public policy should, therefore, continue to work towards the development of electromobility using a policy mix including policy incentives, industrial policy targets as well as transport and infrastructure policy to reach the “Accelerated Path to Electromobility” and its effects on the value added and labour market. An additional 100,000 to 150,000 jobs (direct employment) would contribute to the strengthening of industrial employment in Europe.

The “Cars 21 High Level Group on the “Competitiveness and Sustainable Growth of the Automotive Industry in the European Union” recently developed its Final Report 2012 with a 2020 vision for the automotive industry (EU 2012). In order to achieve this vision of - among others - a strong manufacturing base with strong industrial networks, a portfolio of propulsion technologies and an appropriate recharging infrastructure, an integrated policy approach is necessary. This is congruent with our perspective as well as with the ideas of the experts interviewed for this study (cf. EU, 2012, p. 4).

In addition to the recommendations of Cars21 high level group, which are focusing on e.g. favourable framework conditions, an integrated policy approach and smart regulation on fair FTAs, we propose five more specific “no regret moves” for the European public policy (see Figure 68):

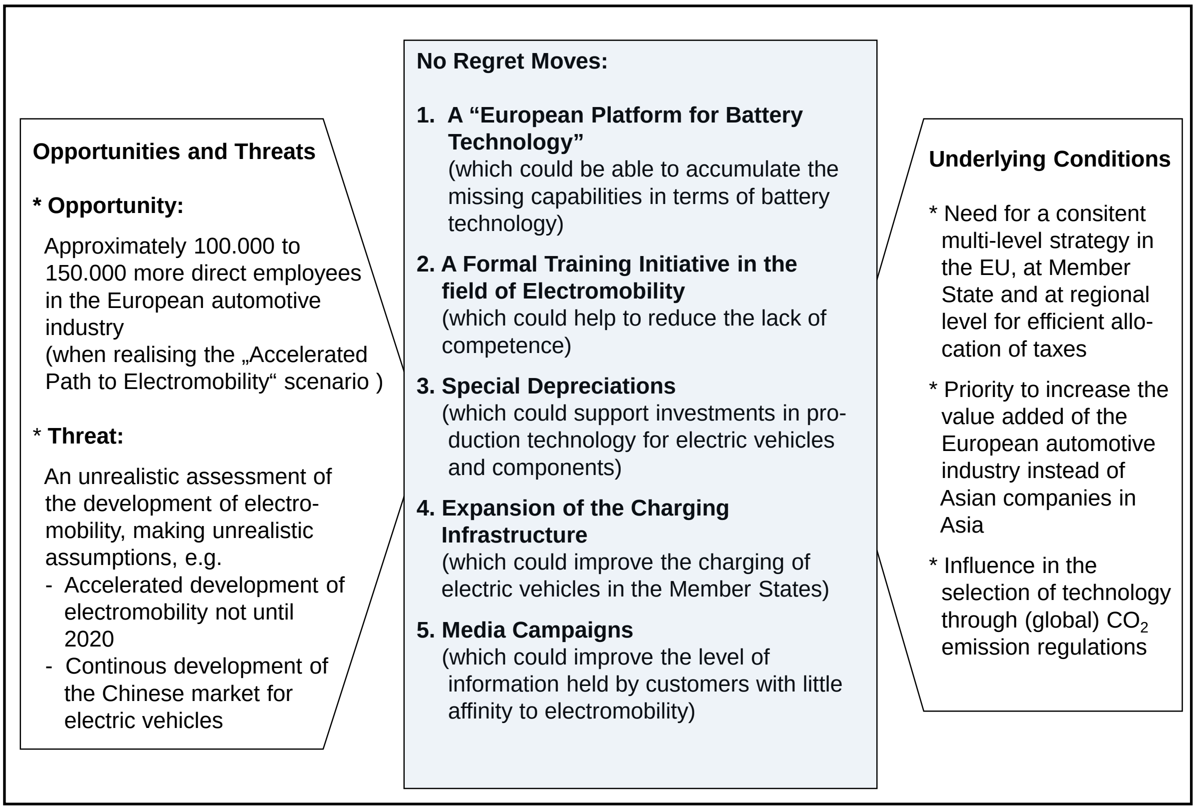
1. A European platform for battery technology to help to develop the missing capabilities in battery technology.
2. A formal training initiative in the field of electromobility to reduce the lack of workers’ competences related to electromobility – likely to be perceived in the medium term.
3. Special depreciation[628]regimes on the national level to support investments in production technologies for electric vehicles and their components.

[628]Certain assets, such as buildings, business equipment, electrical machines and devices depreciate or decline in value over time. An entrepreneur can amortize or write off the cost of such assets over their estimated useful

4. Expansion of the charging infrastructure in order to enable charging of electric vehicles in the individual countries.
5. Focused media campaigns to increase the level of information held by customers with little affinity to electromobility.

Four of those "no regret moves" were previously introduced in this study (in Chapter 3.2), based on the analysis of opportunities (in Chapter 6) and risks (in Chapter 2.6) within the existing practical public policy constraints (in Chapter 5).

Figure 68: Summary of the Policy Recommendations



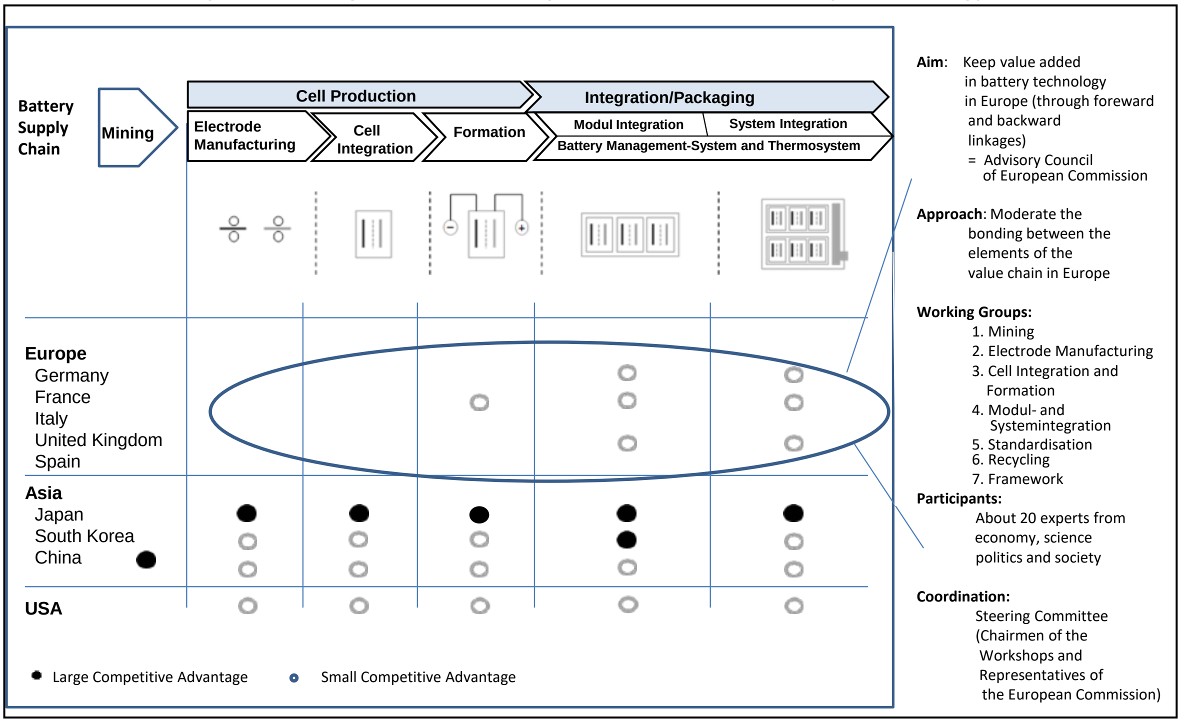
(Source: Own Compilation)

Ad 1: "European Platform for Battery Technology"

The "European Platform for Battery Technology" has been suggested in Chapter 3.2.1.1.1 to address the competitive disadvantages in European battery production (see Figure 69 in extension of Figure 32, Chapter 3.2.1.1.4). Concerning the battery supply chain (from mining of raw materials, like copper and lithium, via the production of cells to the battery system integration) experts from economics, politics, trade unions and society should be brought together similar to the German "Nationale Plattform Elektromobilität" (NPE) to close the technology gaps in the field of battery technology. Various working packages should be defined and coordinated by the EU or a designated steering committee, e.g. mining, electrode production, integration and formation of cells, module and system integration, standardisation, recycling and overall framework. The objective should strengthen the co-operation of the European key players along the battery supply chain and avoid lobbying campaigns. A standard regulation should be defined forparticipation in the European platform in order to exclude unqualified participants and particular interests which may unnecessarily slow down the development.

life in order to reduce the taxable income - but without reducing the cash. Depreciation therefore can be used as an indirect technology support, e.g. in order to promote investments in new technologies.

Figure 69: Proposal for a "European Platform for Battery Technology"



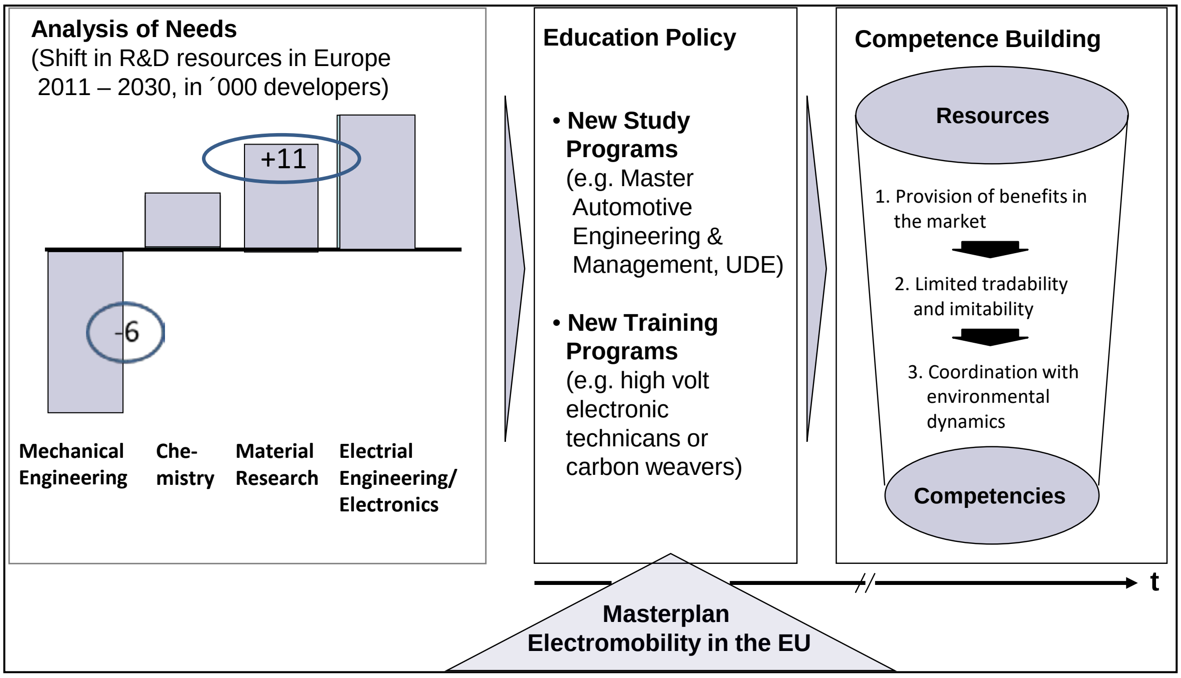
(Source: Own Extension of Huth et al. 201X)

Research and development funding by public policy should concentrate on supporting basic research particularly in the field of battery cells. This proposal was supported by all experts interviewed for this survey (see Figures 63 and 64, Section 5.2) because it was considered as an appropriate approach for the European environment.

Ad 2: Formal training initiative in the field of electromobility

Furthermore, a formal training initiative in the field of electromobility, as proposed in Chapter 3.2.1.1.4, could help reduce the lack of competence in this field. In the automotive industry, the transition to electromobility will be accompanied by a significant change in the structure of qualifications and therefore of competencies particularly in the area of research and development. The share of mechanical engineers who currently account for 90 percent of all engineers in research and development will decline significantly while the share of chemists and material scientists will increase significantly and can more than compensate for the decline of jobs in mechanical engineering (see Figure 70). There are few training positions in this field at present – a problem which could be solved by a European-wide training offensive for electromobility.

Figure 70: Competence Shift in the Automotive Industry in the transition to Electromobility



(Source: Own Compilation and calculation based on McKinsey 2011)

On December 16, 2010, a kick off meeting for the EU project "Identification of national jobs and skills councils in the automotive sector in view of setting up European automotive skills councils"[629] was organised in Brussels in order to prepare the automotive industry players for the changes that will come with the electrification of powertrains. The meeting was organised jointly with the steering group of the "Anticipation of Change" project. The training and retraining of employees will continue with the financial support of the European Social Fund. In our opinion, this is a good approach which should be further developed. In addition to the advanced vocational training of employees, the education of new professionals by vocational education at colleges and universities ought to be pursued in particular.

In Germany, the "Nationale Plattform Elektromobilität" (NPE) has worked out a plan in its working group "offspring and qualification" in order to analyse which tasks have to be fulfilled in the field of academic and vocational education and training so that Germany will become a leading market for electromobility in 2020. This includes the following fields of action:[630] "Infrastructure/Stations", "Infrastructure/Grids", "Automotive Engineering (eCar)", "Ancillary Services", "Production Engineering (eCar)" and "Vehicle Service and Trade". The NPE working group is on the way to define a German roadmap of academic competence, vocational education and training for electric vehicles. This goal should be pursued supra-nationally as well.

A new education policy is also needed. New study Programs and New Training Programs (like the training of high volt technicians and carbon weavers) are needed – and can be supported by the EU by a general project plan "electromobility". However this should be started very soon, as training requires time.

Additional time is also needed for the development of skills by a refinement of resources (for new graduates and specialists). Refinement respectively competence building means: 1. Provision of benefits in the market, 2. Securing a limited tradability and imitability of the competencies and 3.Coordinationof the competencies with environmental dynamics (i.e. Coordination with a highly dynamic environment in transition to electromobility).

Altogether, about 4 to 5 years will pass until enough qualified graduates will enter the labour market and then another year or two in which they have to be trained by the companies to establish and develop their skills. Current qualification measures are leading to competencies in 2018 or 2019 causing an urgent need for action today.

629 EMF (2010)
630 BMVBS (2010)

Ad 3: Special depreciation to support investments in the production technology for electric vehicles and its components

It is possible to support investments in production technology of electric vehicles and their components by means of special depreciation within the taxation system (on the level of the individual EU member country), as already proposed in Chapter 3.2.7. This will reduce the threshold for investments in value added for electromobility which will lead to an acceleration of the transition to this new powertrain technology. In addition, innovations in mechanical and plant engineering will be driven forward. For example, a graduated depreciation scheme depending on the level of technology would be conceivable, however, this will have to be both easy to understand and monitor.

With these special depreciations value-adding activities such as the production of engines or batteries can be directly placed into European enterprises (e. g. the numerous European machine and plant constructors). These depreciations are direct depreciations, i.e. there is an immediate dismissal of the respective amortization period of the relevant investment account.A condition for the possibility of a special depreciation has to be defined, (e.g. in Germany according to § 7g EStG.) The special depreciation can be made for mobile assets (not for buildings or software systems) which are (almost) exclusively used for business (e.g. machine tools and assembly lines for electromobility). The depreciation charge of 20 percent may be distributed over the entire first five years of use. Such special depreciations are common practice, e. g. for photovoltaic systems. Photovoltaic systems are worn assets. Rooftop photovoltaic systems, which are put on roofs can be considered as movable goods, while other types of photovoltaic systems are used as roofs (in-roof systems).Both have an average operating life of 20 years. Small and medium enterprises can make a special depreciation of 20% on the initial costs of purchase or production for movable goods, also for rooftop photovoltaic systems, in the year of purchasing or within the following four years.

Because of the high rate of innovation, the loss in value of electric cars seems to be faster than of traditional cars with combustion engines. According to the German „Nationale Plattform Elektromobilität (NPE)“ a faster depreciation of acquired commercial electric vehicles is justified, compared to a regular depreciation of six years. A special depreciation of 50% of the purchase costs is recommended by the NPE within the first year of use. The commercial customer should receive a special depreciation by a tax deferral benefit for the entire service life.

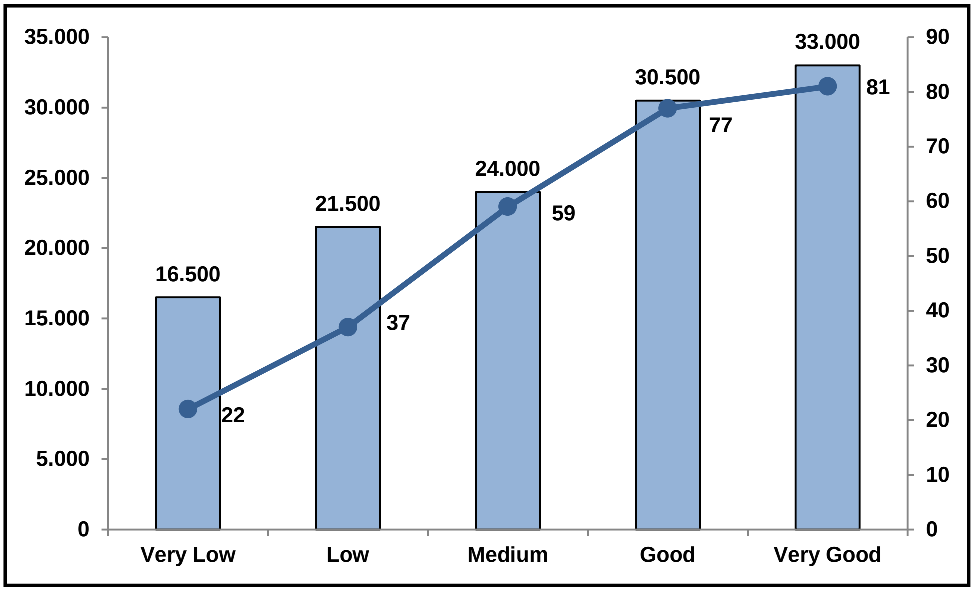
Ad 4: Expansion of the charging infrastructure

There is general consensus that infrastructure for electric vehicles has to be developed since the technology is already mature and that market prospects of electric vehicles are promising. It is, however, likely that public support will be needed since there is still a high uncertainty for the private agents to invest. Importantly, the experts interviewed pointed very strongly to the fact that Europe is very heterogeneous in many areas, e.g. within the charging infrastructure and has to take account of the different conditions of the urban structure (e.g. narrow streets in Italy). Especially in cities, consumers will benefit from electric vehicles because of the short distances, but only a few customers have the possibility to charge their vehicles in a garage. Particularly in large cities like London, Paris, Berlin, Rome or Madrid, public charging stations are essential to encourage market development. For this purpose, already a number of projects exist (see Chapter 4.2.3), but mainly at a local/regional level. A push for infrastructure roll-out will be helpful in order to enable the charging of electric vehicles in the individual countries.

Ad 5: Media campaigns, specifically targeted at customers with less affinity to electromobility

Figure 71 shows the result of a survey conducted by the Center of Automotive-Management (CAMA) at the University of Duisburg-Essen including 700 respondents. The maximum willingness to pay a higher price for an electric vehicle and purchase probability is positively correlated with the state of knowledge about battery electric vehicles.

Figure 71: Maximum Willingness to Pay and Purchase Probability concerning BEVs 2011 – 2014 (according to Consumer Knowledge; n = 700)



(Source: Fojcik et al. 2011)

If thewillingness to purchase depends on the level of information, media campaigns should be targeted specifically to customers who have less interest in buying electric vehicles (as already recommended in Chapter 3.2.5.5.). These customers mainly belong to the private customer segment of “Waverers" (who are open-minded but unconvinced and avoid risky and unsafe purchases) and “Low End Consumers“ (who are conservative, have a low budget and hold on to proven and best practices) (see Appendix III). In terms of the commercial customers, particularly the segment of “Rest of Fleet” has a conservative fleet policy and strong TCO orientation.

According to the experts interviewed, the industry is responsible for the training and qualifying of the sales organization (see Figure 72). Furthermore, they should provide realistic data about safety, cruising range and the usability of electric vehicles. The industry should also build up confidence by providing guarantees (especially on battery performance) and marketing campaigns („let them drive“). This could be part of an awareness campaign for the automotive companies. Public authorities should provide information about the importance of electric mobility and its realistic energy savings capacity. Furthermore public policies should inform customers about their contribution to an effective mobility. Nevertheless, public authorities should also point out the limits of electromobility. Since the perception of electric vehicles, as well as preferences and purchase intentions vary widely (see Appendix II), media campaigns should be discussed at Member State level. Cross-cutting measures at EU level are also possible.

Figure 72: Consumer Information

Industry

- Training/education of the sales organization
- Realistic disclosures according safety, range and possible uses
- Build up trust (e.g. by guarantees)
- Marketing activities encouraging driving experience:

  “Let them drive”

Public Authorities

- Information on the importance of Electromobility
- Information on the customer’s contribution to sustainable mobility
- Realistic information on the energy saving potential of Electric Vehicles
- Clear statements as to the limitations of electric vehicles, including proposed solutions (e.g. use of alternative forms of mobility)
- Standardization of labeling requirements
- Encourage individuals to realistically reassess their mobility needs

(Source: Own Compilation based on expert interviews)

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Appendices

Appendix I: List of Experts interviewed

The following section provides a list of 94 experts interviewed between the end of March and early May 2012.

(1) Europe:

OEM

- BMW (D):
  Dr. Harald Arlt, Head of Planning and Strategy Department Project i
- Daimler (D):
  Prof. Dr. Herbert Kohler, Head of "E-Drive & Future Mobility" Department, Environmental Officer of Daimler AG
- Fiat (I):
  Stefano. Re Fiorentin, General Manager CRF
  Dr. Sergio Leonti, Head of Alternative Propulsion Department
  David M. Storer, Product Research; EU Network- Collaborative Research Coordination
  Paolo Dovano, Concept Initiatives & Public Funded Projects
- Opel (D):
  Prof. Dr. Uwe-Dieter Grebe, Executive Director, Advanced Technology - Alternative Propulsion
- SEAT (E):
  Dr. Tino Fuhrmann, E/EL-Electromovilidad y Estrategia de Innovación
- Volkswagen (D):
  Dr. Lars Heidenreich, Group E-Traction - Head of Program Management

Suppliers

- Bosch (D):
  Dr. Klaus Harms, Senior Vice President, Corporate Research and Development - Advance Engineering Systems - Future Automotive Systems
- ZF Group (D):
  Andreas Hartmann, Chief Representative and Head of Governance/Corporate Development
  Frank Jauch, Competitive Analysis, Innovation Research
- Infineon (D):
  Dr. Georg Pelz, Principal Design Methodology
  Joachim Weitzel

Associations

- The European Association for Battery, Hybrid and Fuel Cell Electric Vehicles AVERE (F):
  Philippe Aussourd, Vice President
- French Ultra Low Carbon Vehicles Program (F):
  Jean-Louis Legrand, Program Leader
- German Association of the Automotive Industry (VDA) (D):
  Dr. Thomas Schwarz, Senior Consultant Electric Mobility
  Dr. Ulrich Eichhorn, Managing Director
- SERNAUTO (E):
  Mrs. Dr. Maria Soria, Secretary General
- Society of Motor Manufacturers and Traders (UK):
  Mrs. Konstanze Scharring, Head of Public Policy & Vehicle Legislation
  Yung Tran, Head of Member Services and Business Improvement

Public and Quasi-Public Organizations

- Barcelona Activa (E):
  Ramon Pruneda, Project Manager
- Bundesministerium für Wirtschaft und Technologie (D),
  Dr. Hartmut Kühne, Head of Unit - Environmental Innovations, Electric Mobility
- Ministerio de Industria, Energia y Turismo - IDAE (E):
  Juan L. Plá de la Rosa, Head of Transport Department
- Ministero dello Sviluppo Economico (I):
  Dr. Vincenco Zezza, Industrial Policy and Competitiveness Directorate
- Ministerium für Wirtschaft, Energie, Bauen, Wohnen und Verkehr Nordrhein Westfalen (D):
  Karl-Uwe Bütof, Director General, State Economic Policy, Industry Service Sector, Clusters, Foreign Economic Affairs
- Office for Low Emission Vehicles (UK):
  Mrs. Kate Warren, Supply Chain Department

Experts

- Alessandro Sciolari, Assoknowledge (I)
- Julia Hildermeier, M.A., GERPISA (F)
- Prof. Cesare Pianese, University of Salerno (I)
- Prof. Dr. Andrea Stocchetti, University of Venice (I)
- Dr. Zirpoli, University of Venice (I), Department of Management and Advanced School of Economics
- Martin Seiwert, Business Journalist Enterprises & Markets, Wirtschaftswoche (D)
- Dr. Peter Holtappels, Head of Programme, Department of Energy Conversion and Storage, Technical University of Denmark (DK)

(2) United States

OEM

- Ford:
  Mrs. Nancy Gioia, Director of Global Electrification Planning
  Dr. Thilo Seibert, Sustainability, Advanced Powertrain Strategy and Electrification Planning
  Dr. Benedikt Schell, CO_2 Technology Innovations and Electrification Planning

Public and Quasi-Public Organizations

- Congressional Research Service:
  Bill Canis, Industrial Organization & Business Resources, Science and Industry Division
  Brent D. Yacobucci, Energy and Environmental Policy, Resources, Science and Industry Division
- U.S. Department of Energy:
  Patrick B. Davis, Program Manager Vehicle Technologies

Experts

- Thomas Klier, Senior Economist, Federal Reserve Bank of Chicago
- Prof. John Paul MacDuffie, Wharton School Philadelphia and Director IMVP

(3) Japan[631]

OEM

- Toyota Motors
- Nissan Motors

Suppliers

- Denso
- Bosch Japan

Association

- Japanese Automobile Manufacturers Association (JAMA)

Public and Quasi-Public Organizations

- German Trade and Invest (GTAI)
- Delegation of the European Union Japan

(4) Korea[632]

OEM

- Hyundai Motors
- Volkswagen Korea

Supplier

- Bosch Korea

Association

- Korea Automotive Manufacturers Association (KAMA)

Public and Quasi-Public Organizations

- European Union Chamber of Commerce Korea
- German Trade and Invest (GTAI)
- Korean-German Chamber of Commerce and Industry (KGCCI)
- Ministry of Environment

[631] Interviews were conducted anonymously.
[632] Interviews were conducted anonymously.

(5) China

OEM

- Audi (China) Enterprise Management Co., Ltd.:
  Dr. Ingo Deking, Director Corporate Planning and Strategy Region China
  Dr. Xiuhua Zeng, Manager Strategy
- Bombardier Transportation GmbH:
  Mr. Marcus Lindemann, Project Management Primove & E-Bus
- Daimler Northeast Asia Ltd.
  Dr. Oliver Storz, Vice President Mercedes-Benz R&D China
- First Automotive Works (FAW):
  Mr. Hongfu Tian, Deputy Director Planning Department
  Mr. Hui Zhou, Assistant to the Section Chief of the Planning Department
- GM China:
  Mr. Raymond Bierzynski, Executive Director Electrification Strategy
  Ms. Jessica Feng, Product Communication Manager
- Vossloh Kiepe GmbH:
  Mr. Thomas Mang, Head of Strategic Procurement

Suppliers

- Schaeffler Technologies AG & Co. KG:
  Mr. Rolf Najork, Head of business unit E-Mobility, Mechatronics and R&D Transmission, Member of the Management Board Automotive
- Evonik Industries AG:
  Mr. Sven Augustin, Head of Automotive Industry Team

Associations

- European Automobile Manufacturers' Association (ACEA) Representative Office:
  Dr. Dominik Declercq, Chief Representative
- EuropElectro - European Electrical and Electronics Industry; under the leadership of the ZVEI, in cooperation with ORGALIME, Mrs. Xu.Wang, Head of EuropElectro

Public and Quasi-Public Organizations

- GIZ (German Society for International Cooperation):
  Mr. Christian Hochfeld, Programme Director Sustainable Transport, Project Director Electro-Mobility and Climate Protection
- GIZ (German Society for International Cooperation):
  Dr. Jörg Binding, Programme Director Sino-German Consumer Protection and Product Safety Programme
- Delegation of European Union China:
  Mr. Joao Santos, Counsellor, Delegation of the European Union, Trade and Investment Section
  Mr. Eliasz Krawczuk, Intern, Delegation of the European Union, Trade and Investment Section
- EU ETS:
  Mr. Klaus Ziegler, European Standardization Expert for China

Expert

- Booz&Co / Synergistics:
  Mr. Bill Russo, Senior Advisor

Appendix II: Methodology

General Assumptions behind the Market Model

- The market model assumes rationality and complete information of the consumers, i.e.:
  - private and commercial consumers behave rationally. Consumers only change to another propulsion technology, if the utility-cost ratio of an alternative propulsion technology is positive. If two propulsion technologies have the same utility-cost ratio, consumers will equally adopt both propulsion technologies (ratio: 50:50).
  - private and commercial consumers have complete information about the benefits and costs of all propulsion technologies.
- In the market model the percentage distribution of private consumers and commercial customers in the different segments remains constant.
- The market model assumes that private and commercial consumers of all segments behave differently, but within one segment consistently.
- The market model assumes equal adaptation and distribution of private and commercial consumers due to different propulsion technologies, i.e.:
  - according to the utility-cost ratio, private and commercial consumers of a segment do not change from one propulsion technology to another in terms of the full-size segment, but adopt an alternative propulsion technology in form of a normal distribution.
  - a change from one propulsion technology to another is only possible after a five year period of usage. This also occurs, if the utility-cost ratio changes within the five year period.
- The market model assumes full availability of all propulsion technologies. Restrictions due to production shortfalls or similar events are not considered.
- The market model considers for all segments and markets an ICE middle class vehicle as a reference vehicle with a general purchase price of 25,000 Euro.
- The market model assumes that private and commercial consumers will always buy a vehicle, i.e. the possibility that consumers renounce an ownership of a vehicle is not included.
- The market model does not take any extreme assumptions into account, e.g. a complete blockage of urban areas for ICEs is not considered.
- Purchase incentives (monetary/non-monetary) for electric vehicles are considered in the market model, as long as these incentives are already available. After 2020, no incentives will be provided in the model.

Logic of the Market Model and Calculation of the Utility-Cost Index

To differentiate the vehicle types used in this study, it was necessary to establish reference information as a basis of comparison (e.g. vehicle consumption).In the market model, the reference is a middle class vehicle with an internal combustion engine and a purchase price of 25,000 Euro. This purchase price is only the base price for electric vehicles to which additional costs for further components (e.g. electric engine, power electronics) were added. Furthermore, time horizon refers to the average of five years duration of use for electric vehicles.[633]All subcomponents with monetary value are considered according to this time period. The determination of the index value has to be expressed in its respective parameter which represents the relevant costs during the assessment period. However, the purchase price is not included directly in this calculation but rather indirectly in the loss of value, resulting in a discrepancy between the purchase price and resale price in a period of five years. In addition, the fuel prices and tax expenses are ICE parameters. The costs results to:

$$C_{ICE} = PP_{ICE} * LV_{ICE,t=5} + \sum_{t=1}^{5}\left(FC * FP_t * \frac{YM_t}{100km} + T_{ICE,t}\right) \tag{1.1}$$

C_{ICE}	= Total Costs Of Ownership ICE
PP_{ICE}	= Purchase Price ICE
$LV_{ICE,t=5}$	= Percentage Loss of Value ICE after five Years of Usage
FC	= Fuel Consumption
FP_t	= Average Fuel Price in Year t

[633] According to DAT 2011 we insinuate an average operating life of five years similar to new vehicles with internal combustion engine, before the owner changes the first time.

YM_t	= Yearly Mileage
$T_{ICE,t}$	= Taxes in Year t

Additional costs are expected in electric powertrains due to its large battery consumption. However, the use of electric vehicles also has advantages, for example,premiums and government benefits supporting electromobility and the possibility of free battery charging in public charging stations.

This reduces the TCO which is valid for:

$$C_i = (PP_{ICE} + AC_i) * LV_{i,t=5} + \sum_{t=1}^{5}\left[(PC_i * EP_t + FC_i * FP_t) * \frac{YM_t}{100km} + T_{i,t} - \left(IU_{i,t} + FCH_{i,t}\right)\right] - PR_i \quad (1.2)$$

with $i\epsilon\{Hybrid, REEV, BEV, FCV\}$

C_i	= Total Costs Of Ownership of Driving System i
PP_{ICE}	= Purchase Price of Comparable ICE
AC_i	= Additional Technical Costs of Driving System i
$LV_{i,t=5}$	= Percentage Loss of Value ICE after 5 Years of Usage
PC_i	= Power Consumption of Driving System i (if directly provided with electric power)
EP_t	= Average Price of Electric Power in Year t
FC_i	= Fuel Consumption of Driving System i
FP_i	= Average Fuel Price in Year t
YM_t	= Yearly Mileage
$T_{i,t}$	= Taxes of Driving System i in Year t
$IU_{i,t}$	= Monetary Utility through Usage of Infrastructure of Driving System i in Year t (e. g. Use of bus lane, free-parking, toll-exemptions)
$FCH_{i,t}$	= Monetary Utility through Free Charging at Public Places
PR_i	= Purchase Premium of Driving System i

Through division, we can calculate the index value of electric powertrains:

$$INDEX_i = \frac{C_{ICE}}{C_i} \quad (1.3)$$

The calculation is rendered by dividing the costs of ICE by the costs of electric powertrains. Thus, calculating the maximum index value for all electric powertrains will determine if a consumer group g will prefer electric vehicles. In each year, the following comparison is made:

$$Max(INDEX_i) - INDEX_{threshold,g} = r = \begin{cases} Rejection, r < 0 \\ Adoption, r \geq 0 \end{cases} \quad (1.4)$$

In the case of rejection, the consumer group will purchase a car with an internal combustion engine. If a group will adopt, on the other hand, the next step would be to identify in which period the comparison would fall in favour of adoption. The process will occur gradually over time. Our model considers how a part of the consumer group decides initially in favour of Electric Vehicles and is eventually followed by the whole group in the upcoming years. The share of private and commercial consumers and the overall market value percentage results are shown in the following formula:

$$P_g = PS * GS_g * S_{g,t-ad} \quad (1.5)$$

P_g = Percentage of a Consumer Group that Buy Electric Cars on the Overall Market
PS = Share of Private/Commercial Consumer on the Overall Market
GS_g = Group Size related to Private and Commercial Consumers
$S_{g,t-ad}$ = Saturation Factor of Consumer Group in Year (t - ad) after Adoption

Now the percentage ratios of different groups are based on similar values (the overall market), so the calculated values can be accumulated and lead to the overall electromobility market values in a certain year. However, the question as to which specific electric powertrain is more attractive in the market still needs to be addressed. To determine the answer to this query, electric powertrains and the consumer groups have to be considered individually. For the purpose of clarity, it is necessary to mention that a group is considered with its preferred electric powertrain with an index value at a certain period of time. It is also comprehensible and logical that the electric powertrain with a better cost structure is more attractive than an electric powertrain near the threshold.

$$i, j \epsilon \{1,2,3,4\}$$

$$1 \triangleq \text{Hybrid}$$

$$2 \triangleq \text{REEV}$$

$$3 \triangleq \text{BEV}$$

$$4 \triangleq \text{FCV}$$

$$P_{ig} = 0 \quad if\ r_i < 0 \tag{1.6}$$

with $r_i = INDEX_i - INDEX_{threshold_g}$ (1.7)

otherwise

$$P_{ig} = \frac{r_i}{\sum_{j=1}^{4} w_j} \tag{1.8}$$

with$w_j = \begin{cases} 0, r_j < 0 \\ r_j, r_j \geq 0 \end{cases}$ (1.9)

and $r_j = INDEX_j - INDEX_{threshold_g}$ (1.10)

The results shown in (1.6) and (1.7) support the idea that an electric powertrain with low index values has no market share at all. This is the exact case when the threshold is above the index value of the powertrain. If this is not the case, a market share results as shown in (1.8) where the distance between the index value of an electric powertrain an the index threshold of one consumer group are compared in relation to the sum of the distances to the electric powertrains which are of interest for a consumer group. These overall market share results from the comparison (1.5 and 1.8) of different electric powertrains further subdivide according to different consumer groups expressed in this formula:

$$P_{ik} = P_g * P_{ig} \tag{1.11}$$

The shares of electric powertrains which have been calculated for each consumer group have to be summarized in order to calculate the shares of electric powertrains on the overall market:

$$P_i = \sum_{k=1}^{10} P_{ik} \quad with\ k\epsilon \{1,2,\dots,10\} \tag{1.12}$$

Here, the symbol k represents all consumer groups including both private and commercial groups.

Limitations of the Market Model

The market model has several limitations. Although the assumption of rationality applies to commercial consumers quite well, private consumers only act completely rational in very rare cases. Insofar, private consumers do not devote/attach their buying decision for or against electric vehicles to the utility-cost ratio. Thus it is possible that private consumers will not change to an alternative propulsion technology, although the utility-cost ratio argues for a modification of the actual used propulsion technology. Furthermore, the assumption of complete information of the consumers should be examined with reservations. Especially in the early phase of electromobility, private and commercial consumers' knowledge about costs and benefits of electric vehicles is limited. Beyond that, the assumption of full availability of electric vehicles cannot actually be supported. Consequently, the market model cannot fully map the situation that the demand for electric vehicles already exists, but a comprehensive supply is actually non-existent. In addition, the market model does not take the feasible case into account that consumers will increasingly abstain from using vehicles. Especially, the growth of various carsharing models and their impact on vehicle sales are not represented in the market model. Furthermore, the assumption that the percentage distribution of private consumers and commercial customers in the different segments remains constant, limits the market model. Thus, possible trends, e.g. growing segments of low-end consumers in various countries, are excluded from the market model. Moreover, possible supporting effects of early adopters, which positively foster the observability and therefore the diffusion process of electric vehicles, are not taken into account in the market model as well.

Validation of the Market Model

Despite from expert interviews, the results of the market model were validated in the German computer market. Both, basic structure of the model and assumptions are identical. Initially, the total market demand for desktop pc and notebooks was determined based on real sales figures from BITKOM (Federal Association for Information Technology, Telecommunications and New Media, Germany) for the years 2009 to 2011.[634] In order to forecast the German market development of notebooks, utility-cost index of notebooks were calculated for each year, comparing the prices of desktop pc and notebooks.[635]

The German market forecast of Notebooks distinguishes between private and commercial customers as well.[636] The segment sizes and index values are in line with the market model for electric vehicles.
Private and commercial consumers behave rationally.Consumers only change to another technology (in this case: notebooks instead of desktop pc), if the utility-cost ratio of the new technology is more attractive. The results of the German market forecast for Notebooks are provided in the following table:

[634] Baseline = 2001
[635] Source: CEMIX Consumer Electronics Market Index; Destatis; C't Magazin
[636] Data representing the allocation of both segments are based on annual reports from BITKOM

Table I: German Market Development of Notebooks

German Market Development of Notebooks (in Million units)				
	2001	**2009**	**2010**	**2011**
Sales Forecast	0,74	7,33	8,64	10,50
Total Sales (real)	1,39	6,90	8,22	10,78
Average Deviation (in %)	9			
Note: 2001 = Baseline				

Source: Own Calculation

The results of the market forecast show a moderate deviation which can be explained by using the same assumptions (e.g. in terms of the customer segments sizes, index values). Customers of desktop pc and notebooks are expected to have different preferences than customers of electric vehicles which are reflected by the accepted value of utility-cost indices.[637]

Calculation of Value Added at Factor Cost

The calculation of value added at factor cost includes two variables: personnel costs and gross profits. The sum of personnel costs and gross operating surplus[638] amounts to the value added at factor cost.[639] The calculation of the value added at factor cost includes the following five steps:

1. Calculation of the Total Turnover in Vehicle Production for 2020/2030
2. Calculation of Personnel Costs and Gross Profits for 2020/2030
3. Calculation of Value Added at Factor Cost for 2020/2030 excluding Electric Vehicles (baseline)
4. Adjustment by
    a. Profits Non-EU (e.g. Manufacturing of Components in Third Countries)
    b. Personnel Non-EU (e.g. Manufacturing of Components in Third Countries)
    c. Less Value Added in Manufacturing of Vehicles with Internal Combustion Engine
5. Calculation of Value Added at Factor Cost for 2020/2030 including Electric Vehicles and non-rechargeable Full Hybrids

In the first step, the total turnover in manufacturing of passenger cars and light commercial vehicles in the EU automobile industry was calculated for 2020 and 2030. We assume that the total turnover of vehicle manufacturing will develop equally to the development of the output (production).

In the second step, future personnel costs were estimated. In order to calculate the personnel costs of the EU automobile industry (2020 and 2030) in the field of manufacturing motor vehicles,[640] the relation of personnel costs and total turnover has been analysed. In the last 13 years, the personnel costs accounted for approximately 13 percent of the total turnover.[641]Regarding the personnel costs, we assume a tendency to remain steady until 2020 and 2030 (therefore compensating further wage increases with additional limited offshore outsourcing activities in third countries). Based on previously estimated total turnover, the personnel costs were calculated for 2020 and 2030.

In order to calculate future gross profits, we initially estimated profit margins for 2020 and 2030 in vehicle manufacturing. Starting from a very high profit margin of about eight percent in the year 2011, we anticipate that the profit margins will decrease to six percent in the long term, particularly due to in-

[637] For reasons of comparison, both basic structure of the model and assumptions are identical to the market model for electric vehicles.
[638] In the following section called "profit"
[639] This method is also used at Eurostat - see Eurostat (n.d.)
[640] Eurostat NACE Rev 2 – Manufacturing of Motor Vehicles, Statistical Classification: C.29.1
[641] Reported in the Eurostat classification NACE Rev 2 – C29.1 “Manufacture of motor vehicles” (INDIC_SB: Total Turnover: V12110 and Personal Cost V13310) since 2008 and NACE Rev 1.1 DM34 until 2008

creasing investments in R&D and saturated markets.[642]The automotive industry will remain innovation-driven in the long term. Due to changes in mobility needs, the current trend of high-priced luxury and premium vehicles will shift to smaller vehicle segments.[643] Based on the previously estimated total turnover for 2020 and 2030, future profits in EU automotive manufacturing were calculated.

In the third step, the personnel costs and gross profits were added. The sum of both figures represents the “value added at factor cost in the EU automotive industry for 2020 and 2030 – excluding electromobility” which has been calculated for 2020 and 2030 (see Chapter 3.3.2.1). Both amounts will serve as “baseline” in order to calculate the development of value added in transition to electromobility.

In the fourth step, the value added at factor cost excluding electromobility has to be adapted to consider the manufacturing of electric vehicles and their components. Initially, assumptions[644] concerning the industrial situation were made in terms of, production capacity of electric vehicles, model mix, and allocation of value added between the EU and third countries in component manufacturing and finally the cost development of components. For example, concerning the production of power electronics, we assume that 50 percent of value added will be performed by the EU automotive industry.[645] The assumptions are mainly based on our project results (see Chapter 2.3.2; 3.2 and 3.3). All assumptions were discussed in the expert interviews.

Based on assumptions,[646] concerning the production capacity of electric vehicles by vehicle type (BEV, Range Extender, Full Hybrid[647], and Plug-In Hybrid)[648] and estimated values of the main electric components (such as power electronics, electric motors, and battery), the total turnover of the production of electric components for 2020 and 2030 was calculated. As not all of the value-added in terms of manufacturing of components like batteries, power electronics and electric engines will be generated in the EU, these amounts have to be subtracted from the "baseline" (Step 3). In order to adapt the value added (baseline), the personnel costs and gross profits which were generated in third countries have to be calculated.

According to different studies (e.g. analysing the share of personal costs in battery manufacturing or future profit margins), shares of personnel costs relating to total turnover and profit margins were estimated. Based on Roland Berger[649], we assume a profit margin of eight percent in battery manufacturing.[650] We expect that the profit in battery production will decrease in the long term especially due to high investments and overcapacities. Due to a high degree of automation in battery manufacturing, the personnel costs were calculated with an average share of nine percent related to the total turnover.[651] Concerning the power electronics and electric engines, we expect profit margins of nine percent. This estimation is based on historical data from Eurostat.[652] We expect that the revenues and profits related to the manufacturing of electric engines and power electronics will increase. Since both components require considerably less investment compared to battery production, we assume a steady relation of total turnover and gross profits. Furthermore, we assume that the share of personnel costs related to the total turnover in manufacturing of power electronics and electric engines will remain stable.As a result, personnel costs and profits which do not belong to the EU manufacturing of electric vehicles and components were calculated.

In the fifth step, the sum of these values has to be excluded from the “baseline” representing future value added at factor cost. Due to an increasing production capacity of electric vehicles, the production of vehicles with internal combustion engines will decrease. The increasing personnel costs and profits resulting from the manufacturing of ICE vehicles must be excluded from “baseline” as well.

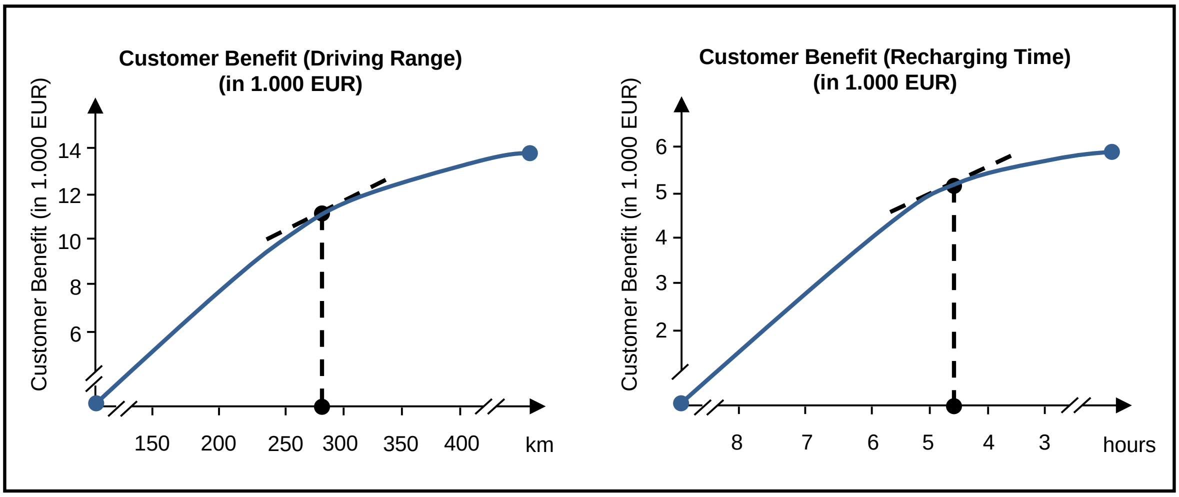
[642] Automobilproduktion (2012a); Automobilproduktion (2012b); Auto Institut (2012)
[643] Roland Berger (2010)
[644] See Chapter 3.3.2.2
[645] See further assumptions in Chapter 3.3
[646] See Chapter 3.3.2.2
[647] Full Hybrid Vehicles are included, since they use batteries and electric components as well
[648] Fuel Cells are not taken into account in the calculation of the value added due to the low market shares (see Chapter 3.3.1, Market Model). We expect a low share of Fuel Cells in series production until 2030.
[649] Roland Berger (2011c)
[650] Average, mainly including the manufacturing of battery cells and battery assembly
[651] Roland Berger (2011c)
[652] See Eurostat: NACE Rev 1.1 and NACE Rev 2, covering the last decade, since more data is not available

Appendix III: Customer Segmentation

Purchase decisions are essentially influenced by socio-cultural factors and sales conditions. Mobility is a basic requirement of a modern society. From the present perspective, mobility can be viewed as an expression of quality of life for millions of people. Nevertheless, it should be noted that the settings regarding individual mobility and the automobile have changed in recent years especially in mature industrial countries. The popularity of electric vehicles will have a major impact on rapid market penetration. In this context, consumer information plays a very important role. The majority is expecting battery ranges of 300 to 400 km and yet this majority does not even use their vehicles more than 100 km a day.[653]

In 2011, we conducted a large study with a random sample of N = 2,623 persons in Germany (Cologne, Duisburg, Essen, Bochum, Dortmund and the district "Wesel") to determine the price-technology relation (see Figure I). Both a driving range up to 280 km and a charging time down to 4.75 hours are great benefits for customers.

Figure I: Impact of Driving Range and Recharging Time on Additional Willingness to Pay



(Source: Fojcik et al. 2011; CAMA Calculations 2012)

Contrary to popular belief, both our own investigations and the results of several studies have verified that the majority of customers consider ecological compatibility more as a hygiene factor than as a motivational factor when buying new a car.[654] A certain degree of environmental compatibility is expected by the majority of customers but the decisive purchase criterion remains the purchase price. Concerning the current utility-cost conditions, most of the consumers are not willing to spend a price premium for environmentally friendly technologies.[655]

Based on the results of our own investigation in the German market regarding the price acceptance of electric vehicles[656] and based on other studies concerning consumer behaviour in global markets[657] in terms of electromobility, 10 different customer segments have been identified. Five segments belong to private customers while the five remaining segments are presented by commercial customers (see Table II).

[653] Accenture (2011b); Ernst&Young (2010); Deloitte (2010); Deloitte (2011)
[654] IHK (2010); ZPrýme (2010); Deloitte (2011)
[655] Proff/Fojcik (2011); BCG (2011); Deloitte (2011); Ernst&Young (2010); Continental (2011)
[656] Proff/Fojcik (2010); Proff/Fojcik (2011) and CAMA calculations
[657] Deloitte (2011); Continental (2011); Ernst & Young (2010); McKinsey (2012)

Table II: Main Customer Segments

Private Customers	Early Adopters	Pragmatists	Unit Consumers	Waverer	Low-End Consumers
China	2%	37%	1%	31%	29%
Germany	13%	9%	6%	19%	53%
Rest of EU	2%	19%	4%	38%	37%
France	5%	17%	2%	33%	43%
Italy	14%	18%	6%	36%	26%
Japan	12%	14%	1%	29%	44%
Spain	22%	20%	3%	38%	17%
South Korea	13%	22%	3%	30%	32%
United Kingdom	11%	14%	2%	29%	44%
United States	12%	4%	20%	18%	46%
Commercial Customers	**Innovative Fleets**	**OEM/Sales Organisation**	**Innovative Rental**	**Rest of Fleets**	**Traditional Rental**
China	2%	5%	2%	61%	30%
Germany	4%	5%	2%	74%	15%
Rest of EU	2%	5%	2%	71%	20%
France	4%	5%	2%	49%	40%
Italy	2%	2%	2%	52%	42%
Japan	2%	5%	2%	71%	20%
Spain	2%	2%	2%	62%	32%
South Korea	2%	5%	2%	71%	20%
United Kingdom	2%	2%	2%	61%	33%
United States	2%	2%	2%	61%	33%

(Source: Own Calculations)

In this study two different customer groups are distinguished:

(1) Segments of Private Customers

(2) Segments of Commercial Customers

Ad. 1:Segments of Private Customers

Table III provides an overview of the essential characteristics of the five private customers segments which we identified:

Table III: Criteria of the Segments of Private Customers

1. Early Adopters	2. Pragmatists	3. Unfit Consumers	4. Waverer	5. Low-End Consumers
Strong environmental orientation	Distinct cost considerations	Inappropriate driving patterns	Open-minded, but unconvinced	Conservative attitude
Innovative attitude	Strong benefit orientation	No possibility of recharging	Avoid risky / unsafe purchases	Low budget
Distinct status considerations	See vehicles as a commodity	Little know ledge about electric vehicles	Average know ledge about electric vehicles	Non-involvement
Interest in environmental and energy issues			Fear of electric cars	Hold on proven and best practices
High budget				

(Source: CAMA 2011)

The segment of **Early Adopters** comprises green enthusiasts which are mainly innovators as well as high-end consumers. These consumers have a strong environmental and innovation orientation or distinct status considerations. We assume that consumers of this group make their purchase decision even though the utility-cost index[658] is lower than the utility-cost index of a conventional vehicle.

The **Pragmatists** are characterized by distinct cost-benefit considerations and a strong benefit orientation. Pragmatists look upon vehicles as being a commodity. They will purchase vehicles at a utility-cost index which has nearly the same level compared to a vehicle with a combustion technology. This customer segment is not willing to acquire an electric vehicle with a suboptimal utility-cost index.

[658] See Chapter 2.3.1.2

The segment of **Unfit Consumers** includes private customers who have inappropriate driving patterns. For many customers of this segment, the range of electric vehicles is not yet sufficient. Therefore, this customer segment will purchase an electric vehicle as soon as the characteristics of electric vehicles fit to their desired usage patterns. Most of the Unfit Consumers have little knowledge concerning electric vehicles.

The segment of **Waverer** includes private customers who are generally open-minded but unconvinced. This group of consumers will wait until the new technology has been proven. Waverers avoid risky purchases. Most Waverers have an average knowledge about electric vehicles.

The **Low End Consumers** prefer vehicles with internal combustion engines as long as the utility-cost relation of the electric vehicles is not significantly higher compared to traditional vehicles. Most of these customers have little money and do not show any interest (low involvement) in terms of alternative powertrains.

Ad. 2: Segments of Commercial Customers

Table IV provides an overview of the essential characteristics of the five commercial customers segments which we identified:

Table IV: Criteria of the Segments of Commercial Customers

1. Innovative Fleets	2. Traditional Rentals	3. Innovative Rentals	4. OEM/Sales Organizations	5. Rest of Fleets
Strong environmental orientation	Distinct cost considerations	Strong environmental orientation	Register electric cars for own use (show cars, company cars)	Conservative fleet policy
Provider of innovative products and services	Strong benefit orientation	Provider of innovative products and services	Signaling of innovative strength	Strong TCO-orientation
Search for a "green" image	Hold on proven and best practices	Search for a "green" image		Low willingness to pay for innovation

(Source: CAMA 2011)

Innovative Fleetscan be both commercial and public customers. While the commercial customers want to project an image of their company as innovative or environmentally concerned, the public authority wants to lead as an example. Therefore, they promote the market penetration of electric vehicles by purchasing electric vehicles for their fleets. Innovative Fleets are willing to buy an electric vehicle although the utility-cost ratio is worse compared to a vehicle with traditional combustion technology.

The majority of experts, which have been interviewed in this study, consider (innovative) Fleets as the real "early adopters" among all customers segments. Although this segment is very small compared to the other customer segments, it is a very important segment in terms of market penetration. In this case, a directive[659] has been developed by the European Union to create the conditions for the purchase of electric vehicles with higher initial costs. In Article 1, the directive requires “contracting authorities and entities as well as certain operators to take into account lifetime energy and environmental impacts including energy consumption and emissions of CO_2 and of certain pollutants when purchasing road transport vehicles with the objectives of promoting and stimulating the market for clean and energy-efficient vehicles and improving the contribution of the transport sector to the environment, climate, and energy policies of the Community”.[660]

Due to limited range, most electric vehicles are currently not suited for the segment of the **Traditional Rentals**. If the cost-benefit index for electric vehicles improves over time (e.g. improved range and lower costs), the segment of Traditional Rentals will gradually enter the market. These customers are willing to buy an electric vehicle, when the utility-cost ratio is better compared to a vehicle with traditional combustion technology especially in terms of cost and range.

Particularly in large cities, a large percentage of **Innovative Rentals** will offer environmentally friendly vehicles in their fleets in order to show that their company is either on the innovative edge or environ-

[659] Directive 2009/33/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009)
[660] EU Commission (2009)

mentally concerned. Due to the range, electric vehicles are currently more suitable for local car sharing or rental solutions (e.g. route from the airport to downtown). For the same reason as with Innovative Fleets, these customers are also willing to buy an electric vehicle although the utility-cost ratio is worse compared to a vehicle with traditional combustion technology.

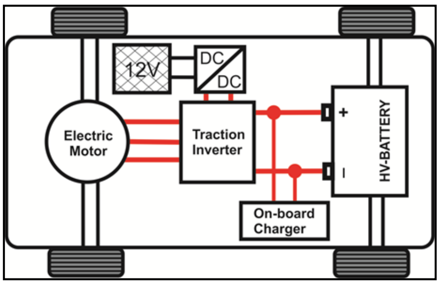
OEM/Sales Organisationswill promote the market penetration of electric vehicles by registering electric vehicles (e.g. showroom cars or company cars). Manufacturers and their trade organisations will register electric vehicles earlier in order to secure market shares.

Customer groups which cannot be assigned to the different customer segments mentioned before form the segment **Rest of Fleets**. This segment is particularly characterized by purchasing decisions which are based on Total Cost of Ownership (TCO). Therefore, customers of this segment will only buy electric vehicles if the utility-cost ratio (cost and range) is better compared to vehicles with traditional combustion technology.

Appendix IV: Description of the Key Components of Electric Vehicles

In difference to combustion engine vehicles, electric vehicles are equipped with an electric powertrain. This drive system basically consists of the following key components: battery, drive inverter, DC-DCcoupler, charging rectifier, electric motor and a high voltage wiring harness. The assembly of atypical electric vehicle is presented in Figure II.

Figure II: Schematic Layout of an Electric Vehicles Propulsion System



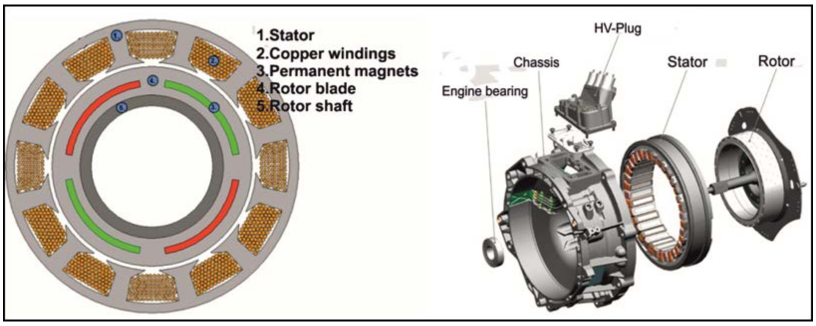
The HV-Battery is connected to the traction inverter supplying the electric motor and the 12V on-board wiring system via the DC-DC converter. Since electric motors used in actual vehicles needs a three phase alternating voltage, the traction inverter hast to transform the battery dc voltage. The onboard charger function is to recharge the battery after driving. The 12V on-board wiring system, which is implemented in electric vehicles, is connected to the traction system via a DC-DC converter reducing the battery voltage to 12V and vice versa in order to supply the 12V wiring system by the high voltage battery. In the following section, the key components of electric vehicles are described in more detail:

1. Electric Motor
2. Power Electronics Components and
3. High Volt-Battery

1. Electric Motor

In an actual electric vehicle, different motor types are used. The Mitsubishi i-MiEV, for example, is equipped with a permanent exited three-phase-synchronous motor with a power of 47kW. Other electric vehicles like Tesla Roadster or the BMW Mini-E are using three-phase asynchronous motors. The basic structure of a permanent exited three-phase-synchronous motor is presented inthe next figure. It consists of a rotor with integrated permanent magnets connected to the gearbox anda stator with copper windings connected to the drive inverter supplying three-phase current. Due to magnetic field interaction between the stator field generated by the three-phase current in the stator winding and the magnetic field generated by the rotor magnets, the machine rotates. The basic structure of such a motor used in electric vehicles is presented on the right side in Figure III.

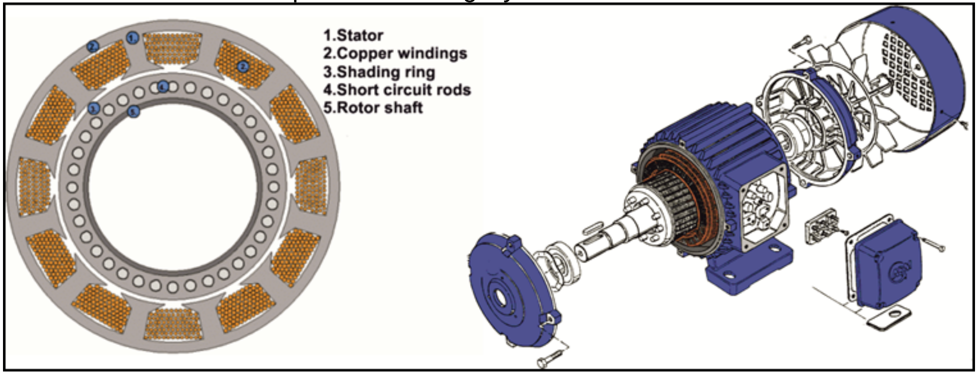
Figure III: Permanent Exited Three-Phase-Synchronous Motor (left)[661] Basic Structure1 (right) Hybrid motor by Volkswagen[662]



[661] Hybrid-Autos (2012a)
[662] Hybrid-Autos (2012b)

Figure IVshows the basic principle of the three-phase asynchronous machine with a cage rotor. It consists of a stator with embedded copper windings which are connected to the drive inverter and acage rotor consisting of short circuit rods mounted on two shading rings. The three-phase currentsupplied by the drive converter generates a rotating magnetic flux in the machine which induces current in the short circuit rods. Due to the interaction between the current in the cage rotor and the stator field, a force is acting on the rotor and the motor starts to rotate.

Figure IV: Three-Phase Asynchronous Motor with Cage Rotor[663](left) Basic Structure (right) Exploded Drawing Synchronous Motor



With regards to performance, package volume and costs, it is obvious that these two types of propulsion motors used in electric vehicles have both strengths and weaknesses. The asynchronous machine has a high efficiency factor at high speed but low load torque. When the load increases, the efficiency factor decreases. The package volume of such a motor is a bit higher compared to a permanent exited synchronous motor. Due to this fact, a small electric vehicle like the Mitsubishi i-MiEV, where maximum installation volume is limited, utilizes synchronous motors.[664]Considering the materials used and its costs, an asynchronous machine has more advantages compared to the synchronous machine. The cage rotor in an asynchronous machine is made up of materials such as alloy while synchronous motor manufacturing uses neodymium magnets. The raw material cost of neodymium has rapidly increased in 2011 making synchronous motors more expensive then asynchronous motors.[665]

2. Power Electronic Components

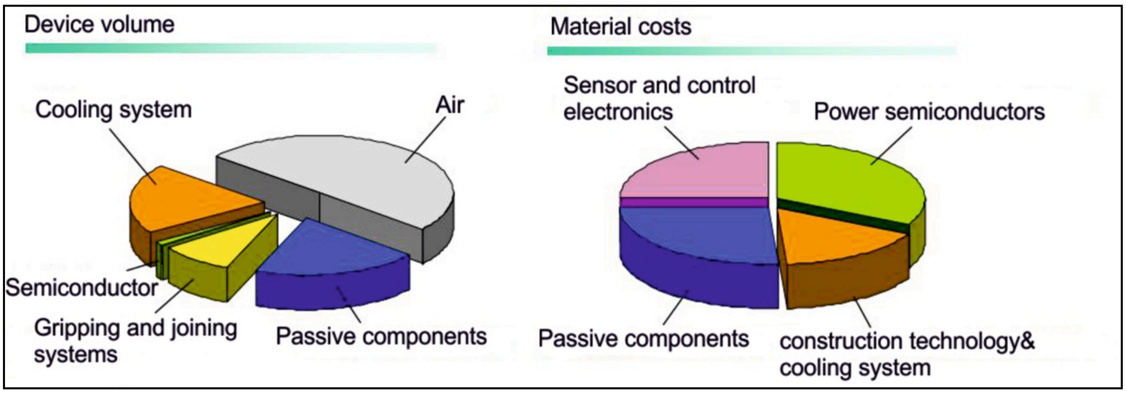
As shown in the schematic layout of an electric propulsion system in Figure I, there are several power electronic components installed in electric vehicles. One main component of the drive train is the traction inverter converting the direct current supplied by the propulsion battery into a three-phase current needed to supply the electric motor. Figure V presents a schematic representation and some examples of such a traction inverter.

Figure V:Schematic Layout of a Traction Inverter (left); (center) Traction Inverter Vektor[666]; (right) Traction Inverter BMW[667]

[663] Hybrid-Autos (2012c)
[664] Gröning (2011)
[665] Magnethandel (2012)
[666] Vectopower (2012)
[667] Autozeitung (2012)

The traction inverter shown on the left (see Figure IV) consists of six switches (Bridge Circuit) operated by an additional control circuit to generate a three-phase current at the terminals of the electric drive. Additionally, a buffer capacitor is installed parallel to the battery terminals to keep the voltage of the bridge circuit constant. Another power electronic component in electric vehicles is the DC-DC converter. It converts the battery voltage of 400V to a 12V voltage level and vice versa. Thus, the 12V vehicle electrical system is supplied by the propulsion battery. The DC-DC converter is often integrated with the traction inverter. For recharging, the propulsion battery of the on-board charger is implemented in actual electric vehicles. This on-board charging device is used to convert alternating current supplied by the grid to direct current which is necessary to charge the battery. Current electric vehicles use different charging methods depending on the power used for the process. Some examples are electric vehicles with single-phase 16A with maximum power of 3.6 kW or three-phase 16A with a maximum power of 10,6kW. The power electronic devices used in electric vehicles mainly consist of power semiconductors, heat sinks and passive components like buffer capacitors, housing and other parts. In Figure VI, the percentage allocation of the costs and overall size of the components in relation to the complete device is shown.

Figure VI: The Proportion of the Different Components on the Total Costs and the Total Volume of Power Electronic Devices[668]



Looking at the figure on the left side, half of the complete volume of power electronic devices is filled by air which can be partially considered as part of the cooling system. The power semiconductor, which is the main functional component of the power electronic device, is relatively small considering the total volume of the device. However, the power semiconductor costs nearly 30 percent of the total costs while the passive components (buffer capacitors, sensor and control electronics) represent approximately 25 percent of the total costs.

3. The High Volt-Battery

The traction battery, which is a very critical component of an electric vehicle, supplies the propulsion system. In an actual electric vehicle, only Lithium-Ion batteries are used because of their good performance data compared to other actual battery technology. The following chapter focuses on traction batteries. In Figures VII und VIII, the basic construction and the main components of such a propulsion battery are shown.

[668] VDE-ETG (2010)

Figure VII: Exemplary Basic Construction of Propulsion Batteries for EVs (left) JCI[669]; (right) SB LiMotive[670]

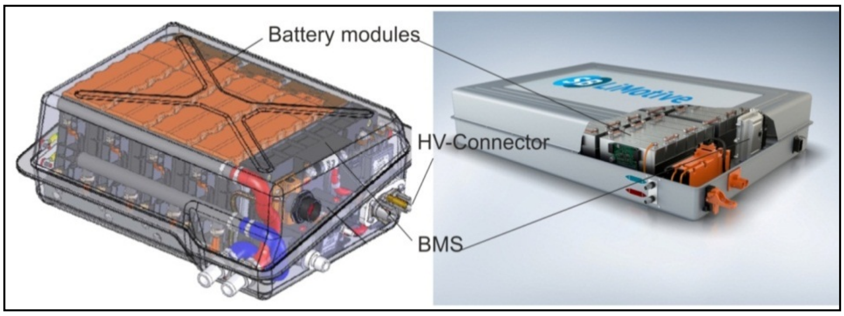
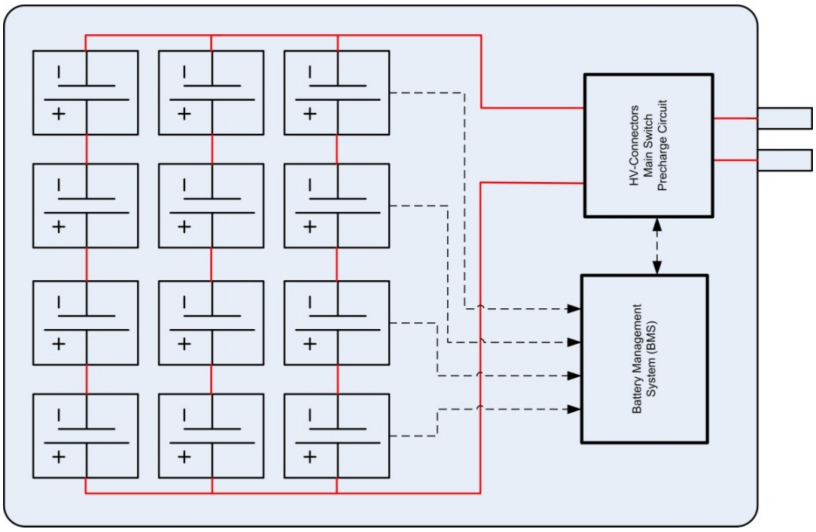


Figure VIII: Schematic Construction of a HV-Battery including their Main Components



Basically, an actual propulsion battery consists of battery cells, the battery management system (BMS) and the High Voltage distribution box. The battery cells store electric energy forpropulsion in form of chemical energy.In many cases, several cells are combined to one cell package. These packages are connected inseries to increase the overall voltage of the system and parallel to increase the total capacity of the battery as presented in Figure VIII. The high voltage distribution box is consists of HV-Relays used for switching the battery in normal operation and in case of a system failure. Additionally, a pre-charge circuit is used to limit the inrush current when activating the vehicle. Some battery manufacturers install a fuse for short circuit protection in the distribution box as well. All internal control and monitoring functions in an actual battery system are managed by the battery management system. As presented in Figure VIII, the controller gets information from the cells in the battery pack like cell voltage, cell temperature, cell State of Charge (SoC) and controls the relays and the pre-charge circuit for providing a safe operation of the system. Additionally, actual batteries are equipped with a liquid cooling system for cell protection and improvement of performance of the whole battery system.

Appendix V: Battery Performance and Safety as a Driver of Electromobility

a. Perception of Battery Performance and Safety

Perception of Battery Performance

On a worldwide view, consumer’s awareness of the existence of electric mobility has already reached a high level. On a national basis, the values fluctuate relatively strongly. But it can be confirmed that most of the people have at least heard about electric mobility. Whether they are well informed or not,

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[669] Johnson Controls (2011)
[670] SB LiMotive (2012)

this forms a broad, essential basis for the implementation of electric vehicles.According to Accenture, the level of consumers aware of the existence of electric vehicles in the international main markets for automobiles is 97 percent. The remaining three percent have never heard about electric vehicles. That can be classified as a satisfactory value by keeping in mind that the share of electric vehicles on the roads is relatively small at the moment.

According to a survey by Fraunhofer/PWC (2010), 39 percent of German respondents state that they are at least averagely acquainted to the field of electric mobility.[671] In other countries, the perception of having sufficient knowledge for an informed choice varies a lot. According to Accenture's study, the national levels are as follows: China with 44 percent, USA with 36 percent, United Kingdom with 32 percent, South Korea with 28 percent, France with 27 percent, Spain with 24 percent, Germany with 22 percent and lastly, Italy with 21 percent.[672] It can be stated that consumers around the world do not feel properly informed about electric vehicle technology which is the reason for doubts about this new technology.

According to studies conducted by Continental, the majority of people in China (68 percent), USA (51 percent) and France (57 percent) expect that it is still going to take a long time until EV technology is sufficiently well-engineered. The German respondents are slightly more optimistic featuring 46 percent.[673]

The results of an Ernst & Young[674] study reflect that the majority of consumers (76 percent) consider that electric vehicles will become more important than conventional vehicles (Europe: 78 percent, US: 74 percent, China: 70 percent, Japan: 80 percent) within the next 10 years.

According to a study by Accenture, the main reasons not to purchase a fully electric vehicle include insufficient battery range to cover daily driving needs (85 percent), insufficient availability of charging points (83 percent) and charging time which is supposed to be too long (70 percent).The percentage indicates that x percent of respondents mentioned that one of the above answers are their top three reasons.

In Ernst & Young's[675] study, similar results were found. The top reason for consumers to be hesitant to choose an electric vehicle are missing access to charging stations (69 percent) followed by price (67 percent) and range (66 percent). Ernst & Young further reflects that battery range is the most significant factor for purchasing PHEVs or EVs in Europe (72 percent, France: 81 percent, Germany: 75 percent, Italy: 62 percent, UK: 71 percent), China (73 percent) and in the USA (75 percent).

Continental's mobility study reveals a similar perception on vehicle's range. The majority perceives that the need of recharging for every 150km as annoying. Germany: 72 percent, China: 72 percent, France: 64 percent and USA: 56. Generally, it can be stated that lack of range is the main criteria in all countries. This obviously influences the option not to purchase an electric vehicle as a next car which can be linked to high range expectation.

Perception of Battery Safety

According to Ernst & Young, safety concerns are among the factors that make consumers hesitant to choose a PHEV or EV as the next vehicle. However, an international average of 41 percent of respondents mention that safety misgivings are not one of the top reasons. This is underlined by theallocation of interviewees having safety concerns: China: 64 percent, Japan: 32 percent, US 41 percent, Europe: 26 percent. Apart from China the large portion of consumers trust in the automobile manufactures.

A study conducted by Continental shows that the USA has the highest ratio (33 percent) of people who are most concerned about the safety of electric vehicles. In China, 28 out of 100 and in France, 22 out of 100 interviewees have doubts in the safety of electric vehicles. The highest rate of confidence was found in Germany where only 9 percent had safety misgivings.[676]

[671] Fraunhofer/PWC (2010)
[672] Accenture (2011a)
[673] Continental (2011)
[674] Ernst & Young (2010)
[675] Ernst & Young (2010)
[676] Continental (2011)

Reasons for safety concerns vary a lot in different countries. In China, 52 percent of the above 28 percent respondents named fear of a defective battery followed by danger due too small of range (26 percent) as reasons for safety. In the USA, the different reasons occurred nearly equally (mainly: Range: 27 percent, Electric Shock: 18 percent, Fire Hazard: 14 percent). French respondents mentioned fire hazard (37 percent), electric shock (28 percent) and danger due to low velocity (23 percent) as their main concerns. In Germany, 45 percent of the interviewed persons have misgivings, 22 percent fear an electric shock and 15 percent a defective battery.

The concerns of consumers about the safety of electric vehicles are intensified by the reports in the media (see the recent reports on the fire hazard of the GM Volt[677]). In Chapter 5 and 6, the information needs of customers will be addressed explicitly, especially concerning the role of the Public Authorities and Industry Actions.

b. Actual Reality of Battery Performance and Safety

Instead of combusting gasoline, electric vehicle use electrical energy for propulsion. This energy is stored in the propulsion battery which is the most important key component of an electric vehicle. Such batteries are implemented in Hybrid, Fuel Cell, and Plug-in Hybrid vehicles as well. This section describes safety and performance issues concerning the propulsion battery which is the most critical component of an electric vehicle.

Battery Performance:

Currently, a total of four different battery types are implemented in electric vehicles including lead acid batteries, NiNaCl (ZEBRA) batteries, NiMH battery batteries and Li-Ion batteries. Lead acid batteries are used in conventional cars and in electric vehicles to supply the 12V vehicle electrical system. This battery is not used as a propulsion battery since it weighs much more than other battery types. In electric, hybrid and fuel cell vehicles, ZEBRA batteries, NiMH batteries or Li-Ion batteries are typically installed to supply the electrical drive. Table II presents the characteristic data of all mentioned battery types. Actual electric and hybrid vehicles are normally equipped with NiMH or Li-Ion batteries. Hybrid vehicles like Toyota Prius or the VW Touareg Hybrid are equipped with NiMH batteries. In actual electric vehicles which need larger battery capacities, Li-Ion technology is used.

Table V: Specific Energy and Capacity of Different Battery Types used in Electric Vehicles[678]

Type	Specific Energy Electrochemistry	Specific Energy Cell Level	Specific Energy System Level	Example Capacity 20kWh System
Lead-Acid	170 Wh/kg	< 40 Wh/kg	33 Wh/kg	600 kg
NiNaCl2	>1000 Wh/kg	125 Wh/kg	80 Wh/kg	250 kg
NiMH	180 Wh/kg	< 70 Wh/kg	60 Wh/kg	330 kg
Li-Ion	714 Wh/kg	150 Wh/kg	110 Wh/kg	180 kg

(Source: Rosenkranz 2009)

Looking at Table IV, it is obvious that battery capacity correlates with battery weight. If a system with a total capacity of 20kWh is installed, the total weight of the battery is 330kg for a NiMH system and 180kg for a Li-Ion system. A ZEBRA battery system has an even better specific energy compared to a battery using NiMH technology. NiMH batteries, however, are used instead of NiNaCl technology due to the reason that the chemical reaction in a ZEBRA battery requires a temperature of 300°C. Thus, such a battery has to be heated actively even if the vehicle is not in a driving mode. For electric vehicles like the Nissan Leaf, which needs a high battery capacity (24kWh), Li-Ion propulsion batteries are used. Concerning Mitsubishi i-MiEV with a battery capacity of 16 kWh and a driving range of 140km, a propulsion battery with a driving range of 600km (compared to a conventional vehicle) would have a total weight of approximately 610kg when using Li-Ion technology and of 1120kg when using NiMH

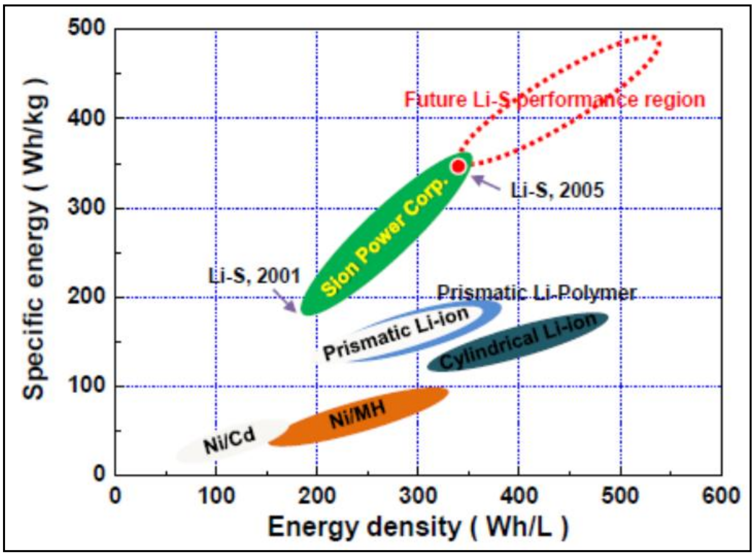
677 Motavalli (2012)
678 Rosenkranz (2009)

technology. Due to this fact, it becomes obvious that further innovations in battery technology are necessary for the success of electric vehicles.

There are two main ways to improve the actual battery technology to increase the range of electric vehicles with unchanged or even reduced weight. On one hand, an improvement potential with regards to the Li-Ion technology and on the other hand, the presence of completely new battery technologies, like batteries using metal-air technology, have to be developed. Considering the Li-Ion technology, mainly three different types of cells (cylindrical cell, pouch cell, prismatic cell) are used.

The specific energy which can be achieved with Li-Ion technology by the optimisation of the anode and cathode materials is limited to between 200 and 250 Wh/kg on cell level[679]. Thus the maximum improvement potential considering the increase of the battery's energy density is about 40 percent. As mentioned before, there are completely new battery chemistries which show great potential for a further improvement of propulsion battery technology. One of these new batteries is the Lithium sulphur battery which has a specific energy density of approximately 350Wh/kg. Figure IX presents the specific energy density of such a battery system compared to actual Li-Ion batteries. For Lithium sulphur technology, a future performance of nearly 500 Wh/kg is assumed. The battery company Sion Power developing such Li-S batteries states a driving range increase of 45 percent and a total battery weight decrease of 20 percent with the usage of their Li-S battery system compared to actual Li-Ion Batteries. This is equivalent to a range extension from 150km to approximately 270km.[680]

Figure IX: Specific Energy Density and Energy of Li-S Cells Compared to Li-Ion and other Battery Chemistries

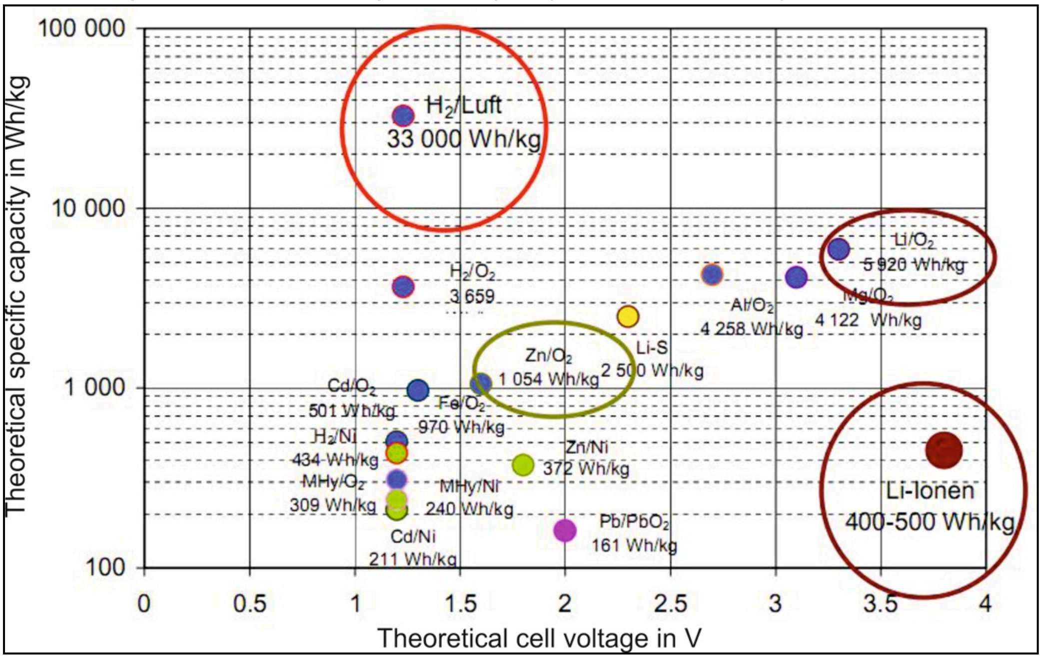


(Source: Shmuel De-Leon 2010)

Battery technologies with even more potential for an increase of energy density resulting in an increasing driving range of electric vehicles can be identified in Figure X. The yellow dot marks the Li-S Technology with an energy density of 500 Wh/kg. On the right side of Li-S, other possible battery chemistries like Aluminium-Air, Magnesium-Air and lithium air with theoretical energy densities of up to 5000 Wh/kg can be seen. For Lithium-Air technology, several companies like IBM[681] are planning battery development.

[679] Wachtler (2010)
[680] Sionpower (n.d.)
[681] Materialsgate (n.d.)

Figure X: Theoretical Specific Capacity of Different Battery Chemistries



(Source: Wachtler 2010)

a) Actual Reality of Battery Safety

Regarding actual electric vehicles and their propulsion systems, focussing on safety and environment is necessary. Concerning the vehicle safety, the most critical aspects are the danger caused by higher on-board voltage and by the propulsion battery, especially when Lithium-Ion technology is used. In contrast to combustion vehicles, electric vehicles are equipped with an additional high voltage wiring system consisting of the propulsion battery, the drive inverter and the electric machine. The operation voltage used in electric and hybrid vehicles reaches from about 200V to 800V.

For safety reasons, the electric propulsion system is completely isolated to the vehicle chassis. This represents a so called IT-System (Isolated System). Such a system has the advantage that a single electrical fault does not result in a short circuit. Thus, such a fault is not critical concerning the function of the propulsion system. Looking at the worldwide standardisation process addressing the electrical safety of electric vehicles, actual standards are currently fitted to the new usage scenarios of electric vehicles. For example, the US standard FMVSS305 demands that safety measures have to realise that the on-board voltage is below 120V per 60s after a crash has occurred.

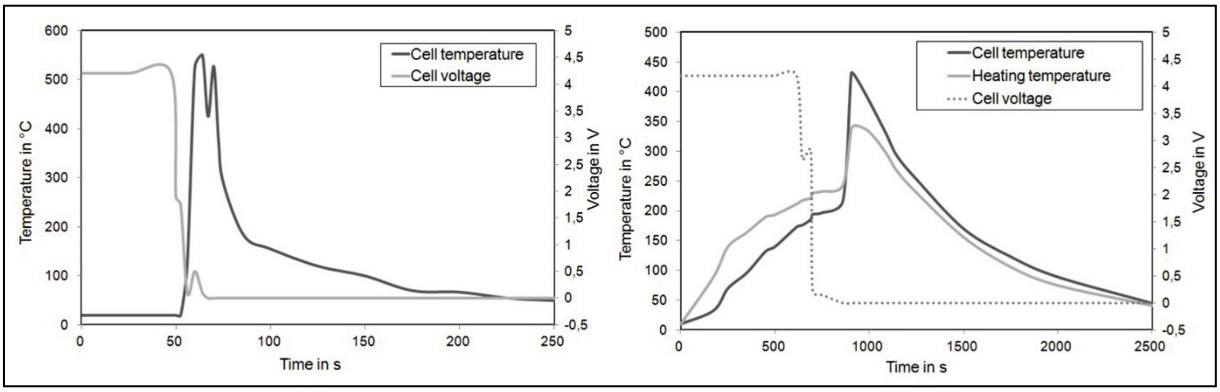
In order to provide adequate safety for the driver and the environment, several monitoring and protection functions are implemented in actual electric vehicles. One of these protection systems is the so called HVIL (High Voltage Interlock Loop). This system monitors the whole electric propulsion system for interruptions. All high voltage cables, plugs and devices are included in this circuit. If an interruption is detected, the system is immediately disabled to prevent the automobile to cause fire by electric arcs (normally by disconnection of the battery). Another system often implemented in such vehicles is an isolation monitoring system. This system permanently monitors the isolation resistance of the whole system and initiates a shutoff if a critical value is reached. One of the most important systems concerning vehicle safety is the coupling between the crash detection system and the battery control system where the shutdown is performed. As presented in Figure XI, it is absolutely necessary that the propulsion system is deactivated directly after a crash especially for effective protection of the driver and rescue teams against hazards caused by electric currents. The most serious problem of today's electric vehicles concerning rescue operation is the missing possibility of a fast identification of the vehicle propulsion system (combustion or electric) and the status of this system (activated or deactivated). One solution could be the use of the eCall system[682] for the transmission of the information just mentioned.

[682] Europe´s Information Society (n.d.)

The traction battery implemented in electric vehicles is the most critical device with regards to safety. Serious hazards can arise caused by energy released during a short circuit. When using Li-Ion technology, hazards can arise when the battery system is mechanically damaged or overheated. Figure XI presents some selected results of crush and overheating tests with cylindrical Li-Ion cells conducted by the US Company Valence INC. The diagram on the left presents the results of the crush test where the cell was mechanically damaged with a crush tool. It becomes obvious that when a cell is damaged, the separator between anode and cathode is destroyed resulting in a precipitous drop of the cell voltage causing an increase in cell temperature of up to 500°C due to the cell`s internal short circuit. The right diagram shows the results of the overheating test with the Li-Ion cells. During the test, the heating temperature is steadily increased until the cell voltage drops and the cell temperature increases rapidly up to 450°C. Looking at the test results, it can be seen that the separator of the cell is destroyed at a temperature of approximately 200°C.

It becomes obvious that if one cell of the battery package is mechanically damaged so that the separator is destroyed, a temperature increase of the cell is sufficient enough to cause high damage to the adjacent cells. Such a scenario is called thermal runaway and results in burning propulsion batteries and electric vehicles. Regarding the chemical safety, batteries using NiMH technology have significant advantages compared to Li-Ion battery systems[683]. Therefore, most Hybrid vehicles like Toyota Prius, Honda Civic Hybrid and VW Touareg Hybrid, which are currently available, use NiMH technology for supplying the drive train.

Figure XI: Selected Test Results of Crush and Overheating Tests Conducted with cylindrical $LiCoO_2$ Cells[684]



(Source: Valence 2007)

Regarding the hazard potential of Li-Ion propulsion batteries and some actual press releases such as the burning battery of a Chevy Volt one week after a side impact crash test, it becomes obvious that these batteries have to be protected sufficiently against mechanical damage. The battery should be installed at a location in the vehicle with maximum stability against mechanical damage such as the vehicle's under-chassis, under the rear bench or in the transmission tunnel.

In summary, it can be stated that batteries still have a lot of potential in terms of their range. The security of battery technology is a top priority in the development of batteries for electric vehicles and not just because of the reputation of the manufacturers. However, the results of different studies underline that a large number of consumers are not sufficiently informed about electric vehicles, their advantages, use and technology.

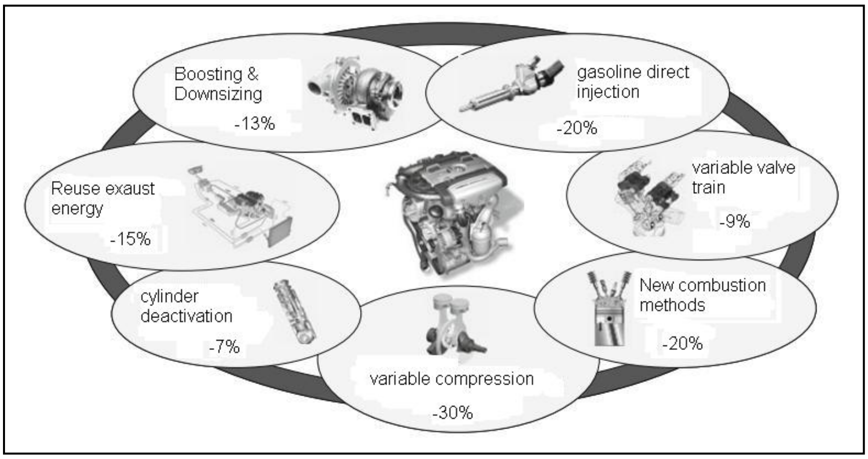
[683] Sauer (2010)
[684] Valence (2007)

Appendix VI: Analysis of the Energy Saving Potential of Vehicles with Internal Combustion Engines

The actual growth of the worldwide traffic and transport volume results in a continuous, increasing emission of green-house gases and consumption of crude oil. Looking into the future, the consequence is the problem of crude oil scarcity which will arise as the process of global warning continues. For exactly this reason, an actual step by step of electrification of motorized traffic has started. Since an immediate transition from vehicles with combustion engines to electrically propelled vehicles is not possible, a reduction of green-house gas emissions by optimisation of conventional vehicles is needed.

Due to the actual development of the EU exhaust emission standards, the optimisation of the conventional combustion engine is currently the most important research activity in the automotive industry. In the next figure, the different optimisation measures and their specific optimisation potentials are presented (see Figure XII).

Figure XII: Optimization Technologies for Combustion Engines



(Source: Wallentowitz et al. 2010)

It is apparent that concerning the optimisation of fuel consumption, the most effective methods are the direct injection of gasoline into the cylinder including combustion methods such as, the Homogenous Charge compression Ignition (HCCI); motors combining the combustion methods of the petrol and the diesel motor; and the realisation of a variable compression and the reuse of the exhaust energy for propulsion.

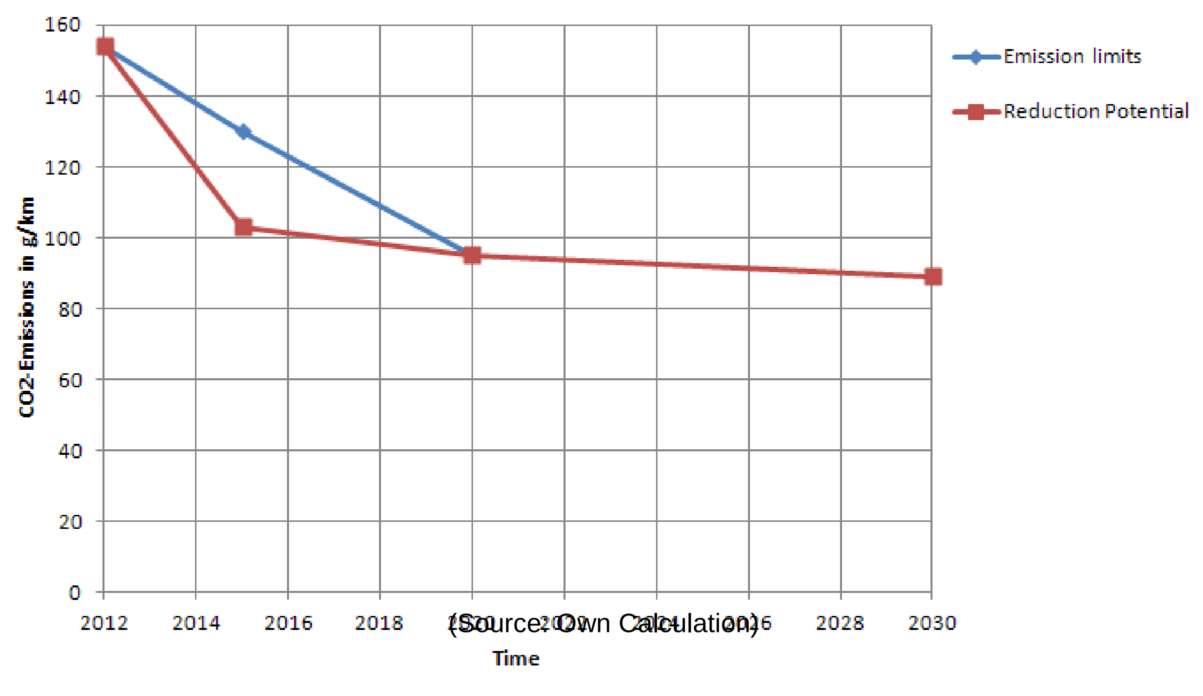
Other methods to reduce fuel consumption are engine downsizing in combination with the use of turbochargers and compressors, the realisation of a variable valve train and the cylinder deactivation in partial load operation. When analysing the future development of fuel saving potential of combustion engines, several studies and expert opinions have to be considered. All studies in the future will forecast a further decrease of fuel consumption of conventional vehicles caused by optimisation processes. The Robert Bosch GmbH expects a future potential for the optimisation of combustion engines of 29 percent for petrol engines and 33 percent for diesel engines.[685] Thus, the fuel consumption of vehicles with petrol engines will decrease from 7.7 l/100km to 5.5 l/100km and vehicles with diesel engines from 5.4 l/100km to 3.6 l/100km. This percentage excludes the optimisation potential by the use of hybrid technology. The VDA (Verband der Automobilindustrie/Germany) also predicts a fuel reduction of 25 percent for conventional vehicles by 2020.[686]

For the determination of future optimisation potential and forecasts for years 2015, 2020 and 2030, a total of four studies containing concrete data were used. As mentioned before, all experts and studies predict a decreasing fuel consumption in the future but opinions about the amount of energy saving differs. An example of this is the period 2010-2030 where a study by Shell predicts a reduction of fuel consumption of 20 percent for petrol engines and of 25 percent for diesel engines[687] while a study by Exxon Mobil predicts a reduction of 41 percent for petrol and of 42 percent for diesel engines[688].

685 IHK (2010)
686 VDA (n.d.)
687 Shell (2010)
688 Exxon Mobil (2011)

The following section describes, the impact of the mentioned combustion engine optimisation, including the use of electric start-stop functions and mild hybrid technology on the future reduction of greenhouse gas emissions of conventional vehicles. The next figure depicts the EU CO_2 emission limits compared to the estimated future reduction of greenhouse gas emissions. Looking at Figure IX, it is obvious that the EU wants to reduce CO_2 emissions by applying more stringent emission standards (blue curve). Thus, the CO_2 emission limits for newly registered vehicles decrease from 154 g/km to 130 g/km in 2015 and to 95 g/km in 2020. For the estimation of the future technical CO_2 reduction potential of conventional vehicles until 2030, the data of four studies was analysed and considered.[689] Considering the fact that was mentioned before, the fuel consumption of these propulsion systems can be reduced by about 35-40 percent until 2030 which will clearly reduce the CO_2 emissions by various engine optimisations. The red curve in Figure XIII represents the estimated future development of CO_2 emissions. The curve indicates that the CO_2emission goal of 95 g/km is reached in 2020 as well as that the emissions decrease further down to 89 g/km until 2030. The use of hybridisation (Full Hybrid), which would have an additional impact in the reduction of greenhouse gas emissions, is not considered in Figure XVIII. For the estimation of reduction potential, only optimisations like downsizing, cylinder deactivation and electrical optimisation methods (such as start-stop functions and mild hybridisation) were considered.

Figure XIII: Reduction of Greenhouse Gas Emissions for Conventional Vehicles in g/km over Time



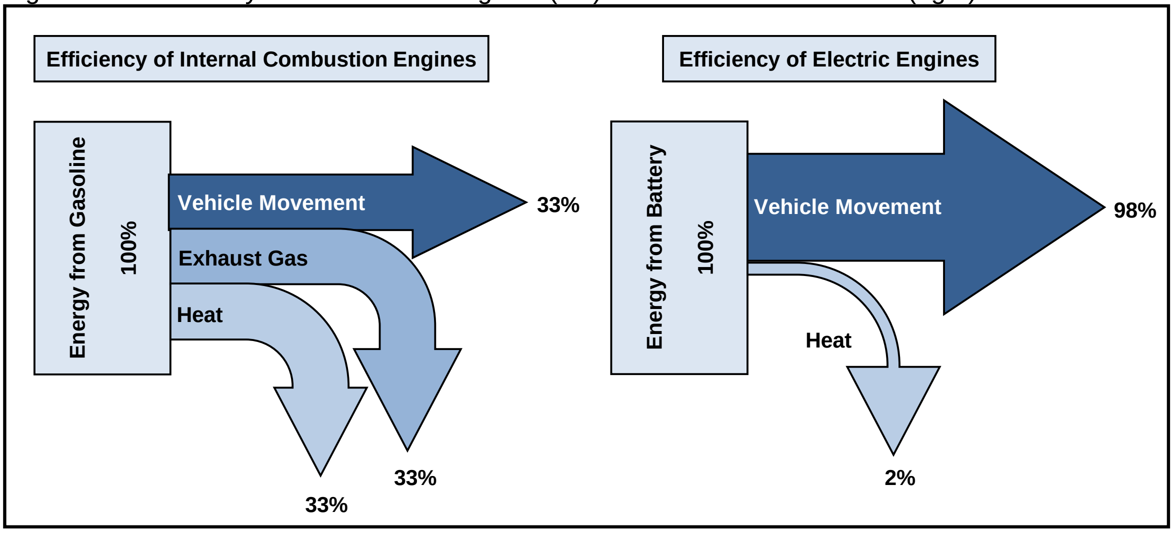
(Source: Own Calculation)

Appendix VII: Comparison of Electric and Conventional Propulsion Systems Regarding Performance and Costs

In the following chapter, electric vehicles and conventional vehicles with combustion engines are compared focusing on their performance and costs. Concerning the performance of the different propulsion systems, the next figure represents the differences in efficiency. Firstly, when looking at the schematics presented in Figure XIV, the drive train efficiency of conventional vehicles is significantly lower than the efficiency of electric vehicles. In conventional vehicles, only 33 percent of the energy from the combustion process is utilized for vehicle propulsion and other functions while an electric vehicle can use 98 percent of the energy from the battery for these purposes. The energy losses or heat waste of 33 percent can be used for heating the passenger compartment at low temperatures for vehicles with combustion engines which is an advantage compared to electric vehicles where the compartment has to be heated using energy from the battery.

[689] Deloitte (2011); Exxon Mobil (2011); IHK (2010); Shell (2010)

Figure XIV: Efficiency of Combustion Engines (left) and Electric Drive Trains (right)

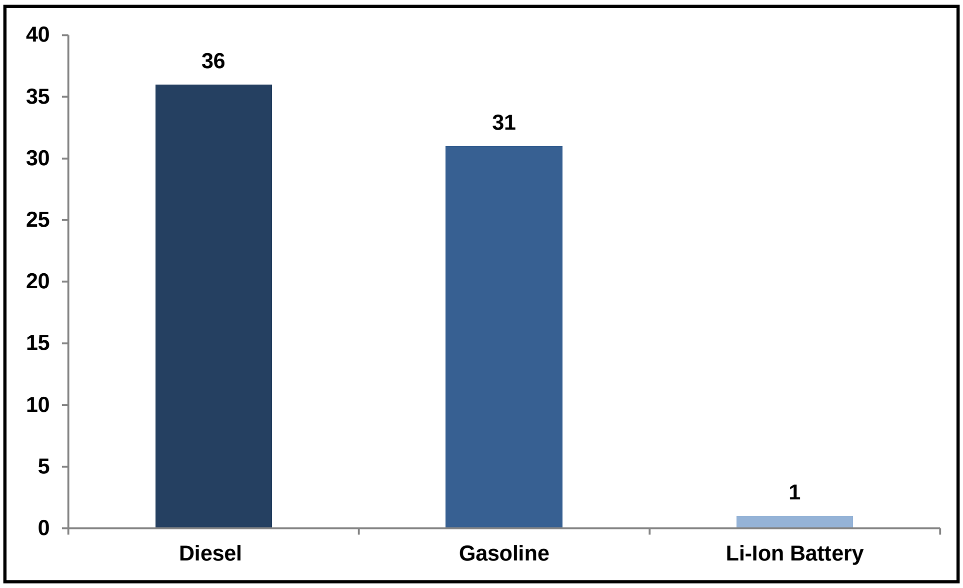


(Source:CBCITY 2012a)

When only considering the efficiency of the drive train (without the energy source), one would expect that electric vehicles have large benefits compared to conventional vehicles.

The next figure represents the main reason why the driving range of electric vehicles is much lower compared to vehicles with combustion engines. It becomes obvious that the energy density of Lithium-Ion batteries used in electric vehicles is much lower compared to diesel or gasoline fuels (see Figure XV). Thus, in a holistic examination, the driving range of actual electric vehicles using Li-Ion technology is limited to approximately 150km while conventional vehicles have a driving range of approximately 800 to 1000 km. Another benefit of conventional vehicles is that the time for refuelling is much lower than the time for recharging the battery of electric vehicles. Further developments, specifically focusing on the propulsion battery, are necessary in the future to improve the performance of electric vehicles compared to conventional vehicles.

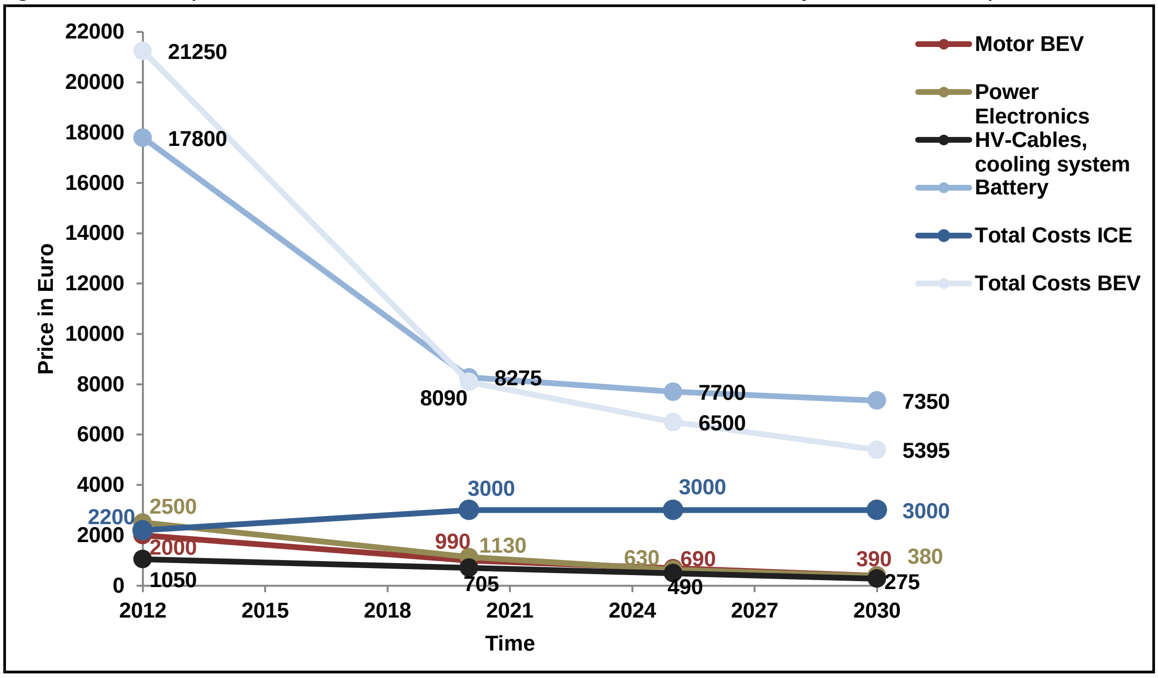
Figure XV: Energy Density of Energy Sources used in Conventional and Electric Vehicles



(Source: CBCITY 2012b)

In Figure XVI, the costs of the two different propulsion systems are analysed on a component level and compared to each other. In this analysis, only pure electric vehicles and vehicles with combustion engine are considered. For the price estimation on component level, a total of 6 studies and data of actual electric vehicles were used. Partially based on the data of several studies, a future perspective until 2030 focusing on the price development of the two propulsion systems is presented. The data considered for the price estimation is listed in the Bibliography. Figure XVI presents the actual costs for both propulsion systems on component level and additionally a forecast until the year 2030.

Figure XVI: Comparison of Electrical and Conventional Drive Train Systems on Component Level



(Source: Own Calculation)

Looking at the results of Figure XVI, it becomes obvious that considering the propulsion system of an electric vehicle, the battery has the largest portion of the total drive train costs. When considering a future increase of the production of electric vehicles, thus, also the components of the electric drive train, the production costs for all components will decrease. Out of all the components, the battery has the largest potential for cost reduction because production and battery technology have not yet reached their full maturity. Components like power electronics or electric motors have less potential for a decrease in production costs. Concerning the costs of combustion drive trains, Figure XXI shows an increase due to further development of such engines to reduce greenhouse gas emissions in the future. The total costs of an electric drive train (light blue curve/BEV) are additional, which means that the cost for the combustion engine is already subtracted. Thus, the cost for a propulsion battery is higher than the cost of the complete electric propulsion system. Based on the assumption that the production of electric vehicles will increase in the future, the total costs of an electric powertrain including the additional technical costs compared to conventional vehicles will decrease rapidly.

Appendix VIII: Assumptions on the Development of Fuel and Electricity Costs

Table VI provides an overview on our assumptions concerning the development of Fuel und Electricity Costs:

Table VI: Overview in the Development of Fuel und Electricity Costs

Market	Cost Category	2011	2020	2030
China	Fuel Cost	1.00 Euro/l	1.30 Euro/l	1.70 Euro/l
	Electricity Cost	0.05 Euro/kWh	0.08 Euro/kWh	0.10 Euro/kWh
France	Fuel Cost	1.56 Euro/l	1.87 Euro/l	2.03 Euro/l
	Electricity Cost	0.14 Euro/kWh	0.16 Euro/kWh	0.17 Euro/kWh
Germany	Fuel Cost	1.60 Euro/l	1.95 Euro/l	2.08 Euro/l
	Electricity Cost	0.24 Euro/kWh	0.25 Euro/kWh	0.26 Euro/kWh
Italy	Fuel Cost	1.73 Euro/l	1.99 Euro/l	2.08 Euro/l
	Electricity Cost	0.19 Euro/kWh	0.22 Euro/kWh	0.24 Euro/kWh
Japan	Fuel Cost	1.29 Euro/l	1.68 Euro/l	2.15 Euro/l
	Electricity Cost	0.18 Euro/kWh	0.20 Euro/kWh	0.23 Euro/kWh
Korea	Fuel Cost	1.26 Euro/l	1.39 Euro/l	1.58 Euro/l
	Electricity Cost	0.06 Euro/kWh	0.10 Euro/kWh	0.12 Euro/kWh
Rest of EU	Fuel Cost	1.50 Euro/l	1.80 Euro/l	2.00 Euro/l
	Electricity Cost	0.17 Euro/kWh	0.20 Euro/kWh	0.21 Euro/kWh
Spain	Fuel Cost	1.38 Euro/l	1.66 Euro/l	2.00 Euro/l
	Electricity Cost	0.18 Euro/kWh	0.20 Euro/kWh	0.23 Euro/kWh
UK	Fuel Cost	1.61 Euro/l	1.85 Euro/l	2.01 Euro/l
	Electricity Cost	0.15 Euro/kWh	0.19 Euro/kWh	0.21 Euro/kWh
USA	Fuel Cost	0.76 Euro/l	0.99 Euro/l	1.29 Euro/l
	Electricity Cost	0.12 Euro/kWh	0.13 Euro/kWh	0.15 Euro/kWh

(Source: Own Estimation Based on AVD 2012; IEA (n.d.), Expert Estimations)

Appendix IX: Utility and Cost Factors

Figure XVII: Utility and Cost Factors

Utility-Factors

	2012	2020	2030
ICE	1.00		
HEV	0.91	0.96	0.89
PHEV	0.81	0.89	1.06
REEV	0.77	0.91	0.99
BEV	0.69	0.76	1.10
FCV	0.14	0.37	0.69

Cost-Factors

	2012	2020	2030
ICE	1.00		
HEV	1.13	1.08	1.12
PHEV	1.21	1.19	1.17
REEV	1.40	1.30	1.18
BEV	1.56	1.29	1.19
FCV	13.05	5.44	1.81

Utility-Cost-Ratio

Utility and Costs Aggregation

	2012	2020	2030
ICE	1.00		
HEV	0.80	0.89	0.80
PHEV	0.67	0.75	0.91
REEV	0.55	0.70	0.84
BEV	0.44	0.59	0.93
FCV	0.01	0.07	0.38

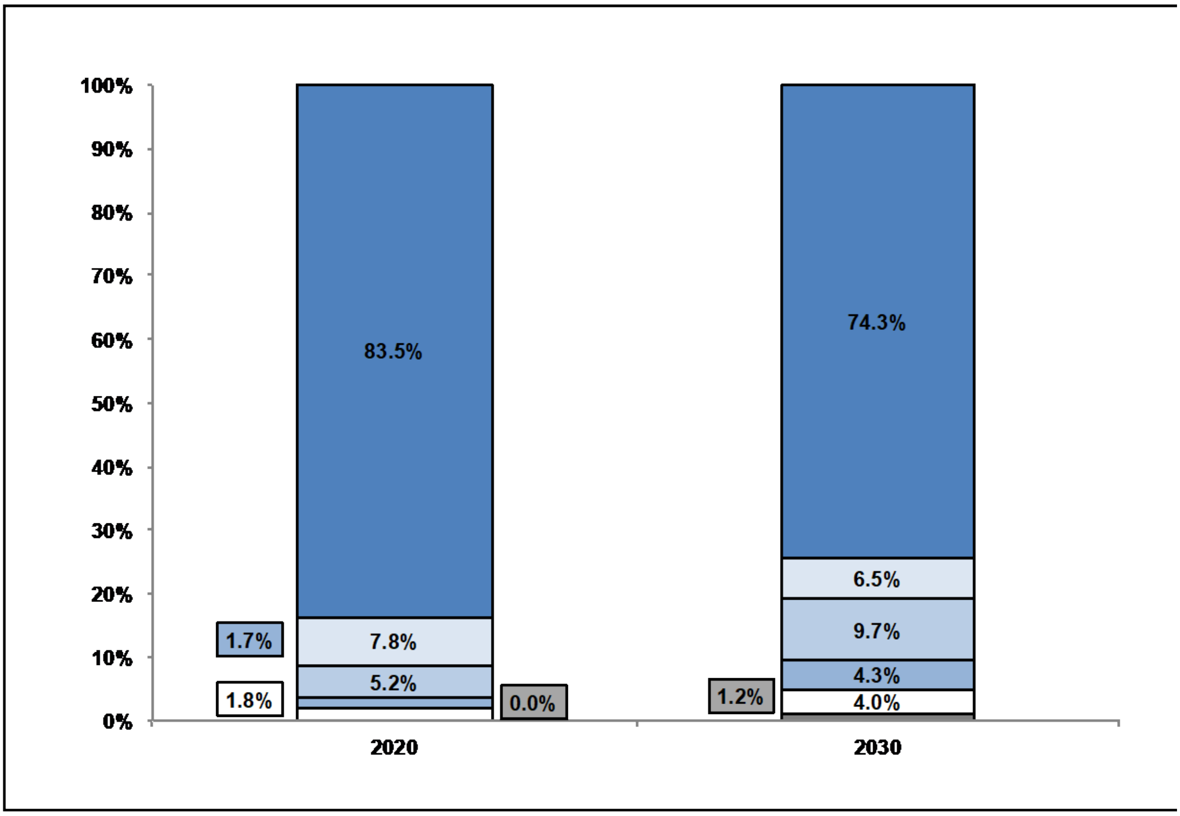
(Source: Own Calculation)

Costs and utility factors of the above mentioned electric vehicles refer to the ICE costs and utility factor in 2012 (Base Line = 1.00). Cost factors higher than 1 indicates the value which indicates that electric vehicles are more expensive than ICE. Otherwise, utility factors below 1 illustrate the value by which electric vehicles are less beneficial than ICEs.The utility-costs-ratio indicates the aggregation of costs and utility for different vehicle types. All values below 1 highlight that the costs outweigh the perceived utility (see Figure XVII).

Appendix X: Market Development of Electric Vehicles in France, Germany, Italy, Spain and the United Kingdom until 2030

In**Germany**, the registrations of new vehicles with traditional combustion engines will decline until 2030 (from 84 percent in 2020 to 74 percent in 2030) while the registrations of electric vehicles will increase (from approximately 9 percent in 2020 up to 19 percent in 2030).In 2020, about 9 percent of the German new vehicles will be electric vehicles, including 5 percent Plug-In Hybrids, and about 4 percent Battery Electric Vehicles and Range Extenders in sum. By 2030 the German electric vehicle registrations will increase. Approximately 10 percent of the new vehicle registrations will be Plug-in Hybrids, 4 percent Battery Electric Vehicles and 4 percent will be Range Extenders. The share of full hybrid electric vehicles, which will be about 8 percent in the year 2020, will decrease until 2030 up to a total share of 6.5 percent. Due to cost reduction and less fuel consumption Plug-In Hybrids gain importance until 2030 instead. In 2030, Fuel Cells will gain in importance but the registrations will remain less than 2 percent. Figure XVIII illustrates the continuous increase in the registrations of electric vehicles in Germany until 2030. Due to the demographic decrease of the German population we expect a decline of the German vehicle market in the long run.

Figure XVIII: German Electric Vehicle Registrations in Percent until 2030



(Source: Own Calculation)

Our market model and almost all the surveyed German experts, initially expect a slow development of electric vehicles in Germany. A majority of the experts consider the 13 percent share of early adopters in Germany as realistic. By 2020, experts assume a moderate market growth, which will increase slightly by 2030. A global German car manufacturer considers the market development of range extenders as limited in the medium term, due to the decoupling of the engine and powertrain. Instead, electric vehicles with optimized battery technology will gain importance or the ability to charge the vehicle while driving (requiring infrastructure development).

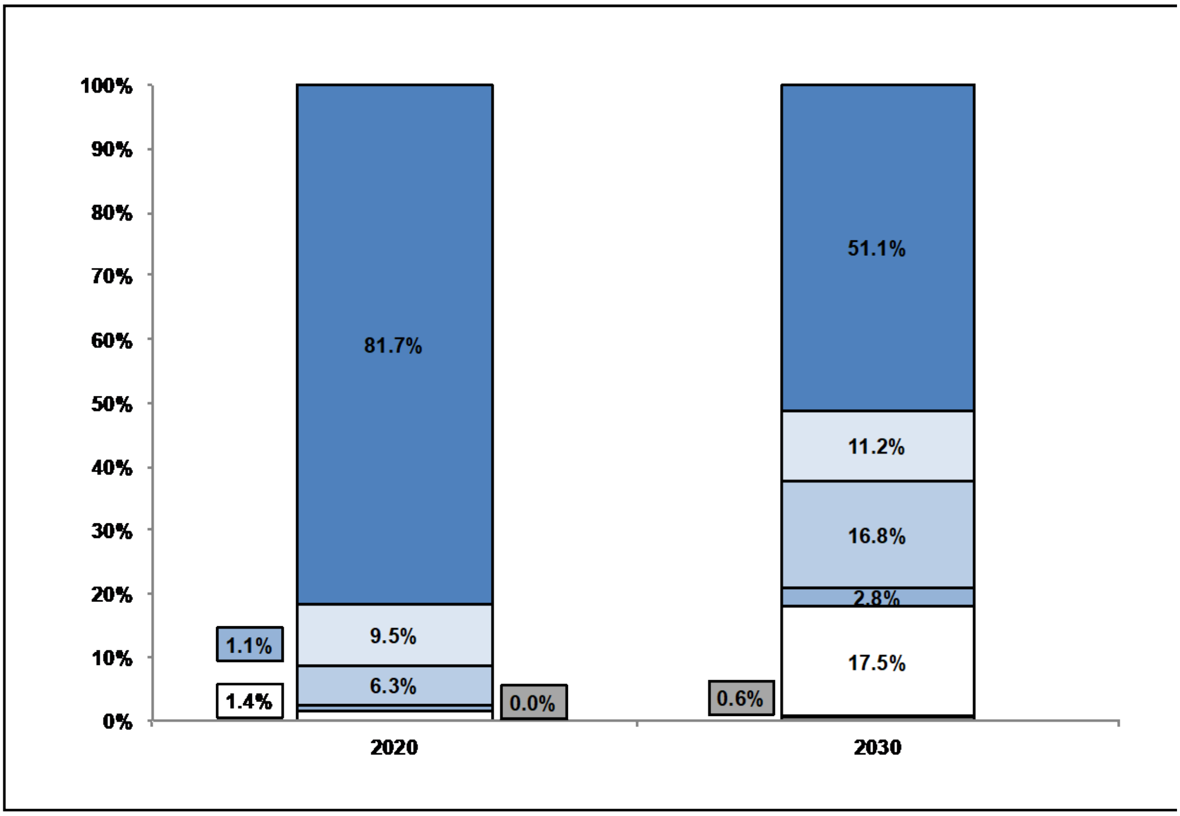
According to the majority of the manufacturers surveyed, Fuel Cells will not gain importance until 2030 in the German market. The majority of experts, however, mainly regard the high costs, lack of infrastructure, lack of (energy efficient) production, storage, and transport of hydrogen as key factors, influencing the market development of Fuel Cells. Most of these issues have been debated for almost 15 years. Fuel Cells have been discussed as being technically feasible and profitable in the near term –

often even announced as being launched "tomorrow". Nevertheless, the VDA (Verband der Automobilindustrie) consider fuel-cell vehicles as an "important part of future mobility." In the medium term both the internal combustion technology, (especially the diesel-technology) as well as the hybridisation of vehicles, are considered to have a great potential by the experts. These assumptions are reflected by the results of our market model.

In contrast to the German market, new vehicle registrations in **France** will show significant differences over time. The French registrations of new vehicles with traditional combustion engines will decrease in 2030 (from 82 percent in 2020 to 51 percent in 2030) while the registrations of electric vehicles will increase (from 9 percent in 2020 to about 38 percent in 2030). While ICE will dominate the new vehicle registrations for the next decade, hybrids will become more attractive until 2020. From 2020 onwards, a rapid increase of the registrations of BEVs will be noticed (see Figure XIX).

Aside from differing consumer preferences, this trend can be explained by the strategies of French car manufacturers. Renault already offers four Battery Electric Vehicles (see Chapter 2.1.1). The PSA Group has launched the first BEV (Peugeot iOn) recently.Thus, the market development of electric vehicles in France depends crucially on the strategy of the French manufacturers. By 2030, about 18 percent of the new vehicle registrations will belong to BEVs. In 2030, Fuel Cells will gain in importance, but the registrations will remain less than one percent.

Figure XIX: French Electric Vehicle Registrations in Percent until 2030

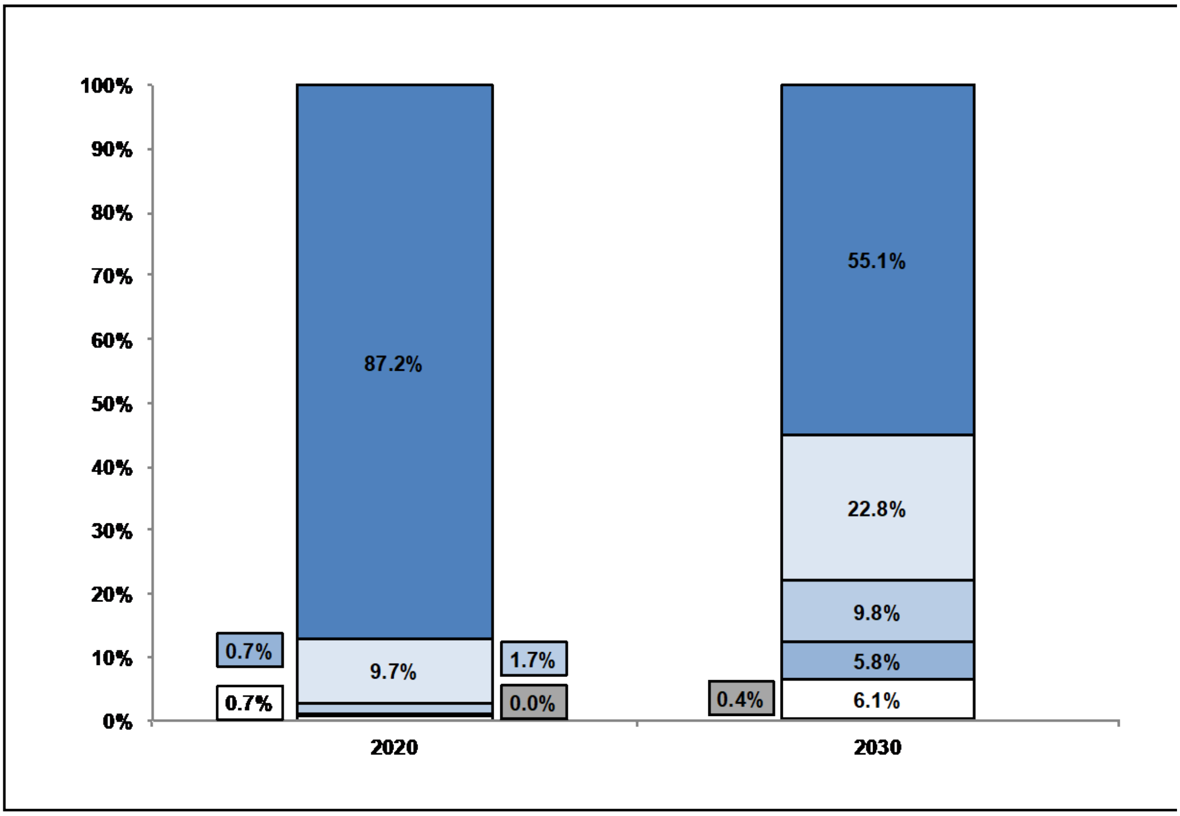


(Source: Own Calculation)

In terms of the development of electric vehicles in France, both the results of our market model and the estimations of most surveyed French experts are very optimistic. Nevertheless, some experts doubt whether the French market will develop faster than the other European markets. In their opinion the operating costs (e.g. electricity costs compared to high fuel costs) will not induce higher registrations of private customers in general, due to the higher additional costs of electric vehicles. Therefore, even in France, the early adopters are expected to be primarily commercial customers. This assumption has been included in our model (see customer segments in Appendix III).Recently, a group of French companies including Electricite de France, SNCF, Air France, France Télécom and La Poste have committed to purchase an initial order of 50,000 electric vehicles. Furthermore, Autolib started to offer microcars in Paris in December 2011 with its car sharing program. Parisians who are members can use small electric cars, for a small charge and for short trips.[690] The Bolloré Group, which is a family-owned industrial holding company behind Autolib, plans to have 3,000 battery electric cars of type "Blue Cars" circulating on the streets of Paris and its inner-ring in the short term.[691] This will help the French population (especially the Parisian metropolitans) to become accustomed to electric vehicles. The French customers will have a good opportunity to "experience" the benefits of electromobility.

In **Italy**, the market for electric vehicles will develop slowly over time. In the long term, the Italian registrations of new vehicles with traditional combustion engines will decline up to 2030 (with a share of 87 percent in 2020 compared with a share of 55 percent in 2030) while the registrations of electric vehicles will increase (3 percent in 2020 compared with a share of about 22 percent in 2030). The ICE technology will dominate the new vehicle registrations for the next decade while the registrations of Hybrid Electric vehicles and Plug-In Electric vehicles will increase rapidly from 2020 to 2030 (see Figure XX).

Figure XX: Italian Electric Vehicle Registrations in Percent until 2030



(Source: Own Calculation)

This development can be explained with the rise in fuel costs on the one hand and the fuel savings (20 to 25 percent) of hybridisation on the other hand. Thus, by 2030 almost 6 percent of the total new registrations are BEVs and a further 6 percent belong to Range Extenders. In 2030, Fuel Cells will gain in importance but the registrations will remain less than one percent. The following chart illustrates the continuous increase in the registrations of electric vehicles in Italy up to 2030.

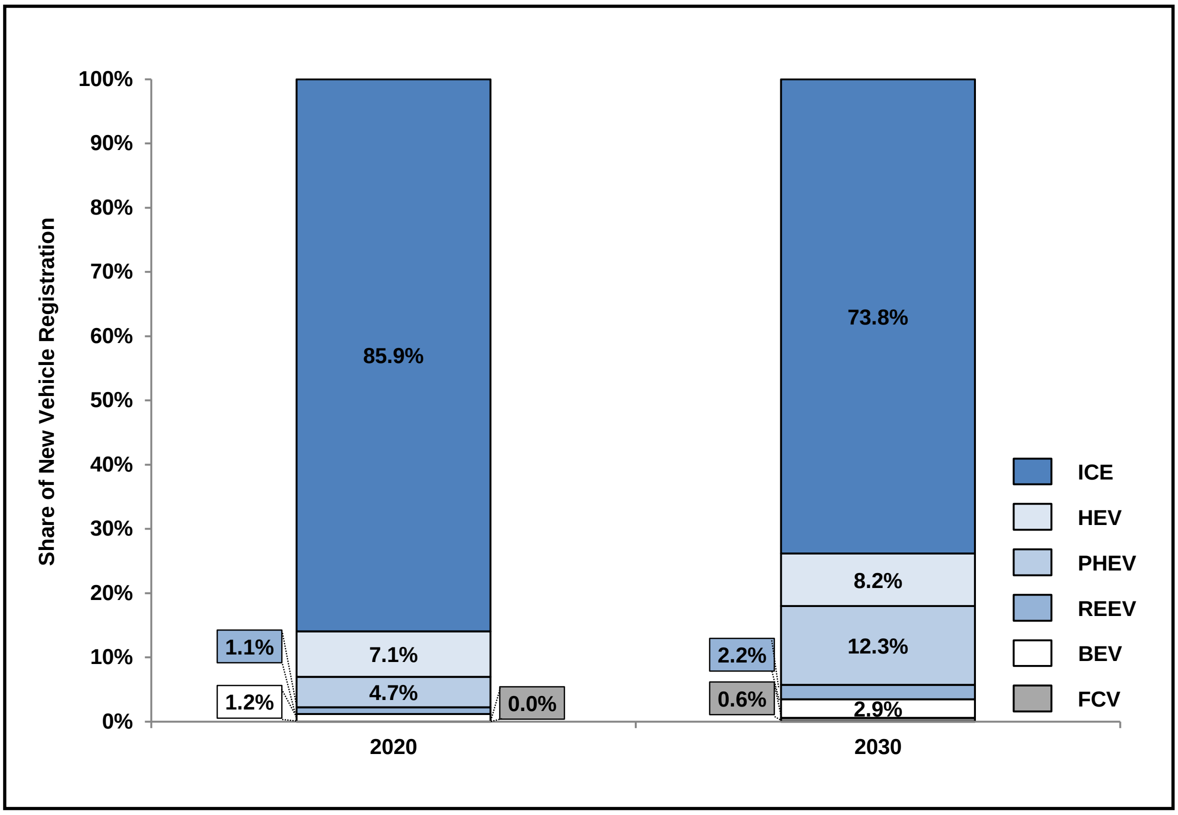
In 2030, approximately 330,000 of the total Italian new vehicle registrations will be electric. Experts believe that both natural gas vehicles and full hybrids will gain importance as well as hybridisation of vehicles with natural gas. Due to the infrastructure (mountainous landscape, narrow streets) and high degree of urbanisation (many people live in or near large cities), the Italian experts, who have been

[690] Autolib (2012)
[691] IEA (2011a)

surveyed in this study, expect that electric vehicles with traditional vehicle architecture will not gain importance in Italy. Because of the deficiencies in the infrastructure, Italian key players are currently working on projects pursuing wireless charging for effective urban mobility (Italian Electrified Mobility Technological Platform).

The market of electric vehicles in the **United Kingdom** will increase slowly. Hybrids will dominate electric vehicle registrations by 2025. The UK government offers purchase premiums, in order to stimulate the purchases of electric vehicles. These purchase premiums also relate to hybrids (depending on their emission of CO2 emissions). The UK new vehicle registrations of vehicles with traditional combustion engines will decline up to 2030 (with a share of 86 percent in 2020 compared with a share of 74 percent in 2030) while the registrations of electric vehicles will increase (7 percent in 2015 compared with a share of about 18 percent in 2030). While ICEs will dominate the new vehicle registrations for the next decade, hybrids will become more attractive until 2020. From 2020, the registrations of PHEVs will catch up. By 2030, approximately 12 percent of the UK new vehicle registrations will be Plug-In Hybrids while 3 percent of new registrations will be Battery Electric Vehicles and 2 percent belongs to Range Extenders. In 2030, Fuel Cells will gain in importance in the UK but the registrations will remain less than one percent. In 2030, approximately 360,000 of the total UK new vehicle registrations will be electric vehicles. The following Figure XXI illustrates the continuous increase in the UK electric vehicle registrations up to 2030.

Figure XXI: UK Electric Vehicle Registrations in Percent until 2030

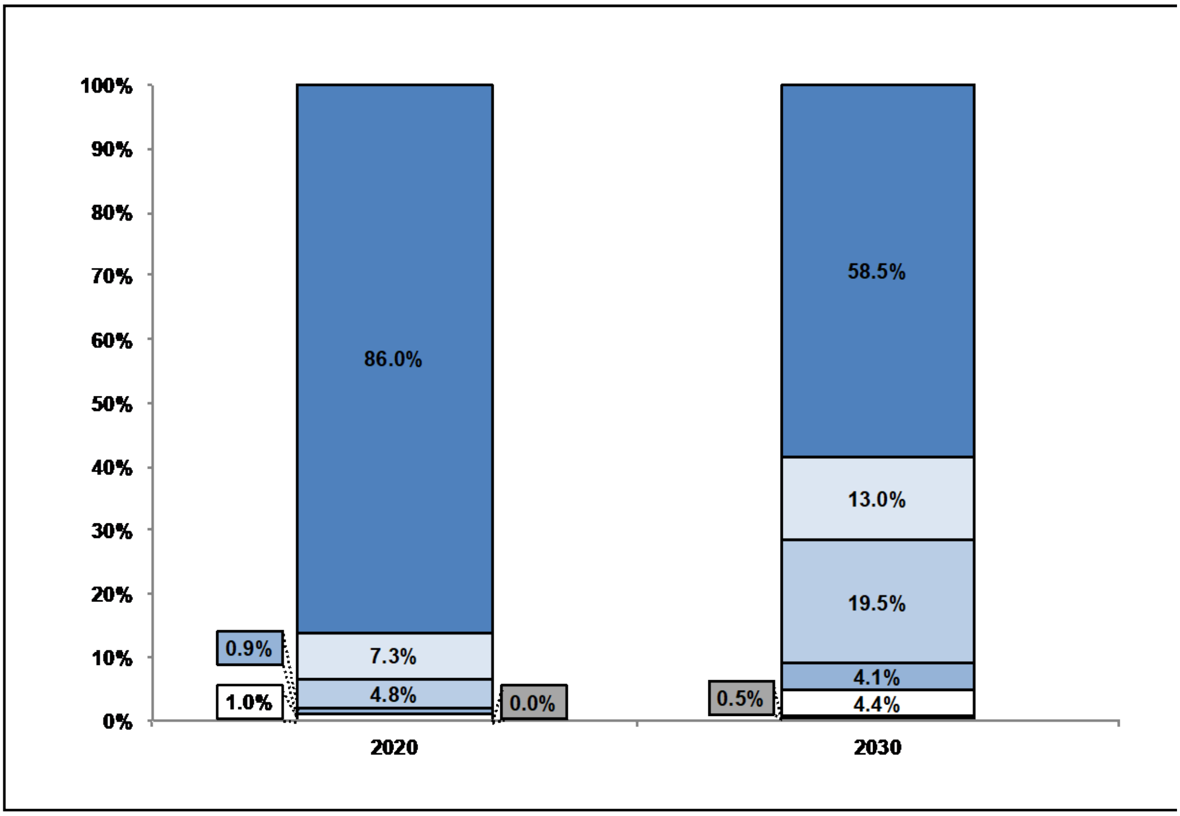


(Source: Own Calculation)

The UK experts consider the commercial fleets as early adopters of electric vehicles in the medium term. The opinions of the UK experts are consistent with the results of the market model. In 2030, the share of electric vehicles is expected to be slightly more than about 20 percent. According to the experts, the UK new electric vehicle registrations will vary between 20 and 30 percent (including BEVs, REEVs, PHEVs and a low number of Fuel Cells) in 2030. Since all of the experts have confirmed the large share of late adopters among private consumers, we consider the results of our market model as realistic.

The **Spanish** registrations of vehicles with traditional combustion engines will decline up to 2030 (with a share of about 86 percent in 2020 compared with a share of 58 percent in 2030) while the registrations of electric vehicles will increase (with approximately 7 percent in 2020 compared with a share of about 29 percent in 2030). The high costs of electric vehicles, which will not fall significantly until 2020, are confronted with very low fuel cost in Spain. Therefore, while the ICEs will dominate the new vehicle registrations for the next decade, hybrids will gain importance from 2020, and by 2030, the registrations of PHEVs will catch up. Figure XXII illustrates the continuous increase in the Spanish electric vehicle registrations up to 2030.

Figure XXII: Spanish Electric Vehicle Registrations in Percent until 2030



(Source: Own Calculation)

According to the results of our market model and also based on the opinions of almost all Spanish experts, approximately 330,000 of the total new vehicle registrations in Spain will be electric in 2030. The registrations of ICEs will dominate the electric vehicle market by 2020 while Electric Vehicles will gain importance by 2030.

In recent years, the new vehicle registrations of private customers have decreased. The percentage of commercial registrations has increased. Due to the economic crisis, most of the experts rather consider commercial customers as "early adopters" of electric vehicles and hybrids than private customers for the medium term (differences in willingness to buy and purchase). Nevertheless, electric vehicles and hybrids are currently being heavily promoted by the Spanish government (see Chapter 5.1.1). Among the taxi registrations, the Toyota Prius is gaining importance particularly due to the purchase premium which is offered by the government. Presently, Toyota benefits from this development although most of the value added of the Toyota Prius concerning the lifecycle currently resides in Asia.

Appendix XI: Current Trade Patterns between Japan and the EU

In 2010 Japan's eight passenger car manufacturers[692] domestically produced about 8.3 million automobiles of which approximately half (about 4.2 million) were exported. In terms of total domestic production volume, absolute figures show a declining tendency since the 1990s indicating saturation on in the domestic market. From a height of about 9.6 million vehicles produced in 1990, production decreased to approximately 8.3 million vehicles in 2010.

In 2010 Japan's eight passenger car manufacturers[693] domestically produced about 8.3 million automobiles of which approximately half (about 4.2 million) were exported. In terms of total domestic production volume, absolute figures have shown a declining tendency since the 1990s indicating saturation in the domestic market. From a height of about 9.6 million vehicles produced in 1990, production decreased to approximately 8.3 million vehicles in 2010.

Toyota is the largest manufacturer in Japan with nearly three million cars produced in 2010 accounting for more than 30 percent of the entire domestic production. Since 2000 Toyota's local production volume stagnated. Due to the company's dominant position in the market, it reflects the overall tendency of growth perspectives: stagnation on a high level.

Nissan is the second largest manufacturer of cars in Japan and a major exporter. Nissan´s sales triggered by the strong currency of the yen, may lead to a long term stagnation of the overall exports. Approximately 50 percent of all domestically produced cars are exported. The development of exports since 1990 is positive. From 1980 to 1990 exports decreased by seven percent and then grew by 4 percent from 1990 to 2000 and again by 13 percent from 2000 to 2010. Due to the strong yen and no indication for a potential change in the overall economic situation, vehicle manufacturers may follow the example of Nissan and reduce exports by shifting more volumes to their transplants. Toyota recently announced that plans are under discussion to double exports to South Korea from plants located in Europe and the United States, not from Japan.[694] These facts indicate that growth expectations in Japan are rather low in the long term. Realistically, export volumes may stagnate at the current level.

Almost 70 percent of all exports are delivered to Europe and the Americas, whereby the share delivered to Europe accounts for ca. 20 percent or about 942,000 units in absolute terms (2010). Vehicles imported from Europe amount to just 145,000 in 2010 resulting in an unbalanced trade relation in favour for Japan. European imports account for more than 60 percent of all imports. Imports from other Asian countries (about 45,000 units) and North America (11,000 units) only play a minor role. Automobiles manufactured by foreign makers play a marginal role on the domestic market. In absolute terms, the total import volumes are low and rather stagnant at a level of approximately 260,000 units since 1990. Hence the growth potential´s tendency can be theoretically regarded as positive. European cars (mostly the luxury segment) enjoy a good reputation already, joint efforts by Japan and the European Union to reduce Japanese non-tariff barriers may lead to an increase in imports from the EU. If South Korean car makers are able to increase product reputation in Japan too, after their success in the last few years in the U.S., European, and Chinese markets, Japanese consumers may be more willing to buy Korean cars. However, although a rather positive long term trend is assumed here, international car manufacturers, particularly those active in the mass segments, may regard the long term prospects of sales in Japan as unattractive.

[692] Daihatsu, Fuji, Nissan, Honda, Mazda, Mitsubishi, Suzuki and Toyota
[693] Daihatsu, Fuji, Nissan, Honda, Mazda, Mitsubishi, Suzuki and Toyota
[694] Schmitt (2012)

Appendix XII: Japanese Kei Car Privileges and Tax Reforms

EBC Automobile Committee
Member Companies

ACEA
Audi Japan
BMW Japan
Fiat Group Automobiles Japan
Jaguar Land Rover Japan
Mercedes-Benz Japan
Nicole Automobiles
Peugeot Citroen Japon
Porsche Japan
Volkswagen Group Japan
Volvo Cars Japan
Volvo Nippon

Key Issues and Recommendations

■ Tax reform

Yearly status report: little progress. Compared with other countries, Japan imposes an excessively heavy tax on the purchase and ownership of motor vehicles.

Recommendations:

The Government of Japan should:

- Abolish the Automobile Acquisition Tax and Tonnage Tax.
- Simplify the structure of the tax on automobiles and reduce the overall tax burden on motorists in line with international best practice.
- Conduct a comprehensive review of the taxation on fuels from the perspective of environmental policy.
- Adopt and implement as early as possible internationally harmonised standards for measuring fuel efficiency and exhaust emissions to assess environmentally friendly vehicles.

■ Harmonisation of technical standards and certification procedures

Yearly status report: some progress. The EBC Automobile Committee welcomes Japan's proposals in WP29 in Geneva for the adoption by 2015 of an International Whole Vehicle Type Approval (IWVTA) system. This would make mutual recognition of vehicle certification possible between Japan and the EU.

Recommendations:

- Accelerate adoption of UN-ECE Regulations.
- Work closely with EU Member States and the European Commission to implement the proposal for an International Whole Vehicle Type Approval system.

■ *Kei* cars

Yearly status report: no progress. The continued existence of regulatory and fiscal privileges for *kei* cars distorts competition.

Recommendation:

- The Government of Japan should put *kei* cars and other motor vehicles on the same footing.

■ Technical guidelines for new safety technologies

Yearly status report: some progress. The European Commission and Japan have reached an agreement of principle on the introduction of "more transparent, streamlined and inclusively consultative procedures for the administration of technical guidelines in relation to new automotive safety technologies." The agreement takes into account many, but not all, of the proposals made by EBC Automobile Committee members. It should pave the way for the more rapid market introduction in Japan of proven European advanced safety technologies.

Recommendation:

- The Government of Japan should implement promptly the terms of the agreement reached with the EU.

Source: Millington (2010)

Appendix XIII: Current Trade Patterns between Korea and the EU

The five Korean automobile manufacturers[695] produced about 4.3 million cars in 2011 in which about 70 percent were exported. The highest production share is allocated to Hyundai Motors, consisting of the brands Hyundai and Kia, which represents approximately 70 percent of the total production volume. Since 1980 the production volume has increased steadily, with short-term drawbacks caused by the financial crisis in the years 1997/1998 and 2008/ 2009. During the last 10 years (2001-2011) production grew by 5.3 percent, exports grew by 8.6 percent (Compound Annual Growth Rate). With a domestic market becoming more and more saturated since the 1990s at a level of around one to 1.2 million car sales per annum, Korean car makers, (in the first place Hyundai, Kia and GM Daewoo) began to internationalise. The first phase of this progress can be seen in export growth. During the second phase, starting around 2000, Hyundai and Kia extended their manufacturing footprint by establishing production plants in Europe and the U.S., among others.[696]

Korean car makers currently export (2011) nearly 3 million passenger cars to overseas markets. In 2010, the largest export markets were the U.S.(about 1.1 million units), the Middle East (about 590,000 units) and Europe (EU about 312,000 units, rest of Europe 211,000 units). Between 2010 and 2011 exports to Europe (EU + rest of Europe) increased by 30 percent to 686,000 units (total) due to the Korea-EU FTA that went into effect in July 2011.[697] Though Europe is the largest importer of passenger cars to Korea (65 percent, Japan 26 percent, U.S. 8 percent) the volume of imports in absolute terms is low. In 2010 Europe exported 59,000 passenger cars to Korea, leaving the trade relation unbalanced. Though imports from the U.S., Europe, and Japan grew strongly during the last 10 years[698], there were ca. 100,000 imported cars sold in Korea in 2011, representing a market share of approximately only 9 percent.

[695] Hyundai, Kia, GM Daewoo, Ssangyong, Renault-Samsung
[696] Lansbury et al. (2007)
[697] Yonhap News Agency (2011b)
[698] Compound Annual Growth Rates 2000-2010: EU 30 percent, U.S. 19 percent, Japan 45 percent.

Appendix XIV: Korean Passenger Cars Production and Korean Import and Export of Passenger Cars

Table VII: Korea – Import and Export by Country 2010, Forecast 2020 and 2030

			Imports by Country[2]				Exports by Country[3]								
		Domestic Production[1]	US	Europe	Japan	Total	North America	Central & South America	EU4	Rest of Europe4	Asia	Middle East	Africa	Oceania	Total
2009	[units]	3,158,417	6,140	37,826	17,027	60,993									
2010	[units]	3,866,206	7,450	59,242	23,870	90,562	677,660	446,619	312,406	211,603	169,933	586,740	171,554	180,317	2,756,832
2011	[units]	4,221.617				105,037			414,707	270,834					
2010 Export Distribution							25%	16%	11%	8%	6%	21%	6%	7%	100%
10-year growth (Based on CAGR 2000-2010):		5,3%	19%	30%	45%	23,2%									8,6%

Scenario 1 - Based on past growth rates

		Domestic Production	US	Europe	Japan	Total	North America	Central & South America	EU4	Rest of Europe4	Asia	Middle East	Africa	Oceania	Total
2020	[units]	4,071,115	8,866	77,015	34,612	120,492	735,939	485,028	339,273	229,801	184,547	637,200	186,308	195,824	2,993,920
2030	[units]	4,286,884	10,550	100,119	50,187	160,856	799,229	526,741	368,450	249,564	200,418	691,999	202,330	212,665	3,251,397

							North America	Central & South America	EU4	Rest of Europe4	Asia	Middle East	Africa	Oceania	Total
2011 (est) Exports and Distribution							677,660	446,619	414,707	270,834	169,933	586,740	171,554	180,317	2,918,364
							23%	15%	14%	9%	6%	20%	6%	6%	100%
10-year growth (Based on CAGR 2000-2010; Exception: Europe 10% additional CAGR/ decade assumed due to KOREUS FTA)			19%	40%	45%										9,6%

Scenario 2 - KOREUS FTA

		Domestic Production	US	Europe	Japan	Total	North America	Central & South America	EU4	Rest of Europe4	Asia	Middle East	Africa	Oceania	Total
2020	[units]	4,071,115	8,866	82,939	34,612	126,416	742,715	489,494	454,519	296,834	186,247	643,067	188,023	197,627	3,198,527
2030	[units]	4,286,884	10,550	116,114	34,612	161,276	814,016	536,486	498,153	325,330	204,126	704,801	206,073	216,600	3,505,586

(Source: [1]KAIDA (2012a); [2]KAIDA (2012b); [3]KAMA (2011); 2010, 2011est based on (Yoo 2011))

Table VIII: Korea - Passenger cars: Share of Import by Country/ Region 1994-2010, Forecast 2020 and 2030

		USA	Europe	Japan	Total
1994	units	1,903	1,962	0	3,865
	share in %	49%	51%	0%	100%
1995	units	2,578	4,343	0	6,921
	share in %	37%	63%	0%	100%
1996	units	4,180	6,135	0	10,315
	share in %	41%	59%	0%	100%
1997	units	4,166	3,970	0	8,136
	share in %	51%	49%	0%	100%
1998	units	1,227	848	0	2,075
	share in %	59%	41%	0%	100%
1999	units	761	1,640	0	2,401
	share in %	32%	68%	0%	100%
2000	units	1,238	3,176	0	4,414
	share in %	28%	72%	0%	100%
2001	units	1,502	5,404	841	7,747
	share in %	19%	70%	11%	100%
2002	units	2,969	10,182	2,968	16,119
	share in %	18%	63%	18%	100%
2003	units	3,172	12,535	3,774	19,481
	share in %	16%	64%	19%	100%
2004	units	3,509	12,999	6,837	23,345
	share in %	15%	56%	29%	100%
2005	units	3,811	18,010	9,080	30,901
	share in %	12%	58%	29%	100%
2006	units	4,556	23,769	12,205	40,530
	share in %	11%	59%	30%	100%
2007	units	6,235	29,522	17,633	53,390
	share in %	12%	55%	33%	100%
2008	units	6,980	32,756	21,912	61,648
	share in %	11%	53%	36%	100%
2009	units	6,140	37,826	17,027	60,993
	share in %	10%	62%	28%	100%
2010	units	7,450	59,242	23,870	90,562
	share in %	8%	65%	26%	100%

CAGR (last 10 years) (0, 9)	19%	30%	45%

Forecast - "Scenario - No Change"

		USA	Europe	Japan	Total
2020	units	8,866	77,015	34,612	120,492
	share in %	7%	64%	29%	100%
2030	units	10,550	100,119	50,187	160,856
	share in %	7%	62%	31%	100%

Source: KAIDA (2012b)

Table IX: Korea - Passenger Car Production, Import and Export 1987-2011, Forecast 2020, 2030: Share of Import by Country/ Region 1994-2010, Forecast 2020, 2030

	Domestic			Imports	
	Production	Export	Sales	Sales	market share
1987	793,125	535,231	249,448	10	0,0%
1988	872,074	564,511	323,561	263	0,1%
1989	871,898	347,273	514,484	1,293	0,3%
1990	986,751	339,672	626,126	2,325	0,4%
1991	1,158,245	378,600	772,548	1,736	0,2%
1992	1,306,752	427,515	876,262	1,817	0,2%
1993	1,592,669	572,402	1,037,488	1,987	0,2%
1994	1,805,895	648,385	1,140,399	3,865	0,3%
1995	2,003,146	856,368	1,149,409	6,921	0,6%
1996	2,264,709	1,056,400	1,238,940	10,315	0,8%
1997	2,308,476	1,155,893	1,151,287	8,136	0,7%
1998	1,625,125	1,228,144	568,063	2,075	0,4%
1999	2,361,735	1,390,071	910,725	2,401	0,3%
2000	2,602,008	1,544,473	1,057,620	4,414	0,4%
2001	2,471,444	1,397,015	1,065,161	7,747	0,7%
2002	2,651,273	1,413,723	1,225,210	16,119	1,3%
2003	2,767,716	1,720,124	1,001,874	19,481	1,9%
2004	3,122,600	2,276,576	857,977	23,345	2,7%
2005	3,357,094	2,456,525	913,550	30,901	3,4%
2006	3,489,136	2,530,180	935,681	40,530	4,3%
2007	3,723,482	2,718,548	986,416	53,390	5,4%
2008	3,450,478	2,508,911	958,854	61,648	6,4%
2009	3,158,417	2,007,230	1,174,743	60,993	5,2%
2010	3,866,206	2,610,949	1,217,764	90,562	7,4%
2011	4,221,617	2,980,659	1,211,284	105,037	8,7%

CAGR (last 10 years)

(0, 9)	5,3%	8,6%	-	23,2%

Forecast - "scenario - no change"

	Domestic			Imports	
	Production	Export	Sales	Sales	market share
2020	4,445,363	3,236,996	1,211,284	129,406	10,7%
2030	4,680,967	3,515,377	12,11,284	159,428	13,2%

Source: KAIDA (2012a)

Appendix XV: Chinese Electric Vehicles in International Markets

After ten years of high growth, China has become the world's largest producer of motor vehicles. It has overtaken Japan (in 2008) and the U.S. (in 2009) to become the biggest car market in the world.[699] Owing to continued high growth rates, rapid urbanization and rising incomes, the Chinese car market has outperformed most other regions and has become a key driver for the international automobile industry. Over recent years, the proportion of commercial and passenger vehicles in total exports have gradually tilted towards the latter. The bulk of motor vehicles exported from China in 2011 were passenger vehicles, accounting for 55.3 percent of the total. [700]

Like other Chinese OEMs, BYD seeks to set up design and manufacturing facilities abroad. In December 2009, BYD produced the first F3 (the ICE version of its F3DM PHEV) at a newly constructed CKD plant in Cairo, Egypt. The facility, which was BYD's first outside China, currently serves Middle Eastern and African markets. By the time of writing in July 2012, the Cairo works had not yet started assembly of the F3's plug-in hybrid version and no announcement had been made of such plans. Similarly, in July 2010, the first F3 rolled off the assembly line at a newly built Russian plant operated by local assembler TagAZ. Targeting the Russian market, the F3 production was severely crippled by the desolate condition of the local counterpart. As in Egypt, no plans were announced to expand production to the F3DM or any other non-ICE model.

In February 2011, it was reported that BYD is planning to set up an assembly operation in the Philippines to manufacture EVs and components thereof.[701] However, as no more recent information was available on the matter, it is unclear if or to what extent the company has followed up on that plan.

So far, BYD has also failed to introduce its EVs to the North American market. In 2009, the company announced that its e6 would go on sale in the U.S. the following year, priced at $40,000.[702] After a severe drop in profits and the forced closure of seven factories due to illegal operation, in October of 2010, BYD shelved its ambitious export plans for another year.[703] According to company statements, BYD intended to ship 50 units of the e6 electric cars to fleet customers in Southern California before the end of 2011. At the same time, the company announced that the vehicle will become available for private customers in the U.S. in 2010.[704] The entrance into the U.S. market was reportedly held back by possible intellectual property infringements surrounding lithium powder which BYD used for its batteries as well as concerns about passing rigorous crash testing procedures.[705] On the eve of the 2011 Detroit Motor Show, Michael Austin, BYD's vice president of marketing and public relations reportedly told journalists that the company would have at least five showrooms in the U.S. and was all set to sell tens of thousands of both its F3DM PHEV as well as its e6 BEV there during 2012.[706] At the same time, the prices for the two models were announced with the PHEV and BEV going for $28,800 and $35,000 respectively (both prices before government purchasing incentives). [707] In October 2011, BYD opened its North American headquarters in Los Angeles[708] and declared that it will not begin retail sales for yet another 18 months – pushing the introduction date to April 2013. [709] According to the company, the delay was largely due to a lack of public charging infrastructure. In the meantime, however, BYD indicated its intention to enter the fleet business with its passenger cars and promote sales of its all-electric buses. [710] In December 2010, fleet testing of the F3DM commenced at the Housing Authority in the City of Los Angeles. The agency obtained 7 units of the PHEV to evaluate vehicle performance under real driving conditions. After results had been satisfactory, the contract agreement was extended for another year, slated to expire at the end of 2012.[711] BYD's electric cars have also found a warm reception with Hertz in the U.S. At the New York Auto Show in early 2012, the rental car company had publicly endorsed the all-electric e6 and announced that it would increasingly adopt the

699 Cars21 (2010)
700 Gasgoo (2012)
701 Manila Standard Today (2011)
702 Autoblog (2009)
703 Bloomberg (2010)
704 The Wallstreet Journal (2010)
705 Plugincars (2011)
706 Ibd.
707 Ibd.
708 Suffering from an unemployment rate above the national average, the city of L.A. had offered BYD incentives worth $2 million.
709 Bloomberg (2010)
710 Ibd.
711 Ecoseed (2011)

vehicles into its U.S. fleet.[712] Hertz has been renting a total of six e6's to its customers in Beijing, Shanghai and Shenzhen since the launch of its Chinese operations in August 2011 and announced to expand the fleet to 25-30 units before year end.[713]

In late 2010, the company had entered into negotiations with the *Los Angeles* County Metropolitan Transportation Authority and transit operators in other U.S. cities over supplying electric buses.[714] The Canadian town of Windsor has announced to bring in 10 of BYD's all-electric buses and start road trials before the fall of 2012. The city, which suffers from high unemployment, also aims to become BYD's North American manufacturing centre. Canadian news media have quoted the town's mayor as saying that the company was contemplating the production of 500 electric buses per year which could create 500 new jobs.[715]

BYD has been most successful in exporting to developing countries. Its biggest deal so far was an agreement signed with the municipal government of Santiago de Chile and the city's largest public transit operators in July 2011. Under the terms of the deal, BYD will ship a total of 1,000 units split between e6 BEVs and K9 electric buses to Chile over a period of five years.[716] In late July 2012, it was announced that the company had struck a deal to deliver 500 of its K9 busses to Uruguay.[717]

[712] New York Times (2012)
[713] New York Times (2011a)
[714] Ibd.
[715] Canadian Broadcasting Corporation (2012)
[716] Sina (2011)
[717] China Automotive Information Net (2012)

Appendix XVI: Non-European Exports of Electric Vehicles to China

According to most industry experts interviewed for this study, Chinese EV imports are very low. This does not only result from the small size of the Chinese EV market but also stems from a variety of regulatory measures which undermine the competitive position of foreign cars in that market. On the one hand, import tariffs and various fees inflate vehicle costs, on the other, purchase subsidies are denied for models developed and/or produced abroad. The Chevrolet Volt, a plug-in hybrid manufactured by GM in the U.S. only, may serve as a case in point. The model was introduced in China in late 2011 and sells for RMB 498,000 in 13 selected dealerships in eight[718] cities.[719] China Automotive Review quoted Raymond Bierzynski, General Motors' executive director for electrification strategy, stating that "these cities have more elites who are inclined to try new technologies and lead the fashion tide."[720] Sales have been extremely slow – LMC Automotive reported that a mere 18 units have been sold during the first six months of 2012.[721] Arguably, the disappointing market reception is due to the high sticker price which results from shipping costs, import tariffs and various government induced fees.[722] Consequently, the Volt[723] costs about twice as much in China as in the U.S. where the 2012 model goes for about $40,000.[724] Since the Volt – as an imported car – does not qualify for central or local purchasing subsidies, as local models do (e.g. F3DM), the price difference is excessively large.[725]

Buyers of BYD's F3DM PHEV, for example don't pay the sticker price of RMB 169,800[726] but can take advantage of central government subsidies worth RMB 50,000 as well as local government subsidies of up to RMB 50,000 depending on where they live. In the best case, the F3DM carries a final price of just RMB 69,900[727] and thus boasts a substantial competitive advantage vis-à-vis the Volt.[728]

[718] Beijing, Shanghai, Hangzhou, Suzhou, Wuxi, Guangzhou, Shenzhen and Foshan.
[719] Sina Auto (n. d.) A
[720] China Automotive Review (2012)
[721] InsideEVs (2012b)
[722] Reuters (2012c)
[723] By the time of writing, the Volt was the only Range Extender available on the Chinese market.
[724] Reuters (2012c)
[725] New York Times (2011b)
[726] Sina Auto (n. d.) B
[727] Example based on purchasing subsidy policy of Shenzhen Municipality. Source: Fourin (2011b).
[728] According to data released by the two manufacturers, both plug-in hybrids have a comparable electric driving range of up to 56 km and up to 97 km for the Volt and the F3DM respectively. The F3DM and the Volt vary in several important technical aspects. The F3DM has a battery-powered electric engine in addition to a regular internal combustion engine. Both serve to propel the vehicle independently with the ICE taking over once the battery is depleted. A manual switch between the two is possible as well. Other than the F3DM, the Volt is always propelled by an electric engine with a battery as a power source. However, the vehicle has a small internal combustion engine that serves to recharge the battery if necessary but does not drive the wheels.

Appendix XVII: Chinese Market Barriers to EU Exports – General Issues

6. A concern for international OEMs and auto parts are a**dditional homologation test requirements** by the Chinese government. Since China is no signatory to the UN ECE framework which defines technical standards and certification procedures, the Agreement on Technical Barriers to Trade has been concluded to avoid double testing and thus ease burdens to trade. However, Chinese authorities continue to insist that all imported vehicles and parts be tested in Chinese laboratories even though they have already passed foreign certification procedures. The additional benefit of second round testing for the Chinese side is unclear since Chinese regulations are closely aligned with international ones, particular the 1958 UN Agreement. Consequently, the requirement for testing in Chinese laboratories which creates costs and consumes time is deemed redundant, disproportionate and undermining the competitiveness of EU exports. The same can be said for mandatory repetitive quality audits of production facilities inside the EU which are manufacturing components subject to the China Compulsory Certification (CCC) system by Chinese inspectors. Much to the dismay of the automotive industry, the number of components which need CCC to be imported has been expanded from three to thirteen since the initiation of the system. In general the CCC has been regarded as a burden as it stands in the way of the adoption of international standards by Chinese regulators.

The certification system for tyres is a case in point. Starting with the introduction of the CCC in 2002, tyres had to be tested according to Chinese regulations instead of accepted international standards drafted by the UN-ECE working party 29 meeting in Geneva. The current situation forces European tyre manufacturers to adjust their production and mark tyres according to Chinese requirements a process which is costly and time consuming. An ongoing dialogue between the Commission and the Administration of Quality Supervision, Inspection and Quarantine has yet to produce an agreement.[729]

Different standards in the design of crash tests to determine the safety of cars in case of an accident also complicate imports. While UN ECE R94 rules require a frontal collision to a deformable barrier at 56 km/h with 40 percent overlap, the Chinese side practices a test set up featuring an impact to a solid target with full overlap at 50 km/h. As the European method is perceived by experts to be more relevant as it comes closer to simulating an actual frontal collision, industry representatives hope that the Chinese side will agree to harmonize its testing procedures with international ones.[730]

7. For automakers, **meeting mandatory emission standards is complicated by the unavailability of appropriate fuels**. In an effort to reduce vehicle emissions, Chinese authorities have set a timetable of emission limits mandatory for all gasoline powered cars sold in the country. All automakers are bound to adjust their product line accordingly and ensure compliance with the changed regulation for every car produced after the official implementation of these standards. However, the usage of fuels of a corresponding quality is an essential precondition for reducing the amount of pollutant contained in vehicle exhaust and meeting the tightened regulatory requirements. Compliance with national emission standards is hard to achieve without appropriate fuel types. Unfortunately, ensuring a sufficient supply of gasoline and diesel of higher grades has proven challenging for petroleum companies. Although the National Emission Standards 3 (NES3) became a mandatory requirement for all new models in July 2006, it took until the end of 2009 to ensure the nationwide supply of vehicle fuel of a necessary quality. The transition to NES4, compulsory for all gasoline powered road vehicles produced after July 2010 was fraught with the same problems.[731] Throughout 2011, gasoline of corresponding quality was practically unavailable outside Beijing and Shanghai and by the time of writing in April 2012, no timeframe had been announced as to when supply could be accomplished throughout the country. This situation has made the reduction of pollution from road vehicles an onerous task and presents formidable problems to automakers who have to ensure their vehicles can meet emission requirements while, at the same time, adjusting their engines to run on various types of gasoline.[732]

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[729] European Commission, DG Enterprise and Industry (n.d.)
[730] European Union Chamber of Commerce in China (2011)
[731] European Union Chamber of Commerce in China (2011)
[732] Id.

8. **Chinese regulations do not allow for a pooling of vehicle emission credit/debit of locally produced and imported vehicles**. International auto makers operating in China are struggling to meet mandatory efficiency and emissions targets for their fleet as it is not yet possible to offset the negative effects of less efficient, high-emission vehicles imported against the more efficient, low-emission vehicles domestically produced.[733] Since the production volume in China is substantially larger than imports, it would be helpful to match the outperformance of China-made cars with the underperformance of foreign made ones. However, according to regulations in place at the time of writing in April 2012, both fleets have to meet their respective targets independently while unused credits go unrewarded and debits are punished. With imports dominated by SUVs, luxury and premium cars, the inability to offset one fleet against another (pooling) creates problems for international companies and removes incentives to outperform the targets defined for locally produced fleets.

9. **New guidelines for government purchases of passenger cars and light commercial vehicles have excluded foreign brands and thus imposed a buy-Chinese policy.** A catalogue containing 412 vehicles certified for use by government organizations was published in February 2012.[734] The Ministry for Industry and Information Technology who was in charge of drafting the document announced that vehicle procurement of state agencies would be limited to Chinese brands. International OEMs and Sino-foreign joint ventures are thus excluded from a RMB 80 billion market of which they had previously claimed an 80 percent share.[735] Audi-branded cars alone had accounted for about one third of the fleets of government organizations and state-owned enterprises. The company reportedly generates 20 percent of its Chinese sales from government procurement contracts while Volkswagen, GM, Toyota and Nissan draw about 10 percent of their revenues from supplying government fleets.[736] This move, intended to boost the image and recognition of domestic brands will have profound consequences for international OEMs.[737]

10. Following the release of the recent edition of China's Development Program for the Automobile Industry in 2004, disputes arose with the EU, the U.S. and Canada about **import tariffs for certain sets of auto parts that the Chinese side considered as complete vehicles**. Instead of applying the lower rate for parts and components, the Chinese customs administration levied the full 25 percent import tariff valid for complete vehicles.[738] This practice discouraged the use of imported parts by Chinese companies and was considered an unfair discrimination. Dispute settlement proceedings on this issue were initiated at the WTO in 2006 and concluded with the ruling that Chinese practices was unlawful and had to be repealed.[739]

[733] European Union Chamber of Commerce in China (2011)
[734] Jianghuai Auto: PEV, BYD: F3DM, Chery: M1-EV, Chang'An: MINI EV and Jiangnan: E300.
[735] Bloomberg (2012)
[736] Ibid.
[737] Cars21 (2012a)
[738] Steward, Terence et al. (2012)
[739] United States Trade Representative (2011)

Appendix XVIII: Key Players in Global Battery Production

The following section provides a short analysis of global key players in terms of battery production for electric vehicles:

The Korean **LG Chem**is one of the world's largest battery manufacturers with an annual production capacity of 40 million cells, including 30 million cells in South Korea (e.g. Ochang) and 10 million overseas (e.g. Detroit, Michigan) in 2008. Today, LG Chem is expected to produce batteries for about 100,000 battery electric vehicles. The Battery R&D Center is based in the LG Chem Research Park in Daejeon/Korea. LG Chem also assembled a global R&D network with satellite labs in the United States, Germany, Russia, and China. The company invested about $300 million in the production of GM Volt batteries in its plant in Detroit/Michigan. LG Chem announced a further investment of about $1.8 Billion altogether for its production sites in Ochang/South Korea and Detroit/Michigan. In 2011, the division "Information & Electronic Materials"[740] generated a total turnover of 3.7 billion Euro.[741] LG Chem, Renault and CEA (France's Alternative Energies and Atomic Energy Commission) are preparing to sign a three-way agreement in September concerning next-generation battery production in France.[742]

Johnson Controls is a leading supplier of start-stop batteries in Europe with the VARTA brand. In plants in Zwickau and Hanover, the company will annually produce over 11 million start-stop batteries. In the American plant in Toledo (Ohio) 6 million will also be produced.[743]Johnson Controls is building a plant for start-stop batteries in China and investing about $100 million. The plant will supply to local car manufacturers in Asia and is scheduled to start production in early 2013.In addition, the company manufactures PrismaticLithium-Ion cellsforuse in electricand hybridvehicles (eg Ford Transitor MercedesBenzS400Hybrid). After the separation from the French battery manufacturer Saft, Johnson Controls is focussing on building up more core competence in the field of system integration in the battery market, even outside the automotive sector. Therefore, the supplier made a strategic decision: system integration will be located in Hanover/Germany and in Milwaukee/U.S. while the cell chemistry will be developed in the U.S. only. The company has been manufacturing cylindrical (2011) and will manufacture prismatic cells (2013) in the U.S. Johnson Controls will build the battery cells either at its Battery Technology Center in Milwaukee or at its new Lithium-Ion battery factory in Holland, Michigan. Johnson Controls invested about 275 million Euro in production capacity expansions in Hanover/Germany.

GS Yuasais a Japanese manufacturer of rechargeable batteries, the largest Asian manufacturer of automotive batteries. Based in Kyoto/Japan, GS Yuasa focuses on Lithium-Ion batteries for future hybrid cars and electric cars.The company generated a total turnover of about 2.7 billion Euro in the fiscal year 2011. In 2007, Lithium Energy Japan (LEJ) was established by GS Yuasa and Mitsubishi. Lithium Energy Japan has a capacity to produce six million Lithium-Ion battery cells in its three production facilities; Kuatsu (start of production in June 2009), Kyoto (start of production in December 2010) and Ritto (start of production in April 2012). This amount of production is equivalent to 67,800 units of the Mitsubishi i-MiEV. Altogether, GS Yuasa and Mitsubishi invested 170 million Euro. Furthermore, the company is in cooperation with Honda; the joint venture is called "Blue Energy". In February 2011, mass production of Lithium-Ion batteries started at Blue Energy´s Osadano plant. Altogether, GS Yuasa and Honda have invested about 150 million Euro in the joint venture. The plant in Osadano has an annual capacity to produce batteries for 200,000 to 300,000 hybrid electric vehicles (e.g. Honda Civic).[744] The company considers South East Asia and China as the most important regions in its annual report. Both regions are defined as "the heart of" the global strategy.

AESC (Automotive Energy Supply) is a joint venture of the Renault-Nissan group (Nissan 51 percent) and NEC (Nippon Electric Company and NEC Energy Devices, Ltd., collectively 49 percent) based in Japan. AESC started its production in July 2009 in Zama, Japan, near the Nissan production plant in Oppama, Yokosuka. Currently the company mainly produces traction batteries for the electric cars Nissan Leaf, Nissan Fuga hybrid and Infinity Mh.According to Roland Berger (2011a), **AESC is expected to be themarket leader in terms of Lithium-Ion battery technology** for passenger cars and

[740] E.g. Batteries, Polarizers
[741] Own calculation based on the Annual Report 2011.
[742] Green Car Congress (2012b)
[743] Presseportal (2011a)
[744] GS Yuasa (2012)

light commercial vehicles by 2015; A possibility, if Renault-Nissan reaches its goal of 500,000 electric vehicles sold by 2015. With investments announced of $600 million in Flins facility (FR), $356 million in Spain and $330 million in UK. **AESC can be considered as a leader in terms of investment in the EU**. If AESC implements its plans by 2014, the alliance will also **become the European leader in terms of capacities** (capacities for more than 300,000 units; see Appendix XVIII), followed by Bosch/BASF, SB LiMotive[745] and Li Tec.

A123 Systemsprovides advanced Nanophosphate Lithium Iron Phosphate batteries and energy storage systems that deliver high power and energy density, long life, and safety performance. Founded in 2001, A123's proprietary Nanophosphate technology is built on novel nanoscale materials initially developed at the Massachusetts Institute of Technology/U.S. The company received a $249 million green-technology grant from the Obama administration in 2009.[746] Today, A123 Systems is headquartered in Waltham, Massachusetts and employs more than 2,400 people worldwide. The company announced to invest more than $1 billion dedicated to capacity expansion. A123 has additional production facilities in Asia (e.g. Shanghai/China, **Changzhou/ China),** Europe (e.g. Leinfelden-Echterdingen/Germany) and North America to mass-produce advanced battery cells and systems to meet increasing global demand.The start-up company generated a loss of $258 million in 2011, after a loss of $152 million in 2010 as well as a more recent second-quarter loss of $82.9 million.[747] Due to little market development in electric vehicles, the A123 factory has been faced with overcapacities. The company has also had problems with production in the fourth quarter of 2011, which led to higher failure rates. Battery systems for Fisker and other customers such as the aerospace and defense contractor BAE Systems had to be replaced or repaired. Wanxiang, which is China’s largest automotive components supplier and one of China’s largest non-government-owned companies, recently announced an investment of up to $465 million in A123, which includes an initial credit extension of $25 million that A123 received in August 2012. Making A123 approximately 80% Chinese owned.[748]

Panasonic plans to expand battery pack production from 100,000 to 1.1 million units in the long term and can be regarded as one of the Japanese key players in the production of lithium ion battery packs (e.g. supplying battery packs for the Toyota Prius and new Ford hybrid versions)(see Appendix XXII).

The Korean-German joint venture **SB LiMotive**between Bosch and Samsung SDI is also a key player in Lithium-Ion battery technology. The company is based in Giheung/Korea (e.g. headquarters, centre for esearch and development and pilot production line for lithium-ion cells).The mass production of Lithium-Ion cells takes place in Ulsan/Korea. The joint venture has an additional office in Stuttgart/Germany, where the development of battery systems, system integration and the management of global sales are located. Two additional sites are located in the United States. In Orion, Michigan, battery systems are produced, while in Springboro, Ohio, NiMH battery cells, modules, packs and systems are manufactured. The joint venture announced investments of about $500 Million up until 2013.According to SB LiMotive, the production capacity of batteries accounts for 50,000 electric cars annually.[749]**Recently, Bosch announced to split up with Samsung**. Bosch intends to develop and manufacture lithium-ion batteries on its own. The joint venture partners originally planned to invest about $500 million dollars until 2013.[750] In 2015 a sufficient capacity in Ulsan (Korea) should be reached to equip 180,000 electric vehicles annually. Bosch's agreement with Samsung included that all development and delivery orders will be fulfilled cooperatively in the future. In addition, mutual access to patents has been agreed. Cell production will remain at Samsung. In the future, Koreans will supply lithium-ion cells to Bosch. Bosch is currently invests investing 400 million Euros in electromobility and in its 1100+ employees in this area, including approximately 300 battery specialists from SB LiMotive in Stuttgart and Cobasys in the U.S..[751]

Besides Johnson Controls and AESC the French battery manufacturer **Saft**operates in Europe as well. Saft is the world’s leading manufacturer of nickel batteries and primary lithium batteries for industrial infrastructure and processes, transportation and civil and military electronics markets. Furthermore, Saft is the world leader in space and defence batteries with its Li-Ion technologies which are

[745] Recently, Bosch announced to split up with Samsung. Therefore, no data on the continuation of investments and capacities are available.
[746] Autonews (2012c)
[747] Autonews (2012c)
[748] Green Car Congress (2012a)
[749] SB LiMotive (n.d.)
[750] SB LiMotive (n.d.)
[751] Automobilwoche (2012b)

also being deployed in the energy storage, transportation and telecommunication markets. Presently, Saft employs 4,000 workers and has 16 global production sites (e.g. Bagnolet (France), Valdosta (U.S.), Jacksonville (U.S.), West Palm Beach (U.S.), Cockeysville (U.S.)). In the first quarter of 2012 Saft generated sales of 148.9 million Euro, representing a reduction of 1.1% YoY.[752] In 2011, Saft's total year sales reached 628.7 million Euro (a sales growth by 7.1 percent) with an EBIT margin of 12.8 percent. Additionally, the company spent 22.1 million Euro for Research and Development activities. The U.S. plant in Jacksonville started the production of Li-Ion cells at the end 2011 and made the first shipment in February 2012 to the European production site for integration into battery systems.[753] The company has announced a cooperation agreement with Nedap, a Dutch industrial public company, to develop and commercialise systems for residential energy storage. The group has also been selected by a major utility in California for a community energy storage system and a smart grid project which require a combination of containerised batteries and smaller battery systems.[754]

[752] Saft (2012a)
[753] Saft (2012b)
[754] Saft (2012a)

Appendix XIX: European Key Players in the Production of Battery Systems

Table X: European Key Players in the Production of Battery Systems

Company	Participants/ Partners	Activities	Country	Capacities p.a.	Investments (also: State incentives)	Production sites
Magna Steyr	Single Company (Automotive Supplier)	Battery packaging (Volvo PHEV); Battery packs, battery cells; Production of lithium-ion battery systems for Volvo Group (Volvo's city buses, heavy-duty distribution vehicles and refuse trucks using the I-SAM parallel hybrid system)	**Austria**	n. a.	Partnership: Magna E-Car Systems: Engineering, development and integration of electric vehicles of any type. Manufacturing of batteries and battery packs for hybrid and electric vehicles. Original investment in the partnership included E-Car Systems vehicle electrification and battery business unit, certain other vehicle electrification assets, and $145 million in cash	Manufacturing and assembly in DE: Bremen, Grevenbroich, Korntal-Münchingen; FR. Hambach; Poland: Tychy; 3 sites in Austria
Umicore	Facilities in China are party Joint Ventures	Production of active cathode material and recycling of rechargeable batteries (Umicore Cobalt and Specialty Materials)	**Belgium**	New production facility in Kobe since 2011, but no capacity disclosure. 25% production capacity extension in Cheonan/ Korea planed for 1H/2013. Total annual production capacity in Cheonan and Guangdong/ China approximately 10,000 tonnes.	2011: Kobe production facility: JPY 4 billion. China: Umicore has invested 127 million Euro in China between 2000-2010.	Alberta (Canada), Alabama (USA), Olen, Bruges (Belgium), Cheonan (Korea), Subic Bay (Philippines),Shanghai, Guangdong, Jiangxi (China)
AESC	Nissan/NEC Group (51:49)	Joint production of batteries in Flins (FR), Spain and in the UK	**France/ Japan**	200,000 units in 2014 (FR); 60,000 units in 2015 (ES); 60,000 units in 2015 (UK)	2009: Announcement of $600 million investment in Flins (FR) facility, Spain: $356 million, UK: $330 million	Flins (FR) (Start 2014), Spain, UK, Japan
Deutsche Accumotive	Daimler/ Evonik (90:10)	Battery systems for electric mobility	**Germany**	50 employees at Kamenz production site	n. a.	Kamenz in Saxony (DE)
Volkswagen	Group (Automotive OEM)	Battery packaging in Braunschweig: 6 fields concerning the electric battery on processes for safety-critical products, hard-a and software, package, mechanics and thermo-management	**Germany**	Investment in production hall for serial battery production	n. a.	Braunschweig, Germany
SB LiMotive	Bosch/Samsung (50:50)	Development, production and sale of li-ion battery technology for the electric power train	**Germany/ Korea**	2013: Capacity for the production of 50,000 electric vehicles and more than 180,000 in 2015; 2010: Production of lithium-ion cells on an area of around 34,000 square meters	$500 million up to 2013	Headquarters/R&D center in Giheung/Korea
VARTA	(Owned by Johnson Controls)	Factory-fitted Start-Stop battery systems. Production of the VARTA cell pack plus battery packaging.	**Germany/ USA**	n. a.	275 million Euro invested in expansion of production capacities in Germany	Germany

(Source: Own Compilation based on Deutsche Bank Research 2009 and Own Research)

Appendix XX: European Key Players in Cell- and Component Production

Table XI: European Key Players in Cell and Component Production

Company	Participants/ Partners	Activities	Country	Capacities p.a.	Investments (also: State incentives)	Production sites
SAFT France	Company	Development and manufacture of high-end batteries for industry and defence.	**France**	First half-year 2012 sales were 314.8 million Euro, 150 million cells/a	2011: 22.1 million Euro for Research and Development activities (First half-year 2012: 11.5 million Euro)	Bagnolet/France
BASF	Group	Developing materials for lithium-ion batteries: Solutions for anodes and separators. Research of future battery concepts: e.g. lithium-sulfur or lithium-air	**Germany**	n. a.	Three-digit Million Euro sum in R&D and production of battery materials; 2012: Acquisition of Novolyte Technologies, Ohio (USA). Novolyte: manufacturer of electrolyte formulations for lithium-ion batteries; 2012: Acquisition of the electrolytes business of Merck in 2012 /acquisition of Ovonic Battery Company (NiMH leader); Over 400 million Euro per year in R&D for products and technologies	Construction of a manufacturing plant for battery materials in Elyria, Ohio/USA; Novolyte operates production sites in Baton Rouge, Louisiana, and in Suzhou, China. An additional site for LiPF6 production is currently under construction in Nantong, China
Bosch/BASF	Bosch/BASF	R&D/manufacturing of lithium-ion-cells	**Germany**	Build-up of a pilot production lane for lithium-ion cells: annual capacity of 200,000 cells/a (in 2015)	$50 million to acquire equity ownership position in Li-Sulfur battery company Sion Power	Battery production in Eisenach
Gaia	Single Company	Cell production: 2010 Start of mass production of the lightweight Lithium-ion starter battery for Porsche. Joint Venture with EnerSys (USA)	**Germany**	n. a.	n. a.	Manufacturing in Nordhausen, DE: Battery assembly for the European market. For the US market out of the Plymouth, USA
Li-Tec	Daimler/ Evonik (49:51)	Production of battery cells for automotive application: “CERIO-motive”-cells	**Germany**	Kamenz facility: Production area: 10,000 square meters. 40,000 EV-equivalent Units/a	Three-digit million Euro amount invested so far	Kamenz/Germany
Süd Chemie AG	Group	Joint venture with LG Chem to manufacture lithium iron phosphate	**Germany**	Series production in 2012: 2,500 tons per year (of lithium iron phosphate) = 50,000 all-electric automobiles or 500,000. 2010: 300 tons of LFP per year (Moosburg)	60 million Euro in the production of lithium iron phosphate (high performance energy storage material) used in batteries for electric vehicle drives	Moosburg/Germany

(Source: Own Compilation based on Own Research)

Appendix XXI: US Key Players in the Production of Battery Systems

Table XII: US Key Players in the Production of Battery Systems

Company	Participants/ Partners	Activities	Capacities p.a.	Investments (also: State incentives)	Production sites
A123	Single Company	In 2011: EV Batteries for GM. Providing of iron-nano-phosphate (Cathode material) for Fisker Karma; Recipient of $249.1 million state incentive to produce iron-phosphate cathode power ad electrode coatings, cells and battery packs	294,000 units in 2015	807 million Euro until 2015	Basically in the US due to state incentives; Planning to build up production in MI
Boston Power	Single Company	Provider of lithium-ion battery cells, modules and systems; Establishing an R&D and electric vehicle battery engineering facility in Beijing	Basis for the battery assembly: 400 MWh battery cells produced in the Liyang facility, CN; USA: Auburn, MA facility: 455,000 square foot manufacturing area	$125 million private equity to scale manufacturing, R&D and business development activities in China (Energy storage technology and products); $100 million Federal Funds for a facility in Auburn: Production of lithium-ion cells and batteries for plug-in hybrid and BEVs	R&D and EV battery engineering facility in Beijing, China; Manufacturing site in Liyang, China. Located in the Shanghai Corridor in 2012
Celgard	Wholly-owned subsidiary of Polypore International (US)	Manufacturing of lithium battery separator membranes	n. a.	2010: $100 million for a new 150,000 square-foot plant in Concord, N.C. (ca. 50% subsidized by the US)	US: North Carolina, Korea: Chungbuk
Cobasys	Owned by SB LiMotive	Formerly: Joint venture between Chevron Corporation (California) and Energy Conversion Devices (MI). Bought by SB LiMotive in 2009; Cobasys has the ability to produce and package energy storage systems using different chemistries including NiMH and Li-Ion.	Cobasys has a 170,000 square foot manufacturing plant in Springboro, Ohio. This facility is capable of producing over 3 million battery modules annually.	Investing tens of millions of dollars to expand their capacity	Springboro, Ohio
Compact Power	(US Subsidiary of LG Chem)	Based in Troy, Michigan. Assembly of lithium-ion polymer battery systems for electric and hybrid vehicles using cells manufactured in Korea LG Chem	n. a.	Recipient of a $151.4 million state incentive to produce separators and lithium-ion polymer cells	Troy, Michigan
Ener1	Enerdel (Subsidiary)	Joint Venture with Wangxiag for the production of battery cells and packs for automotive application	195,000 cells in 2015; Annual cell manufacturing capacity of 300 Million Ah (40,000 electric vehicle battery packs) annually by 2014 jointly produced with Wangxinag	Investment in lithium-ion battery facility in Indiana: $237 million for the company's third site in the state Indiana (State and local economic development incentives are valued at $69.9 million)	Elkhart, Indiana
EnerDel (Indiana)	Ener1	Providing of nickel, manganese and cobalt (cathode materials) for THINK City EVs; Recipient of a $118.5 million state incentive for the production of lithium-ion cells for hybrid and electric vehicles	Mount Comfort: 423,000 square ft plant; Capacity to produce around 120,000 electric vehicle battery packs a year, or 3.12 GWh in Indiana	Expanding its Mt. Comfort-based advanced lithium-ion battery manufacturing plant (est. $237 million, partially funded through an $118 million Recovery Act grant (DOE). Part of an $600 million expansion project in the State of Indiana	Mount Comfort, Indiana
Exide Technologies / Axion Power International	Exide/ Axion	Providing stored electrical energy solutions. Supplier of lead-acid batteries for network and motive power, automotive applications: battery technology; Recipient of a $34.3 million state incentive for the production of advanced lead-acid batteries for micro and mild hybrid applications	Exide: Increase in yearly production capacity of 1.5 Million additional units at two of Exide's current manufacturing locations Bristol and Columbus (USA)	"Exide Advanced Battery Expansion Project": $70 million in direct economic activity in two domestic locations over the 3 year scope of the project (2011-2014)	Operating in 89 countries, with 17 automotive manufacturing plants, 11 Industrial manufacturing plants and 12 Recycling facilities. Bristol (TN), Columbus (GA)
Johnson Controls	Group	System integration in Hanover/Germany and in Milwaukee/U.S. , R&D of cell chemistry in the U.S. only	n. a.	n. a.	Hanover/Germany Milwaukee/U.S.
Saft America	Subsidiary of Sat Batteries	Production of lithium-ion cells, modules battery packs; Recipient of a $95.5 million state incentive	Jacksonville facility: 235,000 square ft manufacturing area	Jacksonville facility 200 million Euro investment (95.5 million Euro public subsidy) for advanced Li-ion batteries, storage, smart grid support	Valdosta(US), Jacksonville(US), West Palm Beach(US), Cockeysville(US)

(Source: Own Compilation based on Canis 2011, Deutsche Bank Research 2009, DOE 2011, IEA 2011a and Own Research)

Appendix XXII: US Key Players in Cell- and Component Production

Table XIII: US Key Players in the Cell and Component Production

Company	Participants/ Partners	Activities	Capacities p.a.	Investments (also: State incentives)	Production sites
3M	Group	Production of anode and cathode powders such as electrolyte additives	n. a.	$3 million Invests in Novel Silicon Anode for Lithium Ion batteries: DOE grant of $ 4.6 million	St. Paul, MN
Applied Materials	Single Company (CA)	Sub-Company: ActaCell, Inc. is an Austin; Texas based technology start-up commercializing next generation lithium-ion battery technology.	n. a.	$5 Million DOE grant for the development of advanced cells for electric drive vehicle batteries until 2013; In total $1 Billion per year on our global R&D efforts	Santa Clara, CA; ActaCell: Austin (Texas)
BASF Catalyst LCC	Part of the BASF Group	2012: Advanced cathode materials production plant in North America: Elyria, Ohio (for lithium-ion battery market); Recipient of a $24.6 million state incentive for the production of nickel-cobalt-metal cathode material for lithium-ion batteries	n. a.	$50 Million in a production facility for innovative cathode materials for lithium-ion batteries used to power hybrid and full-electric vehicles. $24.6 million grant from the US Department of Energy	Elyria, Ohio
Celgard	(Wholly-owned subsidiary of Polypore International, Inc)	Celgard LCC, a subsidiary of Polypore; Recipient of a $49.2 million state incentive for the production of polymer separator material for lithium-ion batteries; Broad portfolio of products available in the lithium battery separator industry	The new 150,000 square-foot plant on 20 acres in the International Business Park in Concord, N.C., is the second phase in Celgard's strategy to expand production capacity. Celgard expects the new plant to come online by 2012	Expanding capacity in Charlotte (manufacturing). New manufacturing facility in Concord, NC for the Electric Drive Vehicle market. $49 million in grant funding from the U.S. Department of Energy. Total investment for the entire expansion: about $100 million	Charlotte, NC headquarters and manufacturing facility; Concord, NC
DOW/Kokam	Owned by Dow Chemical Company, TK Advanced Battery LLC and Groupe Industriel Marcel Dassault	Recipient of a $161 million state incentive for the production of manganese cathodes and lithium-ion polymer battery cells; Production of vehicle batteries, among others in France	60,000 units in 2015	269 million Euro until 2015	Michigan (1,200MWh/a), Missouri (33MWh/a), France(15,000 packs/a) for 5,000 BEV in Le Bouchet, Korea (150MWh/a), Materials supply from site in Midland, MI
Future Fuel Chemical	Single Company	2011. Future Fuel Chemical located in Batesville, Graphite components used in anodes	Produce intermediate anode material: Increase the product supply from the current 1,000,000 pounds/a at an off-site plant to 10,000,000 pounds per year (For 2,000,000 HEVs)	State funding: $12.6 million in financial assistance. Total cost of the project: Est. $25.2 million	Batesville, AR
Honeywell	Single Company	First US producer of lithium salt for use in electrolytes; Electrolyte R&D at the Buffalo, NY and Metropolis, IL (supported with state incentives of $27.3 million); Build the first world-scale US manufacturing facility for LiPF6 a lithium-ion battery component	Production of 183 metric tons of hydrogen fluoride (used in batteries)	Honeywell Secures $27.3 million Grant From U.S. Department Of Energy To Produce Critical Battery Material	Electrolyte manufactured in Metropolis, IL
Toda America Inc	JV: TODA KOGYO and ITOCHU.	Recipient of a $35 million state incentive for the production of nickel-cobalt-metal cathode material for lithium-ion batteries	Battle Creek: 4,000 tons of cathode materials per year (for batteries of around 450,000 HEV's or 125,000 PHEV's)	Plans to construct a $70.1 million plant in Battle Creek for iron oxide and mixed metal oxide particles for lithium ion batteries	Goose Creek, SC
Valence Technologies	Single Company	Production of Lithium-Iron Phosphate, cells and systems (China)	100 metric tones of cathode material per month and 20 MWh per month of U-Charge® battery modules	$4 million in upgrading facilities to increase capacity in Suzhou, China	Suzhou China (Valence Energy Tech)

(Source: Own Compilation based on Canis 2011, Deutsche Bank Research 2009, DOE 2011, IEA 2011a and Own Research)

Appendix XXIII: Asian Key Players in the Production of Battery Systems

Table XIV: Asian Key Players in the Production of Battery Systems

Company	Participants/ Partners	Activities	Country	Capacities p.a.	Investments (also: State incentives)	Production sites
BYD	Single company	R&D/production/sales of vehicles, EVs and lithium-ion batteries	**China**	Current annual capacity of 1.6 GWh. Expect to reach 7.6 GWh in 2014	BYD new energy material production base with an investment of RMB 8 bln. is under construction but currently suspended for environmental reasons	Two production bases in Xi'an, one R&D and production base in Shenzhen, China
Tianjin Lishen Battery Co. Ltd.	Shareholders: CNOOC New Energy Investment Co. Ltd; SDIC High-Tech Investment Co. Ltd.; Tianjin Lantian Power Sources Co.; Potevio New Energy Co. Ltd; Tianjin Jinneng Investment Co.	R&D/production/sales of lithium-ion batteries. Products range includes cylindrical batteries, prismatic batteries, polymer batteries, photovoltaic batteries, supercapacitors etc.	**China**	Annual capacity of up to 500 million Ah	In July 2009, CNOOC invested RMB 5 billion to build 20 power battery production lines after joining Lishen. In the same year, Lishen started a production expansion project for lithium-ion power batteries, investing RMB 1.6 billion	Tianjin and Chongqing, China
Tianneng Battery Group Co. Ltd.	Single company	R&D/production/sales of lead-acid traction batteries, nickel hydride traction batteries, lithium batteries and storage batteries	**China**	Plans to quadruple its production capacity of lead-acid EV batteries in 2012	n. a.	Zhejiang, Anhui and Jiangsu, China
CITIC Guo'An Mengguli (MGL)	Belongs to CITIC Guo'An Group	R&D/production/sales of new composite metal oxide materials and high energy density lithium-ion secondary batteries	**China**	Annual capacity off >2,500 tons of lithium-ion battery cathode materials, 20 million Ah power batteries	n. a.	Beijing, China
China BAK Battery Inc.	Single company	R&D/production/sales of lithium-based battery cells, main products include cylindrical, prismatic and polymer battery cells	**China**	Annual capacity of 1.5 million units per day	n. a.	Shenzhen, China <u>Customer:</u> FAW, Chery, Brilliance, Ytong etc.
Sinopoly	Single company	R&D/production/sales of lithium-ion batteries and related products	**China**	Annual battery production capacity of the Jilin production base: 120 million Ah; Capacity of the Tianjin production base: 130 million Ah (max 2.0 billion Ah annually); Plans annual capacity of two billion lithium-ion batteries by 2015	n. a.	Jilin and Tianjin, China
Wanxiang EV	Belongs to Wanxiang Group	R&D/production/sales of EVs, batteries and automotive electronics	**China**	Annual capacity of 120 million Ah of batteries	n. a.	Zhejiang, China
Zhejiang GBS Energy	merged by Hybrid Kinetic Group, products are joint developed with Elite Power Solutions (EPS)	R&D/production/sales of LiFeMnPO4 power battery packs	**China**	Annual capacity of 40 million Ah	n. a.	Ningbo, China Customer: FAW (Dongfeng)

Microvast Power Systems Huzhou	belongs to Microvast Inc. (U.S.)	Advanced power solutions for applications including EVs, E2Ws and power tools as well as patented battery components such as membrane, anode, electrolyte and cathode	**China**	Planned capacity for first project is 3.6 MWh/day, actual capacity 0.6 MWh/day	n. a.	Huzhou, China Customer: FAW (New Bora), Chery (S18), Zotye, FAW-VW (Kaili)
Shanghai Jiexin Power Battery Systems	SAIC Motor and American A123 to set up a vehicle battery system joint venture	R&D/production/sales of vehicle battery systems	**China**	n. a.	Planned investment of $20 million	Shanghai, China Customer: SVW (Tantus)
China Aviation Lithium Battery Co. Ltd.	jointly invested by 7 enterprises: China Aviation Industry Corporation; China Airborne Missile Academy; Sichuan Chengfei Integrated Technology Co. Ltd.; China Aviation Investment Holdings Co. Ltd.; Aircraft and Aviation Industries Investments Co. Ltd.; Jiang Gijónare Aviation Industry Co. Ltd.; Luoyang Xinghang Investment. Merged with Sky Energy Luoyang Co. Ltd.	R&D/production/sales of lithium-ion batteries	**China**	Annual capacity 180 million Ah	The Industrial Park of China Aviation Lithium Battery Co. Ltd. has a total investment of RMB 3.6 billion, with a planned annual capacity of 1.2 billion Ah lithium-ion batteries and 350,000 sets of battery application system	Henan, China Customer: Lifan (620), Totye (2008)
Harbin Guantuo Power Equipment	Supported with technology from Beijing Institute of Technology, Harbin Institute of Technology and other universities. Invested by Shanghai Beauty Blue Equity Capital	R&D/production/sales of lithium BMS and chargers	**China**	n. a.	n. a.	Harbin Hi-tech Development Zone, China Customer: Zotye (5008)
Chine	JV (BYD, BAK, CNOOC, LISHEN)	Production of Li-Ion-batteries	**China**	360,000 units in 2015	1.4 billion Euro until 2015	China
Hefei Guoxuan Hightech Power Energy	Single company	R&D/production/sales of lithium-ion batteries	**China**	Annual capacity of 100 million Ah of lithium-ion batteries, 500 tons new cathode material, 250,000 kWh lithium battery packs, 50,000 EV applied batteries	Invested capital RMB 300 million	China Customer: Jianghuai (Tojoy)
SAIC	Single company	R&D and manufacturing of battery systems; JV with Samsung SDI and Robert Bosch GmbH to manufacture li-ion batteries; JV: Jiexin Power Battery System Co with A123	**China**	Shanghai Jiexin: Operation starts in 2012: Initial annual capacity of 6,000 sets	Total investment in EV: $1.89 billion from 2011-2015	Li-ion battery production site in China to start production by 2012
AESC	Joint Venture of Renault-Nissan and NEC	Joint venture of Nissan Motor Co. and NEC Corp. The partnership produces EV batteries for Nissan and Renault SA	**Japan**	Sagamihara Plant: Start-up capacity of 13,000 units, ultimate capacity of 65,000 units	JPY 12 Billion (94 Million Euro) investment to mass produce advanced lithium-ion batteries in 2008; Total investment in the JV: $1.8 Billion	Zama/Japan
Blue Energy	GS Yuasa/Honda	Manufacturing, sales and R&D of Lithium-ion batteries for hybrid vehicles	**Japan**	30,000 units in 2015; Osadano Plant: 16,000 square meters manufacturing area	Osadano plant: JPY25 billion (189 million Euro) in 2009	Osadano Plant, Kyoto, Japan
GS Yuasa	Single Company	Major lead acid battery supplier Two 51:49 JVs: with Mitsubishi (Lithium Energy Japan) and Honda (Blue Energy)	**Japan**	Lithium Energy Japan: 3 production facilities, batteries to power 67,800 i-MiEVs, Blue Energy: production plant in Osadano, capacity: batteries 200,000-300,000 HEV (e.g. Civic Hybrid)	Lithium Energy Japan: 170 million Euro Blue Energy: 150 million Euro	Osadano, Ritto, Kyoto and Kuatsu (all Japan)
Hitachi Vehicle Energy	Hitachi Maxell/Shin-Kobe Electric Machinery	Developing and manufacturing of lithium-ion batteries for automotive applications	**Japan**	70,000 units in 2015	351 million Euro until 2015	3 Facilities in Japan: Ibaraki,Shiga and Kyoto

Lithium Energy Japan	JV: GS Yuasa, Mitsubishi Corporation and Mitsubishi Motors Corporation	Development, manufacturing and sale of large lithium-ion batteries since Dec 2007	**Japan**	55,000 units in 2015	144 million Euro until 2015	Production facilities in Kusatsu and Kyoto
Panasonic EV Energy	Toyota/Panasonic Matsushima	Production/Recycling of EV Batteries; Panasonic Group supplies batteries for the Toyota Prius. Contract in 2012 to supply lithium ion batteries for four Ford hybrids	**Japan**	2010: Increase of battery pack production from 100,000 to 1.1 million	85 million Euro until 2015	Taiwa, Miyagi Prefecture, Japan
Sanyo	Single Company	Sanyo and VW: Joint development of lithium-ion batteries; provide key components for hybrid cars. $769 Million within seven years: Begin of mass production in 2009	**Japan**	New facility since 2010: 15,000 to 20,000 batteries a year. By 2015: production capacity to 10 million cells a month, enough for 1.7 to 1.8 Million cars (40% of a global hybrid market)	242 million Euro until 2015; JPY80 billion ($769 million) over the next seven years	LIB at Sanyo's Tokushima factory, Japan
Sony	Group	Considering moving production of rechargeable lithium-ion batteries overseas: Changing the Tochigi Prefecture manufacturing facility to a research institute and move production to China and Singapore by end 2013	**Japan**	200,000 units in 2015	n. a.	Tochigi Prefecture Manufacturing Facility, Japan
Toshiba	Group	Build-up of a second factory for its rapid-charge lithium-ion battery	**Japan**	60,000 units in 2015	214 million Euro until 2015	Kashiwazaki, Japan
HL Green Power Co	Hyundai Mobis/LG Chem	JV for EV battery technology	**South Korea**	2010: Production plant with an capacity of 200,000 battery packs per year; ; Increase the factory's annual capacity to 400,000 battery packs in Uiwang by 2014	$25 million venture is 51 percent owned by Hyundai Mobis; By 2014, Hyundai Mobis and LG Chem spend a total of $39 million	Uiwang, South Korea
LG Chem	LG Group	Batteries: From mobile devices to advanced automotive batteries. Providing cells for for high-volume battery packs for the GM Volt (Main customer)	**South Korea**	Annual capacity to produce batteries for 100,000 electric and hybrid cars	2013: 1 billion Euro in Ochang Techno Park and Detroit Factory; $20 million by the Korean government for batteries for PHEVs; In US manufacturing: $303 million to build a Volt Battery Plant in Michigan	Ochang, South Korea;, Detroit, Michigan
Samsung SDI	Owned by Samsung	Since 2000: Development of lithium ion batteries (LIB) technology as a new business division battery. No. 2 in LIB production	**South Korea**	Batteries for electric vehicles mainly by JV "SB LiMotive" in co-operation with Bosch	KRW 519.6 billion (346 million Euro) in facilities and R&D in 2010	Mexica, China, Hungary, Vietnam
Sk Energy	Belong to SK Group	Market entry in LIB in late 2009. Providing Lithium-ion batteries for upcoming electric vehicles from both Hyundai Motors and Kia Motors	**South Korea**	Second rechargeable battery plant will be built in Seosan about 150 kilometres southwest of Seoul, with capacity to produce 500,000 units annually for hybrid vehicles. Plant: Plant Capacity of 80,000 units for hybrid vehicles	87 million Euro until 2015	Seosan, South Korea
SK Innovation/ Continental	Joint venture	Production of Li-Ion-batteries for automotive applications; SK: Battery cells to the venture and Continental battery management electronics and systems expertise	**South Korea**	SK Innovation will start mass production operations in Seosan, Korea in the first quarter of 2012, which has an annual capacity of 800MWh equivalent to 40,000 units of full EV.	2008: $110 million to expand its lithium-ion battery production	Seosan, South Korea

(Source: Own Compilation based on Deutsche Bank Research 2009 and Own Research)

Appendix XXIV: Asian Key Players in Cell- and Component Production

Table XV: Asian Key Players in Cell- and Component Production

Company	Participants/ Partners	Activities	Country	Capacities p.a.	Investment	Production sites
BTR New Energy Materials	Subsidiary of China Baoan Group Co. Ltd.	Production of lithium-ion battery anode and cathode materials	China	6,000 tons/ year lithium iron phosphate material production	CNY 1 billion in production facilities during 2010/11.	Tianjin, Beijing vicinity
Asahi Kasei	Single Company	Component Supplier/ Separa-tors	Japan	2010: 205 million square meters/p.a.; Increase production capacity for Hipore™ Li-ion battery (LIB) separator by 50 million square meters per year at the plant in Hyuga, Miyazaki, with start-up in 2013	Investment in capacity increase in Miyazaki: JPY6 billion (53.2 million Euro)	Hyuga plant, Miya-zaki and Moriyama Plant Shiga, Japan
Hitachi Chemical	Part of Hitachi Group	Component Supplier, Anode Material	Japan	Est.: 45 percent of worldwide market share in 2009	$44.8 million to add third and fourth production lines manufacturing carbon anode materials for lithium-ion automotive batteries at Yamazaki Works	Yamazaki Works, Japan
Mitsubishi Chemical	Mitsubishi Group	Component Suppli-er/Separators, Cathode, Anode, Electrolyte, Production of Cathode Material in 2005	Japan	Electrolyte: 3,000-5,000 t p.a (Yokkaichi Plant).; Anode: 3,000-5,000 t p.a (Sakaide Plant); Cathode production from 600 tons p.a. to 2,200 tons p.a.; Memphis facility: 10,000 metric tons of electrolyte material p.a.	2010: $13.1 million in the Memphis facility	Japan, UK, USA and China
NEC Tokin	Single Company	Mass production of lithium-manganese electrodes in Sagamihara plant in Japan for the JV" AESC" with Nissan and Renault	Japan	Electrode production capacity: 2 million KWh per year	Investing JPY11 billion ($105,1 million) in the produc-tion of lithium-manganese-electrodes in its Sagamiha-ra Plant. Funding from the Invest Kanagawa scheme	Sagamihara Plant
Nichia	-	Manufacturing of LEDs, laser diodes, battery materials and calcium chloride.	Japan	n. a.	2011 (China): RMB 8.6 billion in equipments, RMB 1.5 billion in R&D. 2012: plan to invest RMB 4.2 billion in equipments and RMB 1.7 billion in R&D.	Japan: Tokushima, Kagoshima.
Nippon Carbon	-	Production of artificial graphite electrodes, impervious graphite products, activated carbon, carbon fiber products, flexible graphite and other carbon products	Japan	n. a.	n. a.	Toyama, Shiga, Yamanashi, Shirakawa
Sumitomo Chemical	Part of Sumitomo Group	Expand lithium-on battery separator business	Japan	Combined capacity of all production lines will reach 25 million square meters annually in 2009; Ehime site area about 2,816,000 square meters	40 percent of investments until 2020 in Fine Chemicals (Battery components); 2011: JPY6.6 billion ($79 million) in the Fine Chemicals: Installations and expan-sion of manufacturing facilities and streamlining of existing facilities	Ehime Works, Niihama, Japan

Toda Kogyo	Toda Advanced Materials in the US is a Joint Venture of Itochu Corp. and Toda Kogyo Corp. All operiations in China are Joint Ventures.	Production of nickel, manga-nese, ternary, and cobalt-based products	Japan	Japan: Currently 2,500 ton per year, expansion of 5,000 ton per year expected by 2012. New 4,000 ton per year operation in US ex-pected by end-2013. Canada: 4000 tons per year.	US Joint venture: $70 million (50% subsidized by the US)	Japan: Otake, Onoda, Kitakyushu, Korea: Wonju, China: Tianjin, Zhejiang, US: Michigan, Canada: Ontario
Tonen/ Toray	50/50 Joint Venture between Tonen General Sekiyu and Toray (2010). Taken over by Toray in 2012.	Production of battery separators	Japan	n. a.	n. a.	Japan: Nasu, South Korea: Gumi
Ube	Separator busi-ness: Joint Ven-ture between Ube Industries, Ltd. (51%) and Hitachi Maxell, Ltd. (49%). Electrolyte busi-ness: 50/50 Joint Venture planed with Dow Chemi-cal	Production of separators, battery materials, polyimides, fine chemicals	Japan	Seperators: Seven production lines in Japan in operation, no data disclosed, but capacity expentsion planed in order to keep up with the growing demand: Capacity of 200 million square meters (two plants) until FY 2014.	n. a.	Japan: Chiba, Osaka, Yamaguchi
Cheil	Affiliate of the Samsung Group	Textiles/ fashion, chemicals, electronic materials (Panax Etec acquired Cheil Industries' electrolyte solution business in 2010)	Korea	n. a.	n. a.	Korea: Gumi, Yeosu, Ochang
E-One Moli	Part of E-Moli Energy Corpora-tion	Partnership with 3M	Taiwan	1 Million battery cells in the Tainan plant, Tai-wan	n. a.	Tainan Plant, Tai-wan; Maple Ridge, Canada

(Source: Own Compilation based on Own Research)

Appendix XXV: European Key Players in Electric Engine Production

Table XVI: European Key Players in Electric Engine Production

Company	Participants/ Partners	Activities	Country	Capacities p.a.	Investments (also: State incentives)	Production sites
Hoyer Electric Motors	Single Company	Supplier of electric motors for various applications	**Denmark**	n. a.		Denmark
Leroy-Somer	Part of the Emerson Group	Production of nearly all types of electric motors; Somer Generator & Electric Motor production facility in Fuzhou, China	**France**	Production area: 26,000 square meters	$20 million to build a new manufacturing facility in Noida, India	Overall 38 Production Units (Europe, USA, China, India). [20 Manufacturing Facilities in China: Shanghai, Shenzhen, Suzhou, Beijing, Tianjin, Qingdao, Shenyang, Nanjing, Zhangzhou, Zhongshan and Xi'an]
Bosch	Group	Applications for plug-in, hybrid, EVs and range-extender	**Germany**	Leading manufacturer of DC electric motors and related components: 100 million units each year in its global factories	$507 million annually to develop EV specific components: li-ion batteries, regenerative braking systems, thermal heat management systems for EV batteries, development work on powertrain electrification	Bosch has set up a new manufacturing facility for electric motors in Hildesheim, Germany.
Continental	Group (Automotive Supplier)	Electric motors, battery and power electronics; Electric motors with a performance range of 5 to 120 kW for hybrid and electric vehicles, Electrification of powertrains in passenger and commercial vehicles	**Germany**	60,000 electric motors per year. Planed production capacities up to 75,000 electro motors in 2012. Due to lack in demand actually much less electric motors are produced in 2012.	Initial investment in the existing Gifhorn facility amounted 12 million Euro	Gifhorn (DE); 20 Production sites in Europe
Siemens	Group	"SEDL" (Siemens Electrical Drives Ltd.): Motors and generators of the same functionality, design and quality as the Siemens factories in Europe and America	**Germany**	Siemens Electrical Drives: Chinese partners: BENEFO and TRIED. JV registered in Tianjin High-Tech Park factory area is 180,000 square meter	2006: $35 million in the Norwood plant: "Global Motor" research and technology development center, contributing to enhancements in Siemens motors sold throughout the world	Siemens Industry's Norwood, Ohio motor manufacturing plant for the design and manufacture of electric motors
Volkswagen	Group	Production of electric motors	**Germany**	Initial production capacity (2013): 10,000 units/a	2009: Investment of 800 million Euro in Kassel facility, Germany for the production of electric motors for PHEV and BEVs	Kassel (DE)

(Source: Own Compilation based on Own Research)

Appendix XXVI: US Key Player in Electric Engine Production

Table XVII: US Key Player in Electric Engine Production

Company	Participants/ Partners	Activities	Capacities p.a.	Investments (also: State incentives)	Production sites
Azure Dynamics	Single Company	Production of electric motors for electric vehicle applications	n. a.		Canadian facility in Burnaby, British Columbia
Baldor Electric	Member of the ABB Group	Manufacturers of industrial electric motors, mechanical power transmission products, drives and generators	n. a.	Investments in manufacturing capacity, including upgrades, modifications, and expansions of existing manufacturing facilities, and the creation of new manufacturing facilities	26 plants in the US, Canada, England, Mexico and China.
Emerson Motor Technologies	Company of Emerson Electrics	One of the largest electrical motor manufacturer in the world, producing more than 330,000 motors every day	330,000 motors / day	2011: $600 million in total capital spending for new products, cost reductions and expansion and upgrade of its infrastructure. Plans call for that figure to be over $700 million in 2012	16 manufacturing facilities and seven engineering centers in six countries: Houston and McKinney, Texas; Nanjing, China; and Sorocaba, Brazil, Kennett (USA)
Fasco	Single Company (NY)	Designing and manufacturing of AC motors and blowers in Six Sigma manufacturing facilities	Production Capacity: 3,000,000 pieces/year, Factory Area: 16,000 square meters	FASCO Motors (Thailand) Limited was formed in 1999 with a registered capital of 1,110 million Baht.	Manufacturing plant in Rochester, N.Y. 13 facilities across North America and Asia Pacific. Continually increasing capabilities on a global scale
General Electrics	Group	Manufacturer of electric motors and generators for 125 years. Full range of products from 1 to 100,000 horsepower units for highly demanding applications around the world.	n. a.	Invest up to $100 million over five years in Peterborough facility; $111 million for electric Motors high-volume global rear-drive electric motors for hybrids and electric vehicles	Peterborough-based motor production facility, Canada; White Marsh, Maryland
GM Powertrain	General Motors	Plant to make “critical components” for plug-in electric and hybrid vehicles. $269.5 million plant for electric motors which represents a core business for the company as part of its plug-in and hybrid electric vehicle development and manufacturing.	n. a.	Expansion electric motor development: Recipient of a $89.3 million DOE (US Department) Award; Baltimore Transmission Plant (White Marsh, Maryland); $246 million investments for a high-volume electric drive production facility for GM’s next-generation rear-wheel drive Two-mode Hybrid system;	Baltimore Transmission Plant, USA
Leeson Elctric	Single Company	Motor, gear motor and drives company, has expanded our product offering with the addition of the Lincoln Motors, Grove Gear and Electra-Gear products. Corporate Headquarters in Grafton, Wisconsin.	n. a.	n. a.	Facility in West Plains Missouri and Juarez, Mexico. In the western Wisconsin city of Black River Falls, Monterrey, Mexico, Lebanon, MO, and Wausau, WI
Ohio Electric Motors	Single Company	Ohio Electric Motors is a premier manufacturer of DC motors.	State-of-the-art production facility for manufacturing of high volume runs	n. a.	Barnardsville, North Carolina
Remy Inc	Single Company	Establishment of a standardized platform of hybrid-electric motors and controls	New facility in Indianapolis: 60,000 to 100,000 electric motors p.a; Total annual output: 200,000 motors in 2010	Recipient of a $60.2 million DOE Award	Locations in Indiana and Fardo, ND also Hungary and Mexico

(Source: Own Compilation based on DOE 2011 and Own Research)

Appendix XXVII: Asian Key Players in Electric Engine Production

Table XVIII: Asian Key Players in Electric Engine Production

Company	Participants/ Partners	Activities	Country	Capacities p.a.	Investments	Production sites
Jiangsu Weiteli Motor	Single company	Main products include various types of conventional motors. Recently started production of induction motor systems and water cooling PMSMs	**China**	Annual capacity of 10,000 sets	R&D spending until today reached RMB 30 million	Jiangsu, China
Shanghai Edrive	Single company	R&D/production/sales of electric engines	**China**	Annual capacity of 30,000 sets	n. a.	Shanghai, China
Shanghai Zhongke Shenjiang EV	Jointly founded by Shanghai Alliance Investment Ltd. (SAI), Shenzhen Institute of Advanced Technology (SIAT) of Chinese Academy of Sciences (CAS), and Shenzhen Xiangnian Science and Technology Co.	R&D/production/sales of EVs and subsystems, incl. motors, controllers, transmissions, BMSs, vehicle control systems. Technology transfer and technical consulting services	**China**	n. a.	Invested RMB 260 million in the project of Jiading District New Energy Vehicle Drive Systems (I)	Shanghai, China
Sichuan Dongfeng Electric Machinery Works	belongs to Dongfeng Electric Corporation (DEC)	business scope: EV drive systems, various generators, nuclear power and photovoltaic components, environmental protection equipment etc.	**China**	Annual capacity of 50,000 sets	n. a.	Sichuan, China
Wanxiang EV	Belongs to Wanxiang Group	R&D/production/sales of EVs, batteries, electric engines, control units etc.	**China**	Expected to bring an annual capacity of 3,000 sets of pure electric commercial vehicle powertrain systems	Electric engine project has an investment of RMB 100 million, which includes RMB 5 million of central government subsidies	Zhejiang, China
Zhejiang Unite Motor	Single Company	mainly engaged in EV drive system (including drive motor, gear systems, control systems)	**China**	Annual capacity for various engines: 5 million sets	Jointly invested RMB 300 million in Zhejiang Jiuli EV project; plans to start a project for electric drive systems with an annual capacity of 1 million sets. Total investment: $50 million	Zhejiang, China
Jeco Co	Jeco Group belongs to Toyota	Manufacturer of automotive clocks, automotive motors, driving equipment, display equipment and other motors.	**Japan**	n. a.	Capital: JPY 1.56 Billion (13.8 million Euro)	Gyoda, Japan
Kokusan Denki	Single Company	A member company of the Hitachi Group. Manufacturer and sales of electric products, generators and motors, especially for motorcycles.	**Japan**	n. a.	LangFang Kokusan Electric Co.,Ltd.(Joint Venture).The registered capital is $4 million	Production of electric motors in Japanese facilities
Nissan	Group	Traction Drive; Drive Inverter	**Japan**	n. a.	$67.9 million for powertrain assembly plant in Decherd (U.S.)	n. a.

(Source: Own Compilation based on Own Research)

Appendix XXVIII: European Key Players in the Production of Power Electronics

Table XIX: European Key Players in the Production of Power Electronics

Company	Participants/ Partners	Activities	Country	Capacities p.a.	Investments (also: State incentives)	Production sites
Bosch	Group	Manufacturing and development of automotive electronic units: Drive inverter production for the Porsche Cayenne Hybrid and the Volkswagen Touareg Hybrid since 2010	**Germany**	Facility: 38,000 square meters	Collaboration with Infineon on semiconductors. 600 million Euro investment in a semiconductor facility; 60 million Euro for building a new production facility in Tetarom Park in Jucu, Romania (electronic components for automobiles); investments in three other Romanian cities: Bucharest, Timisoara and Blaj.	Tomioka Plant, Gunma, Japan: Products: Electronic Control Unit and Transmission Control; Tetarom park in Jucu, Cluj, Bucharest, Timisoara and Blaj, Romania
Continental	Group	Continental: Electronics and system integration. Production of the entire drive train for Renault Kangoo Z.E. und Fluence Z in Gifhorn	**Germany**	At least 25,000 batteries and as many as 40,000 annually for EVs (Hyundai BlueOn and Mercedes-Benz SLS E-Cell)	New battery plant in Seosan, South Korea, as part of a $1 billion investment. Continental spends 170 million Euro annually in research, development and industrialization of hybrid and EV technology	Battery plant in Seosan, South Korea
EPCOS	TDK-EPC-Cooperation	EPCOS and TDK: On-board chargers for electric and hybrid vehicles including inductors, transformers, capacitors and protective components; Tantalum chip capacitors for automotive electronic subassembly customers	**Germany**	Increase production of tantalum capacitors at both Heidenheim and Évora to between 1.5 billion and 2 billion pieces	Investment of $87 million in tantalum capacitor production	Heidenheim (DE-capacitors, inductors and ferrites); Spain (Malaga), Brazil (Gravatai), Austria (Deutschlandsberg), USA (Palo Alto), Portugal (Evora)
Infineon	Group	Semiconductor solutions for plug-in and battery electric vehicles; Inverters (DC/DC and others) and battery management electronics	**Germany**	Kulim High Tech Park, Kedah: 12,000 square meter fab facility with the potential to double production capacity	Production sites in Dresden: Over three billion Euros have been invested; $60 million to expand its production capacity, research & development and to upgrade its manufacturing facilities in Malacca, Malaysia; 250 million Euro to expand its production in Villach (AT) as well as R&D in Graz (AT)	Production in Dreden (DE); Villach (AT) Malacca, Kulim High Tech Park, Kedah (Malaysia)
Siemens	Group	The Volvo/Siemens develops electric drive technology, power electronics and charging technology initially for Volvo C30 Electric vehicles and other models.	**Germany**	Siemens Electrical Drives Ltd. (SEDL): Tianjin High-Tech Park factory area is 180,000 square meters for fully digital controlled AC and DC drives and motors (35,000 square meters)	55 million Euro in Tianjin, China production facility	Tianjin High-Tech Park
VW	Group	VW Continental Automotive Systems: strategic partnership for the development and supply of power electronics for future hybrid projects: Hybrid drive modules, including power electronics together with ZF Friedrichshafen AG	**Germany**	n. a.		
Magneti Marelli Holding S.p.A.	Owned by Fiat	Manufacturer of automotive components. Divided into five business areas; Lighting, Electronic Systems, Engine Control, Cofap Automotive Suspension, Exhaust Systems.	**Italy**	Production facility in China: 28,000 square meter production area, 4.5 million pieces of powertrain components	Investment of 75 million Euro in Electronic Systems; $53.7 million to expand its manufacturing plant in Pulaski, Tennessee (USA) and create 800 jobs	6 production facilities, 3 research centres and 5 application centres in Italy, France, Germany, Spain, Brazil, USA, Mexico and China
Brusa Elektronik AG	Single Company	Development of power electronics for hybrid and electric vehicles; Complete electric drivetrain 250 Volvo C30; Development of highly efficient power electronics for electric mobility (hybrid and electric vehicles); BRUSA Lithium-Polymer batteries; Start of serial production of rapid charger in 2012.	**Switzerland**	600 square meters production hall (doubled in 2007): Production for lots of up to tens of thousands of units per year	n. a.	Sennwald, CH

(Source: Own Compilation based on Own Research)

Appendix XXIX: US Key Players in the Production of Power Electronics

Table XX: US Key Players in the Production of Power Electronics

Company	Participants/ Partners	Activities	Capacities p.a.	Investments (also: State Incentives)	Production Sites
AC Propulsion	Single Company (California)	Battery management and monitoring systems that extend battery range and operating life. Inverters, e.g. for BMW MINI-E	Expand output by constructing a new electric drive manufacturing facility in Beijing, China. AC Propulsions' doubles production capacity in the Asian country	China is committing more than $15 billion to the initiative	Beijing, China
Azure Dynamics	Single Company	Traction Drives; Drive Inverter; Battery Charger; DC-DC converter; Development and production of hybrid electric and electric components and powertrain systems for commercial vehicles; hybrid electric vehicle controller technologies; Azure Dynamics and Ford Motor Company are collaborating to create an electric version of the 2010 North American Truck of the Year, the Ford Transit Connect Electric	The current production plan includes an initial quantity of vehicles to be built in late 2010 with full production began in April 2011.	State Incentives: Amount: $15,000 For Transit Connect Electric purchased by a fleet USD 20,000 For Balance™ Hybrid Electric trucks and buses purchased by a fleet; $30,000 For Balance™ Hybrid Electric school buses purchased by public school districts	Canadian facility in Burnaby, British Columbia; Woburn, Massachusetts facility
Delphi Automotive LLP	Belongs to Delphi Group	The world's leading supplier of automotive components. Offering hybrid vehicle manufacturers and consumers affordable power electronics	Expansion of manufacturing for electric drive power electronics components in Komoko, IN by a $89.3 million DOE Award; Expand its capacity in Tangier, Morocco	$89.3 million DOE Award in the Komoko facility, IN	Milwaukee, USA; New manufacturing facility at Moldova Noua in the southwest region of Romania
GM Powertrain	GM Group	Construction of U.S. manufacturing to produce electric drive system	Capacity for thousands of vehicle electrification components	$23.5 million for additional production of vehicle electrification components at White Marsh	White Marsh, MD / Wixom, MI
UQM Technologies	Single Company	Power-dense, high-efficiency electric motors, generators and power electronic controllers. $100 million invested in preparation for the electrification of the automotive industry. Propulsion systems for battery electric vehicles in all vehicle segments: Cars, trucks and busses. Hybrid electric systems for vehicles in all vehicle segments.	New headquarter: Annual production of 130,000 square ft; Production lines for 40,000 systems/ year	$100 million invested in preparation for the electrification of the automotive industry; $45.1 million state incentive for the expanding of propulsion systems	Longmont, CO

(Source: Own Compilation based on DOE 2011 and Own Research)

Appendix XXX: Asian Key Player in the Production of Power Electronics

Table XXI: Asian Key Player in the Production of Power Electronics

Company	Participants/ Partners	Activities	Country	Capacities p.a.	Investments (also: State incentives)	Production sites
Jiangsu Weiteli Motor	Single company	Main products: various types of conventional motors. Recently started production of induction motor systems and water cooling PMSM system	**China**	n. a.	n. a.	Jiangsu, China Customer: Geely and Zotye
Tianjin Santroll Electric Science and Technology Co. Ltd.	Single company	Provide drive system solutions and core accessories for EV, HEV etc.	**China**	Annual capacity of 10 thousand sets of electric motors and controllers.	Santroll entered into the new energy vehicle field with an initial investment of RMB 100 million bringing it close to bankruptcy. Thanks to government funding and supports in the amount of RMB 10 million granted over past few years, the company is able to operate.	Tianjin, China
Xi'an Unite Motor	Belongs to Zhejiang Unite	R&D/production/sales of EV drive system	**China**	n. a.	n. a.	Shaanxi, China Customer: Jianghuai
Shanghai Edrive	Single company	R&D/production/sales of electric engines, control units etc.	**China**	n. a.	n. a.	Shanghai, China Customer: Cery, Changán, FAW, Geely etc.
Tianjin Qingyuan EV	Jointly invested by China Automotive Technology and Research Centre; Tianjin Lishen Battery Co. Ltd.; Tianjin Lantian Power Co.; Tianjin Automotive Industry (Group) Co. Ltd.	R&D/production/sales of EVs, EV powertrains and key components	**China**	n. a.	In 2006, the company invested RMB 165 million in a major industrial project in Tianjin named "EV powertrain industrialization and EV production demonstration". Planned to invest RMB 1.2 billion into the development of EVs, buses and trucks.	Tianjin, China Customer: Hafei (Saibao EV)
Wanxiang Qianchao Co. Ltd.	Belongs to Wanxiang Group	Specializing in the production of chassis and suspension systems, automotive braking systems and other independent automotive components. Recently started production of electric engines and electronic control systems	**China**	n. a.	Plans to invest RMB 100 million in R&D, testing and initial production of electric motors between 2010 and 2012. Another RMB 100 million will be invested into the development of electric motor control units during the same time frame.	Zhejiang, China Customer: FAW and Dongfeng
Aisin Seiki Ltd.	Aisin Group	Electronic technology for automotive components; Drivetrain Related Products (40 percent of net sales); Transmissions and hybrid systems (Aisin AW Co Ltd.)	**Japan**	2007: 20,000 dual-motor systems a year to Ford (Ford Escape Hybrid and Mercury Mariner Hybrid)	Total investments of $102.7 million from Aisin Group	Handa Electronics Plant (Japan): Electronic components

Denso Corp	Single Company	Segments: Powertrain Control Systems; Electric Systems; Electronic Systems; Thermal Systems; Information & Safety Systems; Hybrid vehicle systems including control technologies for the vehicle engine	**Japan**	Jhajjar plant: Site area 73,000 square meters	$52.2 million in the Indian Jhajjar plant; $39.6 million in Gurgaon plant, India	Construction of DENSO East Japan's manufacturing plant; Michigan, California, Tennessee, Canada, Mexico
Hitachi Automotive Systems	Part of Hitachi Group	Entire range of electrical equipment. Segments: Engine management systems, electronic powertrain systems, drive control systems, and vehicle information systems.	**Japan**	Electric powertrain systems using electric motors and inverters, such as Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), Electric Vehicles (EVs) and Fuel Cell Electric Vehicles (FCEVs).	$74.5 million investment in new US facility in Harrodsburg, KY	Five facilities in Japan; Three plant in Kentucky
Toyota	Automotive Group	Development and manufacture of automobile-related electronic components and devices such as DC-DC converters for hybrid vehicles, traction drives and drive inverters	**Japan**	Honsha plant: 430,000 square meters production area	n.a.	Honsha Plant (Hybrid systems)
Daesung Electric Co	Single Company	Manufacturing of automotive switches and relays. Wholly owned subsidiary of LS Mtron in the LS Group.	**South Korea**	n. a.	Initial investment of $7 million in Qingdao facility	Qingdao (CN) Wuxi (CN), Chennai (India), Banweol (KR), Shiwa (KR)
Korea Electric Terminal	Single Company	3,000 types of connectors. Partnership (manufacture, sales and technical) with Yazaki of Japan for automotive connectors. Plant for connector assembly in North Korea.	**South Korea**	China (Weihai) Building 20,406 square meters; North Korea: (Gaesung) Building 3,983.5 square meters	n.a.	Assembly in North Korea and China

(Source: Own Compilation based on IEA 2011a and Own Research)

Appendix XXXI: Research Strategy Patent Research

In order to obtain significant results with a worldwide patent search, an appropriate research strategy is a requirement. Due to the immense relevance of the applied research strategy, the approach is briefly explained below. It has to be pointed out, that the research results can vary significantly depending on the chosen search terms.

Innovations and inventions in the field of alternative drive systems cover a wide range of different areas of electrical engineering, mechanical engineering, chemistry and related sciences. Likewise, the innovations and inventions are not limited to individual components of the powertrain, but also affect a large number of related components - from the actual power transmission to energy storage, power electronics, and energy recovery. For this reason, a limitation of the patent search to specific classification according to IPC 2011.01 is not very reasonable since a clear-cut distinction from conventional drive concepts would not be possible. However, it can be assumed that applicants already ensure a proper indexing in the title or abstract to allow an appropriate assignment of the patent application into the field of alternative drive systems. It is, therefore, obvious that patent applications in the field of alternative drive systems can best be achieved by title and abstract keyword searches. A full-text search is less suitable for this purpose because there is a high probability that, erroneous hits will occur, which for example, refers to the state of the technology or technical alternatives. However, it must be noted, that a keyword search contains certain fuzziness such as patent publications in other languages or with other terminology that are not included. Nevertheless, the international patent collections also use English titles and abstracts which reduces the systematic search error or results to a similar extent for all applicants.

There are already several studies on the topic "E-mobility and Patent Applications" exemplified here are the studies of KOCH/MEISINGER (2011), KARL/JAEGER (2011), STAHLECKER/LAY/ZANKER (2011) and LOWE/TOKUOKA/TRIGG/GEREFFI (2010) are pointed out. While KOCH/MEISINGER carried out a global search with an international database called "Delphion", KARL/JAEGER took only the German patent applications as well as companies based in Germany into account.[755][756] STAHLECKER/LAY/ZANKER (2011) conducted an examination of the state of Baden-Württemberg, Germany, in which particularly comparative data for the USA, Japan, South Korea, France and Italy was raised.[757] LOWE/TOKUOKA/TRIGG/GEREFFI (2010) conducted an analysis of patents and research papers related to lithium-ion batteries.[758] To add an insight into the patent situation, as part of this study, a further global raw data collection for the years 2001 - 2012 was carried out by key word searches based on the database ESPACENET of the European Patent Office. An interpretation of the research results from the year 2012 was omitted, therefore the research results from 2011 should be treated with caution. The background to this is the fact, that the research generally includes only documents which have already been published; the publication date is approximately 18 months after the filing date. For this reason, still successfully registered patents for the years 2012, 2011 and 2010 in part are added to the database. For the keyword search in title and abstract, the search terms "electric vehicle", "hybrid vehicle", "electric vehicle", "hybrid vehicle", "traction battery" and "fuel cell" were connected by an “OR” Boolean operator. In addition, the relevance of company-specific keywords in the box "Applicant" has to be noted, as the search term "Toyota Motor" returns a significantly different number of hits as the search term "Toyota." The search terms used for the included companies are given in the table above in the "Company / Applicant" column. The results of the quantitative output were inspected in terms of quality by sorting out hits with a lack of relation to electric mobility issues. A qualitative assessment of the results concerning future relevance or inventive steps was not performed. The raw data collection carried out and the visualization of patent applications based on the raw date is only able to show the relation of the individual companies, countries or regions to one another and over time. Due to the uncertainties listed above, the interpretation of absolute numbers is not recommended.

[755] Koch/Meisinger (2011), p. 7.
[756] Karl/Jaeger (2011), p. 1.
[757] Stahlecker et al. (2011)
[758] Lowe et al. (2010)

Appendix XXXII: Patents in Electromobility 2001 - 2011 (Dates of Research: 2012-03-15 and 2012-03-16)

Table XXII: Patents in Electromobility 2001 -2011

Group	Country	Company / Applicant	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	∑
OEM	Japan	Toyota Motor	154	131	230	357	728	888	1164	1595	1906	1661	636	**9,516**
OEM	Japan	Nissan Motor	93	194	296	526	659	817	637	283	270	340	115	**4,244**
OEM	Japan	Honda Motor	229	320	460	423	424	424	384	254	423	417	296	**4,073**
OEM	USA	Ford	20	62	54	25	33	55	55	92	122	112	127	**772**
OEM	Japan	Mitsubishi	148	219	189	188	180	167	192	146	145	126	136	**1,843**
OEM	South Korea	Hyundai	46	45	120	118	143	97	212	288	373	222	258	**1,958**
OEM	Germany	Daimler	28	44	49	85	42	29	28	103	135	160	213	**923**
OEM	USA	General Motors	52	72	73	70	101	77	14	20	5	2	4	**494**
OEM	France	Peugeot Citroen	4	7	13	11	14	13	22	47	53	56	62	**308**
OEM	Germany	Volkswagen	20	11	17	15	37	23	15	16	26	29	35	**245**
OEM	Japan	Mazda Motor	10	2	4	1	8	2	9	28	17	34	30	**145**
OEM	Germany	Bayerische Motoren Werke	4	10	7	23	13	17	14	25	30	27	32	**203**
OEM	Japan	Suzuki Motor	24	22	14	15	21	22	14	13	8	21	25	**203**
OEM	USA	Chrysler	1	0	0	0	1	0	1	2	3	0	0	**8**
OEM	Italy	Fiat	0	0	0	1	1	1	1	0	0	0	0	**4**
OEM	China	BYD	0	0	0	0	0	10	25	61	27	21	9	**153**
OEM	China	Chery	0	0	0	0	0	0	3	18	39	32	31	**123**
OEM	China	Geely	0	0	0	0	0	0	0	1	5	10	18	**34**
OEM	USA	Fisker	0	0	0	0	0	0	0	0	0	3	3	**6**
OEM	USA	Tesla	0	0	0	0	0	0	0	6	10	12	1	**34**
Supplier	Japan	Denso Corp	33	50	27	54	58	47	45	55	39	43	33	**486**
Supplier	Germany	Robert Bosch	8	15	21	23	22	16	28	32	49	77	81	**381**
Supplier	Japan	Aisin Seiki	25	34	52	62	112	103	74	63	90	84	35	**741**
Supplier	Germany	Continental	0	0	1	0	0	0	1	9	15	17	24	**67**
Supplier	Canada	Magna	0	0	1	4	0	1	2	0	0	0	5	**14**

Supplier	South Korea	LG Chem	0	0	3	3	10	20	78	37	26	15	17	**210**
Supplier	France	Faurecia	0	0	0	0	0	0	0	0	0	0	1	**1**
Supplier	USA	Johnson Controls	0	0	0	0	0	0	1	1	0	1	1	**4**
Supplier	USA	Delphi	9	21	37	41	15	16	15	10	9	10	13	**197**
Supplier	Germany	ZF	1	2	1	1	2	2	4	3	22	13	10	**64**
Supplier	USA	TRW	0	1	0	0	0	0	0	0	0	0	0	**1**
Supplier	South Korea	Hyundai Mobis	0	0	0	1	8	28	2	0	0	1	7	**47**
Supplier	France	Valeo	6	3	3	0	0	4	1	5	3	4	6	**35**
Supplier	Japan	Toyota Boshoku	0	0	0	0	2	0	1	3	5	9	8	**29**
Supplier	USA	Lear	0	0	0	1	0	1	1	0	1	0	2	**6**
Supplier	Japan	Yazaki	2	2	3	2	3	1	7	5	1	6	6	**39**
Supplier	Japan	Sumitomo Electric	6	4	6	9	12	16	18	9	2	0	4	**88**
Supplier	Germany	BASF	3	4	6	11	5	7	6	13	17	10	17	**99**
Supplier	Japan	Hitachi Automotive	0	0	4	7	0	0	0	0	0	7	14	**32**
Supplier	Germany	Benteler	0	0	0	0	0	0	0	0	0	0	1	**1**
Supplier	Italy	Magneti Marelli	0	0	0	0	0	0	0	0	2	0	0	**2**
Supplier	United Kingdom	GKN Driveline	0	0	0	0	0	0	0	0	0	0	0	**1**
Supplier	USA	3M	3	1	11	12	23	26	25	16	17	12	14	**161**
Supplier	Germany	SB LiMotive	0	0	0	0	0	0	0	0	0	0	3	**3**
Supplier	France	Saft	0	0	0	0	0	1	0	1	0	1	0	**3**
Supplier	USA	A123	0	0	0	0	0	0	2	2	0	1	0	**5**
Service provider	USA	General Electric	3	3	8	31	18	18	24	20	7	28	9	**169**
Service provider	Germany	RWE	0	1	0	0	0	0	1	0	0	8	8	**19**
Service provider	USA	Better Place	0	0	0	0	0	0	0	0	2	5	4	**11**
Service provider	France	Electricite de France	0	0	0	0	1	1	1	1	1	1	2	**8**
			932	**1,280**	**1,710**	**2,120**	**2,696**	**2,950**	**3,127**	**3,283**	**3,905**	**3,638**	**2,356**	**27,997**

(Source: Own Compilation)

Appendix XXXIII: Korea Resources Corporation (KRC) – Scope of Business

Table XXIII: Korea Resources Corporation (KRC) – Scope of Business

1	In order to achieve the objectives under Article 1, the Corporation shall conduct the following businesses:	
	1.	Exploration and development of mineral resources (includes overseas mineral resources and deep sea mineral resources), stone and aggregate resources and relevant investigations, research, technical guidance, feasibility studies, and mineralogical tests
	2.	Loans for mining funds, stone and aggregate industry funds, mineral product processing funds, and mineral product reserve fund (including bill discounts and guarantee of the debt; the same shall apply hereinafter)
	3.	Stockpiling mineral products
	4.	Sales, placement, import, export, and rental of machinery, apparatus, facilities, and equipment for the development of mineral products and mineral, stone, and aggregate resources
	5.	Training, technical guidance, and equipment support for mine safety
	6.	Mine management
	7.	Investment in other companies (including foreign companies) engaged in the exploration and development of mineral, stone, or aggregate resources or relevant business
	8.	Services, research and other business incidental to those in Item 1 through 7 and relevant fields
	9.	Other businesses entrusted by the government, local government, public institutionsand mining-related organizations
2	In Item 2 of Paragraph (1), "mineral product reserve fund" refers to the fund necessary for purchasing, storing, controlling and supplying key energy minerals and heavy industrial raw minerals to prevent sudden fluctuations in the price of key energy minerals and heavy industrial raw minerals and facilitate their regional and seasonal supply.	
3	The applicable items, methods and information necessary to stockpile mineral products under Item 3 of Paragraph (1) shall be determined by the Minister of Knowledge Economy in consultation with the Minister of Strategy and Finance.	

(Source: Korea Resources Corporation Act, Article 10, Act No. 9182, Dec. 26, 2008)

Appendix XXXIV: First Mover Advantages

First mover advantages include four dimensions:[759]

- **Economic factors**, which lead to scale and experience economies and marketing cost asymmetries
- **Pre-emption factors**, which can support the pioneer to achieve absolute cost advantages, (e.g. procurement contracts which ensure the delivery of raw materials at prices which are lower than those that later entrants have to pay) or differentiation advantages by selecting the most profitable niches (e.g. in terms of locations, product characteristics or marketing channels)[760]
- **Technological factors**, advantages resulting from product, process or organisational innovations which lead to a cost and/or differentiation advantage[761]
- **Behavioral factors,** which constitute opportunities for the pioneer to achieve a differentiation advantage e.g. in terms of contractual switching costs (supplier-buyer relationship). The customers are likely to know more about the product of a pioneer than followers' offerings (information asymmetry). Pioneers could benefit from information advantages resulting from a greater familiarity of the customers e.g. with a brand name or with brand properties (e.g. image). Furthermore the pioneer is able to influence consumers' perceptions of the relative importance of product attributes since the consumers are likely to know little about the product and its attributes in the early stages of the market evolution.[762]

Figure XXIII demonstrates an ideal typical profile for market entry as a first mover or follower.

[759] Nakata/Sivakumar (1997), p. 479; Kerin et al. (1992), p. 39 ff.
[760] Gerpott (2005), p. 222; Kerin et al. (1992), p. 42.
[761] Kerin et al. (1992), p. 42.
[762] Gerpott (2005), p. 222; Kerin et al. (1992), p. 42.

Figure XXIII: Ideal Typical Profiles for Market Entry as a First Mover or Follower

Market Situation		
Strong	Market Development (short term)	Weak
Fast	Market Diffusion	Slow
Known	Customers	Unknown
Weak	Technology-related Barriers to the (different) Markets (e.g. infrastructure, standardisation)	High
Fast	Technological Development (e.g. rate of change)	Low
High	Importance of Product Technology (e.g. fuel savings)	Low
Competitive Situation		
High	Intensity of Competition	Low
Important	Access to Resources	Less important
Strong	Technological Leadership	Low
Product		
High	Product/Technology Complexity	Low
Strong	Switching Costs (Customers)	Low
High	Differentiation Potential (e.g. range, usability)	Low
↓		↓
High probability of suc-cesswhen enteringas a **first mover**		High probability of successwhen en-teringas a **follower**

= Example of Electromobility

(Source: Own Compilation according to Gerpott 2005)

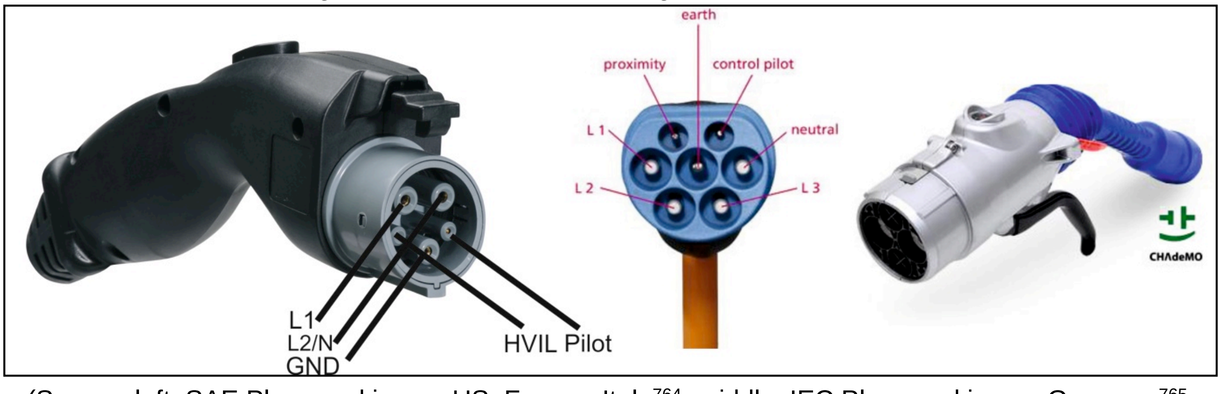
Appendix XXXV: Additional Information on Vehicle-to-Grid-Communication and Smart Charging

These communication modes can be mainly divided into wireless and wired communication. For wireless communication, services like GPRS, UMTS, and WLAN can be applied. Using the mobile telephone network GPRS and UMTS respectively, has the advantage that a communication between the vehicle and grid can be realized nearly everywhere, for example, to provide information about the next free charging station to the driver. The main disadvantage from the viewpoint of the energy providers and the customer is that data transmission via the mobile telephone network generates additional costs. During the charging process, a wireless communication can be established via WLAN. In this scenario, the vehicle and the charging station are equipped with a WLAN modem and a charging station which has access to the internet as the provider's backbone network.

To give an example of a very simple vehicle authentication, the electric vehicles used in the German E-mobility project colognE-Mobil are identified for billing purposes at the charging station via an RFID (Radio-Frequency Identification) chip. The customer can use an ID-card to authenticate his vehicle at the charging station. After this process is completed, the plug on the right is opened and the vehicle can be connected to start the recharge process.

Another possibility for data transmission between the vehicle and the grid is the usage of wired communication. Before explaining the wired communication method used during charging process, the next figure presents the different worldwide most commonly used plugs. For AC recharging, there are two main standardized types of plugs used worldwide and in the EU. In the EU, for example, especially in France the type 1 plug is used (Figure XXIII left), (standardized by the US organization SAE) while for Germany and the Netherlands the type 2 plug is used (Figure XXIII middle), (standardized by the IEC). Considering the DC recharge process, the Japanese Chademo plug is used in all countries in the EU. This DC quick charge function is only provided by Japanese vehicles like the Nissan Leaf, the Mitsubishi i-MiEV and the cars of the Renault-Nissan alliance (Renault Fluence ZE). The actual standardized plug for electric vehicles used in Germany as well as the SAE plug used in France and Italy does not include an additional wire for communication purposes. The possible wired communications are divided into data transmission via an additional cable and via the existing cables. When looking at the different plugs presented in Figure XXIII, only the Japanese Chademo plug has wires included for communication purposes via CAN (Controller Area Network).[763]

Figure XXIV: Standardized Plugs for Electric Vehicles



(Source: left: SAE Plug used in e.g. US, France, Italy[764]; middle: IEC Plug used in e.g. Germany[765]; Right: Chademo Plug for DC-Quickcharge used in e.g. Japan[766])

[763] Chademo (n.d.)
[764] Pressebox (n.d.)
[765] E-mobility21 (n.d.)
[766] Charge Yazaki Group (n.d.)

When focusing on the standardized plugs for AC charging, a communication via CAN (Controller Area Network) or Ethernet can only be established when using an additional cable. Thus, a disadvantage in using such communication is that an additional cable and plugs and the charging station side are needed. The other possibility considering the AC charging plugs is to use the existing wires and establish a data connection via powerline technology transferring the data in parallel to the energy over the charging cable. In this scenario, the vehicle and the charging station are equipped with a powerline modem and the charging station has access to the internet, respectively to the supplier's backbone network. When focusing on the different necessary and additional communication services which can be provided to the customer during the charging process, it is obvious that the authentication and the information about the maximum charging current and the charging process, with low data rates are sufficient. When realizing additional services like internet access for the customer, an even higher data rate is needed. This maximum data rate depends on the connection of the charging station to the internet and the performance of the connection between the vehicle and the grid. Considering the communication between the vehicle and the grid, a sufficient data rate for all required and nearly all additional services can be provided using WLAN, Ethernet, BPLC (Broad Band PowerLine Communications) and the UMTS network if available. A UMTS or GPRS has to be implemented in the vehicle and the charging station when a mobile telephone network is used. When using WLAN or wired communication, the charging infrastructure has to be connected to the supplier's network in addition to the modem needed in the vehicle and charging station. Comparing the two scenarios and considering the additional costs, a mobile phone network has the advantage since no additional costs arise from this form.

Appendix XXXVI: Model for the Assessment of the Market Potential for Car Sharing in Europe

Studies show that car sharing is an urban phenomenon and only economically feasible within urban areas. Therefore, the degree of urbanization in a country can be used to deduce the potential of the market for car sharing assuming that local differences in city architecture and infrastructure have no larger impact on regional user's behavior.

It is assumed that the level of income is negligible for the decision to participate in car sharing. Since sharing a car leads to a certain economic benefit for the user in many cases, it is therefore more attractive for citizens with a lower income. A higher income does not influence the decision to participate in car sharing either, as recent studies show that about 60 percent of today's car sharers hold a university degree which often goes along with an above average income.[767]To evaluate the future market potential of the EU, the degree of urbanization has been investigated for the largest 11 car sharing markets (2011) within the EU27 and correlated to the current market potential. The data referring to the degree of urbanization has been taken from the website of the Central Intelligence Agency (www.cia.gov). The data referring to the population has been taken from the website of the International Monetary Fund (www.imf.org). Table XXIV displays the degree of urbanization in the examined countries.

Table XXIV: Degree of Urbanization in Selected Countries

	Population (million), 2011	Urbanization (%), 2010
Austria	8.331	68
Belgium	10.958	97
Finland	5.404	85
France	63.210	85
Germany	81.821	74
Ireland	4.462	62
Italy	60.619	68
Netherlands	16.585	83
Spain	46.144	77
Switzerland	7.341	74
UK	62.644	80

(Source: Own Compilation)

As the degree of market development differs within this group, the calculated numbers have been applied to a common basis. As a basis, the estimated future degree of the market-development of the German car sharing market has been used. By including the degree of urbanization and assuming a certain adjustment-effect (0.5), the German market development can be transferred to other European markets.

$M_{A,11} = N_{A,11} / (Pop * Urb)$
$M_{A,20}=[1+ [0,5*(M_{A,11}-M_{D,11})]/M_{D,11}]/M_{D,20}$
$N_{A,20}= M_{A,20} * Pop * Urb$
$M_{A,11}$= Degree of Market Development in country A in the year 2011
$M_{D,11}$= Degree of Market Development in Germany in the year 2011
$M_{A,20}$= Average degree of Market Development in country A in the year 2020 (reference number: Germany)
$M_{D,20}$= Average degree of Market Development in Germany in the year 2020
$N_{A,11}$= Number of car sharers in country A in the year 2011
$N_{A,20}$= Number of car sharers in country A in the year 2020
Pop= Population (assumed to be constant)
Urb= Degree of Urbanization (assumed to be constant)

A detailed study performed by the Wuppertal Institute in the year 2007 distinguishes between four potential scenarios to evaluate the market potential of car sharing in Germany in 2020. In the best

[767] Frost & Sullivan (2011a)

case scenario, 6.4 million potential users were identified in Germany assuming that all theoretically interested parties become future car sharers. According to the study, the market potential decreases to 2.1 million users if only the strong interested parties take part in car sharing and it decreases even further to 1.5 million users if providers have a limited willingness to invest. In the worst case scenario, the market potential is narrowed down to 0.87 million potential users due to a lack of service expansion in urban residential areas.[768]As recent studies show that providers both in Germany, as well as in other European countries, have a strong interest to invest in the development of the car sharing business and related infrastructure in urban regions (this will be further explained in the following chapters). We assume that the second market scenario, identifying 2.1 million potential car sharers in Germany in the year 2020 is the most realistic case.Another study from the year 2004 also analyzing the potential German car sharing market volume came to a similar conclusion by calculating the number of potential car sharers in Germany to 1.5 – 2.0 million customers.[769]

Using the average value regarding these two studies (2.1 million and 1.75 million), the number of users in Germany can be calculated to 1.925 million users in 2020 which equals to 2.35 percent of the German population (81,821,000 in 2011). Adjusted by the degree of urbanization, this leads to the following table (Table XXV) showing the market potential for car sharing in the chosen countries in 2020 (rounding errors: up to 0,03 percent).

Table XXV: Market Potential of Car Sharing in Selected Countries in 2020

	M (2020)	N (2020) (thousand)
Austria	0,02573295	145,779
Belgium	0,02066249	219,627
Finland	0,02030796	93,283
France	0,01825372	980,745
Germany	0,0317932	1925,000
Ireland	0,01772776	49,043
Italy	0,01847737	761,654
Netherlands	0,02767276	380,931
Spain	0,01746492	620,544
Switzerland	0,10914904	592,935
UK	0,03217095	1612,253
		7381,793

(Source: Own Calculation)

Based on the assumptions presented earlier, the market potential in the selected countries can be calculated to 7,381,793 users or roughly 2 percent of the population.

As the analysed economies together have a population of 367,519,000 citizens, they count for 72.8 percent of the whole European (EU) population (505.5 million citizens). The chosen economies are also the economically, strongest European countries with an above average degree of urbanization. In addition, they are the countries with the most developed car sharing markets in the EU27. Altogether this leads to the assumption, that these will be the countries within the European Union which will account for a major part of the whole European car sharing market in the near future.As there are no numbers available concerning the market volume of car sharing in other European countries, no fact-based statement about the car sharing market for those EU-members can be made.It is assumed, that the average market volume of other European countries is slightly lower than the market volume of the selected countries due to the presented facts. We assume it to be less than 1 percent of the total population in 2020 or roughly one million users.

Altogether this leads to an assumed market potential of 8.382 million users in the scenario in the year 2020. As the analysed studies focus on the near future (until 2020), no well-grounded predic-

[768] Wuppertal Institut für Klima, Umwelt, Energie GmbH (2007)
[769] Loose et al. (2004)

tion about the car-sharing market in the years after 2020 can be made. However, to evaluate the market potential of car sharing at that time, we will assume that by 2030 the numbers calculated in the best-case-scenario (6.4 million users in Germany) presented in the study performed by Wuppertal Institutewill be realized.[770] Using the formula presented above to transfer the German trend to the European market would lead to a rather optimistic forecast of 24,542,066 users in the selected markets in 2030 (see Table XXVI).

Table XXVI: Market Potential of Car Sharing in Selected Countries in 2030

	M (2030)	N (2030) (thousand)
Austria	0,08555369	484,668
Belgium	0,06869607	730,188
Finland	0,06751738	310,134
France	0,0606877	3260,659
Germany	0,10570206	6400,000
Ireland	0,05893904	163,051
Italy	0,06143124	2532,252
Netherlands	0,09200293	1266,471
Spain	0,05806518	2063,107
Switzerland	0,36288511	1971,315
UK	0,10695795	5360,219
		24542,066

(Source: Own Calculation)

Calculating a market share of 1.25 percent in the other European Markets by 2030 (about 1.725 million users) would lead to 26,266,829 users in total by that time. The total number of cars employed in car sharing organizations in Germany was 5,000 at the beginning of 2011 with 190,000 users[771], or one car for 38 users.

In the presented scenario, this would lead to 220,574 cars employed in car sharing organizations in 2020. This number is similar to the number of cars calculated by Frost & Sullivan, who expect 200,000 cars used for car sharing in Europe by 2020.[772] In the 2030 scenario, 691,232 cars would be employed in car sharing organizations. As the findings show, the number of cars employed in car sharing organizations is very likely to increase in the next few years. Though this trend implies, that citizens, especially the younger generation, are very open-minded towards using this new form of mobility, it does not however necessarily imply that due to car sharing, significantly less cars will be sold in the EU27 in the future. A recent survey performed by Ernst & Young questioning 2,000 German users about their future mobility behavior, resulted in 85 percent of the interviewees judging having their own car as being of high importance. In addition the survey also shows that, while up to 58 percent of the interviewees define their future participation in car sharing as “very likely” only one of nine questioned persons (1/9) would fully forgo owning their own car.[773]As mentioned earlier they narrow down the current market potential for car sharing in Europe to six million users, replacing about 200,000 private cars (1/10,Momo, 2011).

[770] Wuppertal Institut für Klima, Umwelt, Energie (2007)
[771] BCS (2011)
[772] Frost & Sullivan (2011)
[773] Ernst & Young (2012)

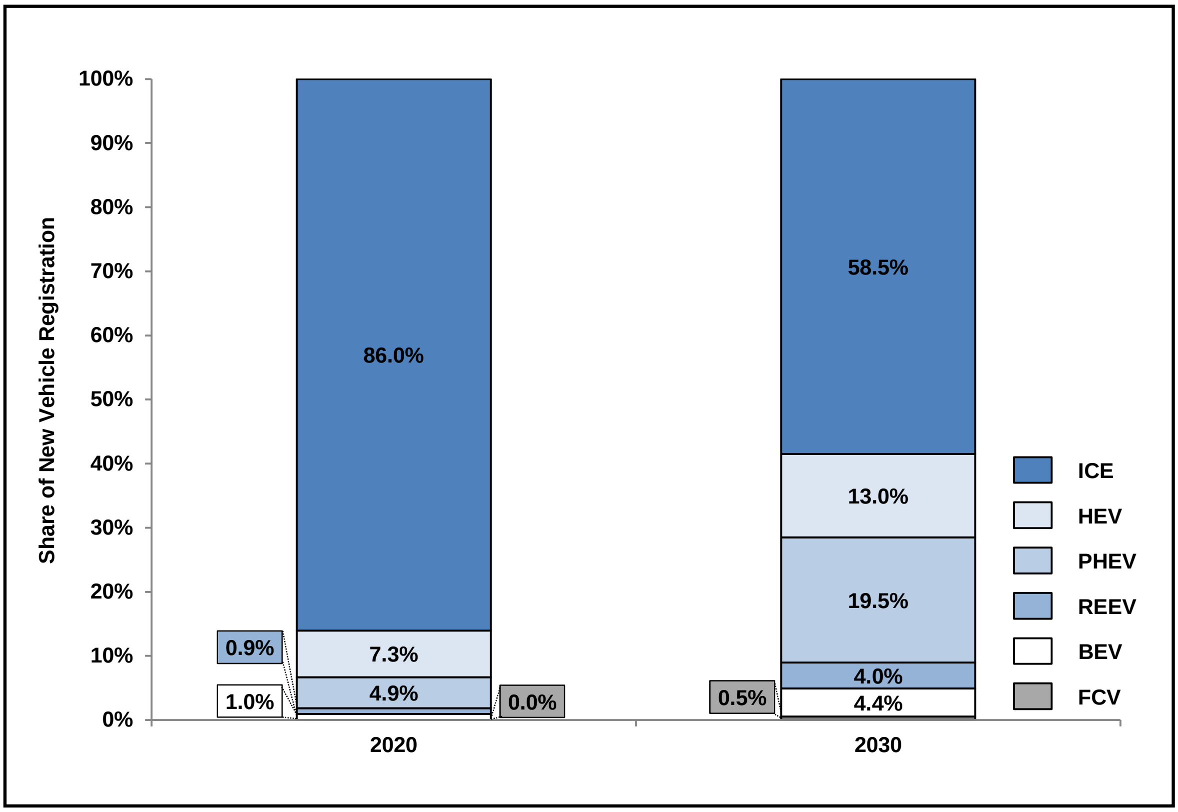
Appendix XXXVII: Questionnaire

Example: Spain

I. Market Situation

Spanish New Electric Vehicle Registrations by Type of Propulsion System

Figure: Spanish New Electric Vehicle Registrations by Type of Propulsion System



1. Would you consider this scenario realistic [presentation of the results/Spanish market forecast]?

a) Discussion of Key Assumptions
- Extensive government subsidies for electric vehicles by the State until 2020
- Very low fuel costs (currently about 1.35-1.40 Euro/l super petrol), increase by ___ (50%) until 2030 (higher increase compared with the EU average due to the very low fuel costs at present time)
- Moderate electricity costs, increase by __ (25%) until 2030 compared with the EU average
- High share of Early Adopters among the private customers (discussion of the consumer segmentation)
- Low proportion of private registrations, high proportion of rental companies’ registrations

b) Further Characteristics

Discussion of Spanish market development, EU market development, new vehicle registrations, etc.)

Global New Electric Vehicle Registrations by Type of Propulsion System

2. Would you consider this scenario realistic [presentation of the global market forecast]?

- Presentation of the results
- Discussion (e.g. impact of Chinese market development)

3. Which of the following propulsion technologies do you expect to become more relevant until 2020/ 2030 (Fuel Cell Vehicles, Plug-in Hybrids, Range Extenders, Battery Electric Vehicles)

4. What do you expect from the technological development of the main components (a) battery, (b) e-motors and (c) power electronics by 2020, 2030 in terms of

Costs:
Technological Potential (e.g. Performance, Range):

5. Which optimization potential do you expect in combustion engine technology regardingcosts and fuel efficiency?

II. Industrial Situation - Europe

Forecast Value Added EU Automotive Industry 2020/2030

- **Presentation of the results of the development of value added in EU automotive industry**
- **Discussion of key assumptions**

6. Would you consider this scenario realistic?

Key Assumptions:

- EU motor vehicle production in 2020 and 2030 (units):
- Share of electric vehicles in EU motor vehicle production: ___% (2020) and ___% (2030)
- ___% of the value added of battery production will be located within the EU countries
- ___% of the value added of electric motors will be located within the EU countries
- ___% of the value added of power electronics will be located within the EU countries
- The remaining shares of components will be purchased from third countries
- Rapid cost reductions among components until 2020 (batteries, power electronics and electric
- motors)

7. How do you consider the competitive position of the Asian/US automotive industry in terms of R&D and the production of electric vehicles compared to the EU?

8. a) Which countries will assume a leading position in R&D and manufacturing of the following components?

- Batteries
- Electric motors
- Power electronics
- Assembly

b) How will the value added be divided between the different players in the future?

- OEM (2011: ___%)
- Supplier (2011: ___%)
[e.g. Discussion of New Entrants]

9. In which specific area of electromobility will new alliances be formed? Will co-operations among large companies play a more significant role than co-operations with inventors and small technology companies?

10. Do you expect synergies from the production of electric vehicles and gasoline vehicles on a shared assembly line? Do you think that a flexible manufacturing model involving both vehicle types will be feasible?

11. Which role do the following drivers play concerning the evolution of the "Industrial Situation"?

a) Discussion

- Access to raw materials
- Technological leadership
- Labor productivity
- Labor costs
- Market proximity
- Transport costs
- Role of public policy
- Know-how in related industries
- Existing supplier-buyer Relationships

- Further:

b) Evaluation

- Access to raw materials

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

- Technological leadership

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

- Labor productivity

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

- Labor costs

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

- Market proximity

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

- Transport costs

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

- Role of public policy

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

- Know-how in related industries

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

- Existing Supplier-Buyer Relationships

Significant ☐ ☐ ☐ ☐ ☐ Not Significant

III. Industrial Plans [only enterprises]

12. Which factors do you consider to be the fundamental sources of competitive advantage for your company in electromobility?

13. R&D
a) What is the focus of your R&D activities?
b) Are you focusing on only one specific technology (BEV, Hybrid- or Fuel Cell technology)?
c) Please give an estimated amount of your R&D budget for electric powertrain over the next 10 years.

14. What share of electromobility do you expect for your company's R&D and production operations until 2020 and 2030?
- R&D
- Production

15. Capacities/Investment

a) Will the transition to electromobility lead to the establishment of additional capacities or will it rather cause a transfer of capacities from other departments in your company?
b) In which countries do you plan to expand your capacities? Why?

16. How do you evaluate the significance of national platforms for electromobility?(e.g. the National Platform Elektromobilität NPE in Gemany)

IV. Services

17. Which of the following services will succeed in establishing independent business models?

- Charging infrastructure?
- Car sharing?
- Maintenance and repair?
- Disposal/recycling?

[Discussion]

18. How do you rate the market opportunities of these services?

V. Public Policy Framework

19. Which role should public policy play in the transition to electromobility?

a) Indirect technology support (e.g. tax incentives)
b) Direct technology support (e.g. by grants)
c) Sales promotion
- Government procurement
- Purchase premiums
- Infrastructure (e.g. high occupancy lanes)
- Regulation

[Discussion]

20. What should be the focal point of the government support?

a) Promotion of R&D/further development of alternative propulsion technology
b) Attraction of manufacturing operations
c) Infrastructure development

21. How can public policy compensate for the decrease in tax revenues resulting from fewervehicles using ICE technology?

a) Budget
b) Taxes from other types of mobility
c) Consumption taxes
d) Miscellaneous
e) Will lower tax revenues lead to a problem in the long term? Until when?

22. Consumer Information
a) Is there a need to educate consumers about electromobility?
b) What information should be provided?