CHALMERS
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Gaining a competitive advantage with sustainable business – implementing inductive charging using systems thinking

A Benchmarking of EVs and PHEVs

Master thesis in Industrial Ecology

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In collaboration with China-Euro Vehicle Technology, CEVT

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Gothenburg, Sweden 2014

ABSTRACT
One of the most discussed topics in Industrial Ecology is incorporating sustainability into business. One of the key barriers in this process is companies' fears associated with hindering company activity and increased costs. This master thesis examines the implementation of inductive charging technology for cars, and discovers the competitive advantage gained by using a sustainable system approach in companies.

Market research has shown that PHEV consumers don't plug-in their cars as often as thought, indicating a problem of convenience. A convenience problem believed to be solved by inductive charging. The interest of OEMs and CEVT lays in the convenience of consumers.
The thesis has evolved around a benchmarking of current EVs and PHEVs, in order to understand the dynamics of the current market as well as an in-depth analysis of inductive charging. Covering the basics of the technology, suppliers and their different variations, and consumer perspective on inductive charging. With the aim of developing a sustainable[1] business plan for CEVT regarding inductive charging in C-segment cars.

A sustainable business model for inductive charging is presented as a result, with specific targets depending on market, indicating that inductive charging should be presented as a luxury feature. The overall conclusion is for OEMs to "make room" for the technology solution in order to be compatible with inductive charging, as well as being involved in the standardization work.

Keywords: *Inductive charging, Wireless charging, EV, Electric cars, PHEV, Plug-In Hybrid Electric Vehicles, Sustainable business model, Market analysis, Porters' Five Forces*

[1] Sustainability is a business strategy that drives long-term corporate growth and profitability by mandating the inclusion of environmental and social issues in the business model.

FOREWORD

The thesis is written as a completion to the master Industrial Ecology, at Chalmers University of Technology in Gothenburg, Sweden. The work entitles 30 Hp, higher education points, per person and was executed during the spring term of 2014.
The thesis was performed on behalf of CEVT, China Euro Vehicle Technology AB.

We would like to present a thank you to;

- *Sven Sjöberg, Hybrid Technologies at CEVT, our supervisor, for guiding us through this work and for valuable advice and support when needed.*
- *Henrikke Baumann, Docent at Energy and Environment, Chalmers University of Technology, our examiner, for her valuable advice and knowledge within the subject are of sustainable business models.*
- *Everyone giving us the opportunity for an interview; Bengt Axelsson, Tommy Fransson, Mats Josefsson, Hamish Laird, Tommy Lindholm, Crister Lunde, Hans Göran Milding, Dr Song, Mats Williander, and suppliers (Siemens, Qualcomm, and WiTricity and TDK).*
- *Magnus Karlström for his valuable advice and guiding.*

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ABBREVATIONS

BEV	Battery Electric Vehicle
CEVT	China Euro Vehicle Technology
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FOD	Foreign Object Detection
HEV	Hybrid Electric Vehicle
IEA	International Energy Agency
IEEE	Institute for Electrical and Electronics Engineers
LOD	Living Object Detection
NEV	New Energy Vehicle
PHEV	Plug in Hybrid Electric Vehicle
SAE	Society of Automotive Engineers
VCC	Volvo Car Corporation

1 Competitive advantage through systems thinking

As the need for sustainable business becomes more and more apparent, it becomes increasingly obvious that one of the lacking aspects of sustainable business is a developed strategy from company perspective. The leading papers on sustainable business are very generalized, while others analyze companies from a social perspective rather than a company perspective (see chapter 8). Car companies are so focused on competing against each other, but this may blind them: an increase in public transportation use shows that the real competitors of car companies may not be other car companies but public transportation. Car companies could be fighting for their existence, instead of merely trying to gain an advantage over a competitor, showing the importance of changing the current business model to include the whole system. Using the car example, this thesis shows the benefits of using Industrial Ecology or systems thinking approach to gain a competitive advantage.

First, it is important to understand the overall pollution problem. This gives us a perspective on how it relates to the automotive industry. Emissions can be separated into sector sources to find a pollution-reduction method that will have the greatest impact. Although this thesis is focused on wireless charging technology for PHEVs and EVs, it also looks at PHEVs and EVs the sales of both the cars and this new technology are so interdependent.

According to the International Energy Agency (IEA) 2012 report, the transportation sector was responsible for 22% of global CO_2 emissions in 2010, second only to the emissions produced from heat and electricity generation (41%). [1] In the US, 30% of CO_2 emissions come from the transportation sector, 60% of which come from cars and light trucks. [2] Even though the amount of extractable fossil fuel resources is decreasing, the IEA foresees that the demand for transport fuel will increase by 40% by 2035. [1] Clearly, these values demonstrate an impending conflict for transportation in the future, one that will need to solve the combined financial, energy, and environmental problems.

With growing environmental problems and a growing need for transportation, Plugin Hybrid Electric Vehicles and Electric Vehicles are more and more often considered the solution to these issues. According to the IEA (International Energy Agency), a vehicle sale of 75% of PHEVs and EVs is needed in order to reach the 2-degree target. [3] Which have generated a “20 million EVs by 2020” guideline. [4] However, companies across all sectors are still hesitant in reducing their environmental impacts because of a fear of increased costs.

In the United States, the Energy Independence and Security Act of 2007 defines PHEVs more strictly as vehicles that;

- Draw motive power from a battery with a capacity of at least 4 kilowatt hours
- Can be recharged from an external source of electricity for motive power, and
- Is a light, medium, or heavy, duty motor vehicle or non-road vehicle. [4]

The purpose of PHEVs is to reduce emissions by running the car on electricity rather than the traditional fossil fuels. However, Toyota performed studies of PHEV usage and discovered that users were not primarily using the cars in electric mode. The effects are significant - in fact the efficiency decreases by 84%. Among other observations a Japanese study observed - as examples - the PHEV charging behavior of one housewife and one daily commuter in Tokyo. The study saw that the daily commuter charged the car at the most once per day (when they were at home), and got an efficiency of 40 km/l – the car often ran on fuel instead of electricity. By comparison, the housewife charged the car 3.4 times per day, and got an efficiency of 249 km/l. [5]

Other studies show that users do not like to charge the cars because of the inconvenience. With a PHEV you have to both refuel the car now and then, and also charge it. With time, a significant amount of people reduced the amount of times they charged their car. This means that the car's usage defeats its purpose. To conclude, PHEV users do not use the cars as intended because of the inconvenience associated with battery charging.

Another question is, if so many people are interested in reducing emissions for environmental reasons, why is it that so few customers are interested in PHEV and EV vehicles? Some argue that it is unfamiliar territory and their impression of electrified vehicles is negative, but studies show that when people drive them they are actually very pleased with the performance. [6] Therefore, the most significant problem with society adopting PHEVs as a mode of transportation is the convenience rather than the technology itself.

One way to increase convenience is to reduce the charging process. Charging is perceived as inconvenient, takes time so you have to plan ahead, you have to remember to charge, and the cords can be unpleasant to handle because they can be heavy, dirty, and wet. Car companies aim to solve this inconvenience with wireless charging, also known as inductive charging, in order to increase charging of PHEVs and EVs as well as increase the desire to own one.

Convenience is what attracts customers to the product, but there are other barriers that involve both customers and companies – the cost. According to the IEA, the most urgent need in all EV markets is the financing of charging, [7] to finance the charging infrastructure and build up a functional payment process. Vattenfall and other energy companies are looking into ways of simplifying and unifying payments for energy-use. [8] This would allow a customer's public charging bill to his monthly energy bill, or, if there are different users, they could have different accounts so they each get charged appropriately. This means you could just park and not worry about paying. There are many possibilities, and each one aims to streamline the payment system.

Overall, research has shown that specific aspects need to be addressed in order for EVs to be broadly successful. These are: safety, affordability, interoperability, performance, and environmental impact. [9] The challenge of interoperability is directly connected to standardization, especially standards regarding charging. Assessing factors that make the aspects possible, by using a systemic approach, is what makes it possible to find where one can gain a competitive advantage. The advantages of using a systems approach far outweigh a traditional customer business model: they can increase the rate of technology adoption and decrease costs for both companies and customers.

2 CURRENT MARKET SITUATION

Understanding one's market situation and dynamics is crucial when trying to implement a new technology solution. Systems thinking for gaining a competitive advantage is an expansion on conventional business models[2]. Business models focus on companies and customers, and this is still an important element in systems thinking: without it, there would be no purpose in expanding the system. However, reaching out beyond the traditional business model expands the perspective to what could be considered a new, comprehensive market strategy. This expanded understanding of the market dynamics gives one the opportunity to understand the root problems and develop solutions that target them. This allows for a more strategic approach, one that addresses the market as a whole instead of a few selected market indicators.

More information about the specifics of the system is available in chapter 3, Technology description, while the usage of system perspectives in business is described in chapters 5 and 8.

2.1 Electric - and Plugin Hybrid Electric Vehicles

The current market of EVs and PHEVs, the basis for this thesis, is constantly changing and growing. The price of an EV or PHEV is still higher that an equivalent combustion engine vehicle, so the market is highly dependent on government subsidies and incentives to bring down the high price of the cars.
This also indicates the need for increasing the value associated with these cars. The added value associated with these vehicles at the moment is the environmental aspect, as well as the low charging cost and possibly driver benefits.

The question is though, is this enough? Are the current added values enough for consumers to pay more to shift from combustion cars to EV or PHEV cars?

The worldwide sales of EVs and PHEVs amounted to 102 335 [10] sold vehicles, for 2014 (Jan-Jun). To put this in perspective, the total amount of vehicles sold so far in 2014 is 72,33 million vehicles [11], meaning that EVs and PHEVs account for just 0,14% of total number of vehicles sold. Clearly, EVs and PHEVs still account for a very minor part of the car market.

2.1.1 Standards

One important aspect related to the introduction, or perhaps better viewed as acceptance, of these vehicles is development of associated standards. Standardization allows for interoperability and safety standards, reducing some of the fears hindering EV and PHEV acceptance.
The electrification of vehicles has resulted in 60+ standards issued by the SAE. The standards cover topics such as:

- **J537 (RIP),** Storage Batteries
- **J1634 (RIP),** Electric Vehicle Energy Consumption and Range Test Procedure
- **J1773,** Electric Vehicle Inductively Coupled Charging
- **J2289,** Electric-Drive Battery Pack System: Functional Guidelines
- **J2344,** Guidelines for Electric Vehicle Safety
- **J2847/1 (RIP),** Communication between Plug-in Vehicles and the Utility Grid

[2] The concept of system thinking in business is further described in chapter 8.4.

- **J2889,** Vehicle Sound Measurement at Low Speeds
- **J2936 (WIP),** Vehicle Battery Labeling Guidelines
- **J2954 (WIP),** Wireless Charging of Electric and Plug-in Hybrid Vehicles
- **J3012 (WIP),** Storage Batteries - Lithium-ion Type

A full list of standards in place and under development is presented in appendix 9.4.

The standards regarding electrification of vehicles have been, and are, crucial in the implementation of EVs and PHEVs on the private vehicle market. They allow for the unification and quality assurance of these new vehicles. These have resulted in focused development of the technologies needed for EVs and PHEVs to become competitors to combustion engine cars. Standards, such as the ones regarding wireless charging, have been developed in order to secure an equally, if not more, convenient method of charging vehicles, and ensure the technology's compatibility across markets. The standardization process can be seen as the unification of key aspects of wireless charging, allowing companies to design products with guaranteed interoperability and consequently reducing customer's fear of products becoming obsolete.

2.2 Market Descriptions

Overall, the market indicates that there is a problem of convenience regarding EVs and PHEVs. Plugin Hybrid users are already paying more to own a plugin hybrid, but they do not charge them nearly enough as intended. This charging behavior essentially turns PHEVs into inefficient HEVs. Why would customers pay more for a technology but not use it?

One inconvenience is that charging an EV or PHEV requires additional work – users have to plug the car in everyday for it to run on electricity. In comparison, owners of combustion cars need to fill up their cars once every few days, depending on how much they drive. This convenience clearly affects product use, even if it seemingly contradicts the customer's product choice.

2.2.1 Global Market

The global outlook and perspective on the future of EVs and PHEVs seems positive. All reports, studies, and publications found during the writing of this thesis show a growth in PHEV and EV use, and predict growth in the future. One such study by Navigant Research, presents a prediction of the future global market, figure 1, indicating sales of over 100 million EVs and PHEVs before 2050.

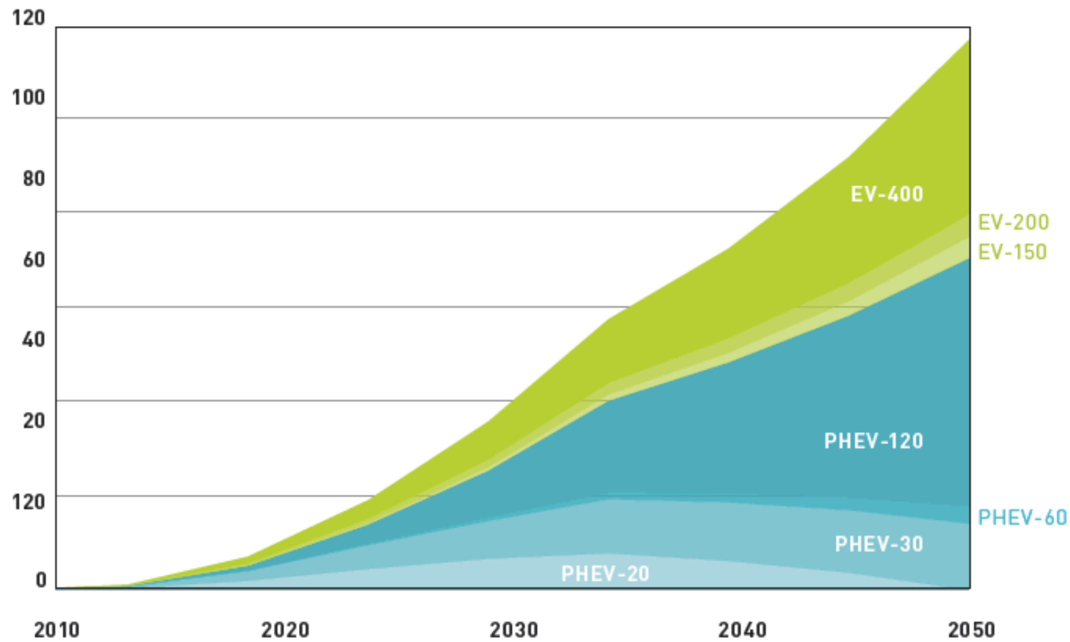


Figure 1- World EV/PHEV sales (millions per year)[3] [12]

The greatest hurdle for PHEVs and EVs introduction to the vehicle market is the existence of combustion vehicles. Combustion cars are flexible to use, quick and easy to refuel, and cheaper than their PHEV and EV counterparts. Even though people's awareness about climate and environmental problems is growing, the image of the electric car is still that of inefficiency, hassle, and increased cost.
Ironically, one of the factors hindering the introduction of clean energy vehicles is the increased efficiency of existing cars. Existing legislation restricting CO_2 emissions has generated a shift towards more efficient cars. Because these new combustion engine cars are less environmentally damaging, they create a bigger threat to the implementation of PHEVs and EVs by decreasing the difference in environmental impact between combustion and cleaner vehicles. According to Tommy Lindholm, Vattenfall, the electrified car will not be able to compete for the mass market if it needs to be plugged in every day. The inconvenience factor, as well as the unpleasant association of handling wet and dirty cords, is considered to be the defining factor preventing EVs and PHEVs of taking a larger market share.

Even if the technology were accepted by the public, there would still be other limiting factors preventing the widespread use of the technology. One of the largest hurdles would be infrastructure development. The most obvious aspect would be the charging infrastructure, although the importance of this obstacle varies from region to region (some countries are able to develop infrastructure much faster than others). Other aspects include resource availability and energy grid capabilities.
A government's approach to EVs and PHEVs can be seen in its subsidies, incentives, and effort put in charging infrastructure. In order to get a general overview of the perspectives and efforts of

[3] Expected vehicle sale by technology type and range in km

governments regarding EVs and PHEVs, table 1 states the financial, infrastructure, and RD&D incentives of the major developed/developing countries in the world.

Table 1 - National Policy Initiative, 2012-2013 [13]

Countries	Financial*	Infrastructure*	RD&D*
China	Purchase subsidies for vehicles of up to € 6 930	-------	€ 800 million for demonstration projects
Denmark	Exemption from registration and road taxes	€ 9.4 million for development of charging infrastructure	Focus on integrating EVs into the smart grid
Finland	€ 5 million reserved for vehicles participating in national EV development program, ending in 2013	€ 50 million reserved for infrastructure as part of national EV development program, ending in 2013	-------
France	€ 450 million in rebates given to consumers buying efficient vehicles. With 90% of that amount from fees on inefficient vehicles, Remaining 10% (€ 45M) is a direct subsidy.	€ 50 million to cover 50% of EVSE cost (equipment and installation)	€ 140 million budget with focus on vehicle RD&D
Germany	Exemption from road taxes	Four regions nominated as showcase region for BEVs and PHEVs	Financial support granted for R&D for electric drivetrains, creation and optimization of value chain, information and communications technology (ICT), and battery research
India	€ 1 200 or 20% of cost of vehicle, whichever is less. Reduced excise duties on BEV/PHEVs	The National Mission for Electric Mobility will facilitate installations of charging infrastructure	Building R&D capability through joint efforts across government, industry, and academia. Focus on battery cells and management systems
Italy	€ 1,5 million for consumer incentives, ending in 2014	-------	-------
Japan	Support to pay for ½ of the price gap between EV and corresponding ICE vehicle, up to € 7 000 per vehicle	Support to pay for ½ of the price of EVES (up to €10 000 per charger)	Major focus on infrastructure RD&D
Netherlands	Tax reduction on vehicles	400 charging points	Focus on battery RD&D

	amounting to 10-12% net of the investment	supported through incentives	(30% of 2012 spending)
Spain	Incentives up to 25% of vehicle purchase price before taxes, up to € 6 000. Additional incentives of up to €2 000 per EV/PHEV also possible	Public incentives for a pilot demonstration project. Incentives for charging infrastructure in collaboration between the national government and regional administrations	Five major RD&D programs are operational with incentives for specific projects
Sweden	€ 4 500 for vehicles with emissions of less than 50 grams of CO_2/km. € 20 million for 2012-2014 super car rebate	No general support for charging point besides RD&D founding (€1 million in 2012)	€ 2,5 million for battery RD&D
United Kingdoms	-------	€ 45 million for thousand of charging points for residential, street, railway, and public sector locations. Available until 2015	The UK Technology Strategy Board has identified 60 collaborative R&D projects for low-carbon vehicles
United States	Up to € 5 400 tax credit for vehicles, based on battery capacity. Phased out after 200 000 vehicles from qualified manufactures	A tax credit of 30% of the cost, not to exceed € 21 600 for commercial EVSE installations; a tax credit of up to € 720 for consumers who purchase qualified residential EVSE. € 260 million for infrastructure demonstration projects	2012 budget of € 160 million for battery, flue cell, vehicle systems & infrastructure R&D

*All values are converted into euros according to todays (2014-04-30) exchange rate
** All values are rounded to nearest ten

According to industry and our research, standardization plays a crucial role on a global scale. Standards allow products to be adaptable and usable in all markets and countries. The role of standards regarding EVs and PHEVs is extremely important - global standards would allow OEMs to sell the same model in all markets and not having to adjust it for each one separately, allowing for easier and more streamlined global implementation. The more standardized the market, the easier it is to introduce the technology on a larger scale.

This thesis examines three markets specifically, namely the US, European, and Chinese markets. The US market is rather new in terms of environmental regulations, although California has been pushing its own environmental regulations much faster than the federal government (the California market is so large that sometimes car manufacturers address this market specifically). The US market is a result of people who are enthusiastic about the environment, rather than the government implementing environmental regulations. The European market on the other hand, has environmental regulations in place and the government is much more involved in decreasing environmental impacts. The third market is the Chinese market, which has recently become the largest car market in the world. The Chinese market differs from the other two primarily because of the possibilities of change in the country – the political situation in China allows for much faster change than in both the US and Europe.

2.2.2 US Market

The US is the leading market for PHEV and EV sales, along with Japan. Barack Obama stated in 2011 that the goal is to reach 1 million electric cars on the roads in the US by 2015. [9] Governor Jerry Brown of California just signed legislation to have 1 million zero emission vehicles on California roads by 2023, by implementing policies that help low-income families and areas in purchasing these vehicles and developing the necessary infrastructure in the vicinity. [14] Make zero emission vehicles available to people with low incomes is one of the key steps necessary in shifting towards electrified transportation.

In terms of readiness to adopt the technology, it is common for households to have a garage or a private parking space. Most customers would charge at home, and would not necessarily need public charging. Meaning that the infrastructure changes inform of implementation of charging poles (or ground pads for inductive), mainly would be needed at homes and offices. Charging cars with electricity would quadruple the total amount of energy consumed by the house. Usually, this energy consumption would take place when everyone gets home from work. The energy grid is not able to deal with such an increase in energy usage. The most significant problem in the US therefore is the energy grid capabilities of charging PHEVs and EVs.
However, with the significant increase in renewable introduction into the energy grid, energy companies need to completely rebuild the grid. In that case, an implementation of inductive charging might fasten the rebuild.

Federal and local financial incentives in the form of subsidies, tax reduction, or user benefits such as no tolls have made the US the country with the most PHEV and EVs. The level of subsidies and tax reduction is regulated by the state, at the moment the most beneficial state is California. Currently, according to Navigant research, US customers would be interested in buying a PHEV for $26,000. After including the tax incentives, this means that the selling price of the car can actually be $33500 for customers to be interested. However, even if the price were to be the same, research has shown that the buying cycle is very long for a PHEV, up to six months from interest to purchase, longer than for a traditional car. [15]

2.2.3 Chinese Market

Although the US is the largest environmental car market, China is the largest car market in general. However, China has severe air quality problems that are negatively affecting citizens, and therefore the economy. The air quality sometimes reaches levels magnitudes higher than deemed safe in the western world. This problem actually has a visible negative impact on the economy [16].
As a result, China has financial incentives to help reduce the problem. China offers subsidies for PHEV and EV owners to encourage clean air vehicles. Some cities offer additional subsidies, as well as much easier ways to getting license plates – in China, the government needs to allow you to purchase a car, and it controls sales by awarding license plates. It has a special license plate for

clean energy vehicles, and the waiting line for these is much shorter than that for combustion vehicles. Still, clean air vehicle sales are not enough, and so the government is extending the period of time for which the subsidy programs are in effect. One of the largest strengths with the Chinese market is the government's ability to cause change from one day to the next. Because of the top down government approach, change happens much quicker than in democracies, for example, where discussion and voting need to take place.

An initiative from the Chinese government towards increasing the amount of clean vehicles is the push for NEV (New Energy Vehicles). NEVs are tiny electric vehicles that can be legally used on most paved surfaces. In 2013, Chinese automakers invested RMB 15 billion (€1.8 billion) in increasing the production of NEVs in reaction to government incentives that allowed for the registration of these new vehicles in the country. [17]

One of the most significant problems is that there is no public charging infrastructure, and private infrastructure is nearly impossible to develop in the busy and packed cities across China. In China, people living in cities do not have access to their own garage and often even have problems finding a parking space [16]. Therefore, the largest setback for introducing EVs and PHEVs in China is for Chinese municipalities to install public charging systems so individuals have a place to charge, rather than fixing the entire grid system. The energy grid problem is second to making it physically possible for PHEV and EV drivers to be able to charge in cities. Therefore, the hurdle here is introducing public charging stations to allow for the use of EVs and PHEVS.

One of the benefits of China, compared to Europe and the US, is that the energy grid is being developed every day along with power plant construction. It is much easier to adapt a changing system to accommodate new energy requirements than to change static ones.

2.2.4 European Market

Out of the three markets, the European market seems to be the most balanced, where legislation and citizens equally responsible for creating the vision of a society with greener cars. As a result, several green strategies were developed to shift towards more sustainable transportation. In order to reduce the amount of urban vehicles running on petrol or diesel, the European union has set an overall goal of 50 % reduction by 2030 and a 100% reduction of conventional fossil fuel vehicles in cities by 2050. [18] However, the degree of the standards and incentives for EVs and PHEVs differ depending on the European country even though the European union has stated a goal that involves all countries.

The leading market in Europe, and globally in 2013, was the Netherlands, with a 23.8% market share for PHEVs (in December 2013). In 2013, new registrations of clean vehicles were dominated by PHEVs at 85% (about 19,670 vehicles), and EVs at 15% (about 3,480 vehicles). [19] The main reason for these sales is claimed to be the local incentives, which is supported by the fact that sales dropped down to below 1,000 cars in January 2014 when the incentives were removed. [20] This meant that now Norway became the country with the highest market share of PHEVs and EVs. Norway's strong EV and PHEV market is largely a result of incentives, such as charging infrastructure and subsidies. The government directed a significant amount of resources into developing charging infrastructure in 2009, which created over 4,500 charging points over all of Norway by the end of 2013. [21] Norwegian subsidies amount to a value of €11,500 for EVs (this value cannot be directly related to subsidies in other countries, for example the $7500 in California, because cars in Norway are more expensive). The financial incentives are in the form of exemptions. Customers are exempt from: the congestion charge in Oslo, recurring vehicle fees, sales tax, VAT, annual road tax, vehicle tax, and import duty. However, some argue that it's the non-financial incentives that have the largest impacts: free parking in public parking areas, free electricity to charge EVs, free use of bus and taxi lanes, and free use of toll roads. [22] The Netherlands and Norway have clearly shown how incentives, financial and non-financial, are crucial in the implementation of EVs and PHEVs. They make EVs and PHEVs competitive with combustion cars on a price basis, as well as enticing customers to improve their quality of life with other benefits. Inductive charging is perceived to be the next sales point, as it potentially may offer a level of convenience that doesn't exist today. [23]

2.2.5 Overall

The uniqueness of each market offers the ability to have a different global and local strategy. Even with standardization, every market relies on different factors that would enable it to shift too more electrified transportation. The US market would be best characterized by enthusiasts who are willing to buy the cars and who have the required space to use them before the development of public infrastructure. The European market depends on public policies and depends more on public infrastructure than the US market. In China, the shift towards electrified transportation can happen very quickly, but the key-enabling factor of the technology implementation is the public infrastructure.

3 TECHNOLOGY PERSPECTIVE

Even though the overall market may be in support of electrified transportation and the need for a more convenient method of charging, it is important to understand the internal dynamics of the market as well as the offered technologies. The development and implementation of a technology involves not only the company itself, but also many other stakeholders in society. The understanding of these complex interactions is essential for developing and understanding a business plan that addresses the market comprehensively. This chapter visualizes and defines all primary stakeholders, as well as their interconnections and current constellations (the mini networks inside the market), and shows the technologies they focus on. An in-depth technology description is also presented to show the differences between the different inductive charging technologies offered by different companies. Even though the specific technology selected will most likely not affect the user experience, it may still play an important role in other aspects, such as resource limitations and the resulting stakeholders.

3.1 Inductive Charging Technology and System Description

Before going into specific details of the technology, it is important to understand the whole system to see the overall picture. This allows one to understand all the interactions that come down to the implementation of one technology, and also see strategies associated with its implementation. Therefore, the involved stakeholders are presented first to show the stakeholders and system needed to introduce this technology.

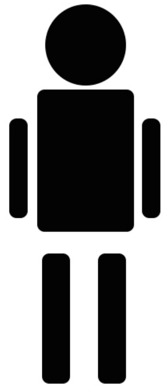
3.2 Stakeholder Descriptions

Incorporating all perspectives into the business strategy is essential for a successful technology introduction. Although some stakeholders are affected more than others, introducing a new technology could change this balance, making it important to include all stakeholders. The socio-technical system is far more complex than conventional business approaches acknowledge, especially when introducing new technologies.

One of the primary stakeholders for both conventional and expanded system perspectives is customers. Without understanding customers and providing value for them, companies have no business, and the expanded system perspective becomes obsolete.

The following is list of stakeholders and the symbol used to represent them later on in the thesis.

3.2.1 Customer

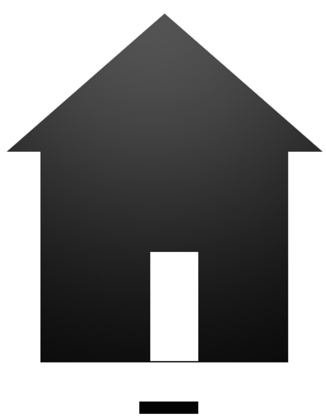


The customer is the user of PHEV and EVs. There are two types of customers: those who live in houses with a private garage space, and those who rely on public parking.

3.2.2 PHEV or EV

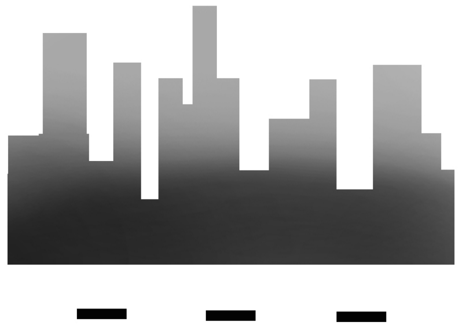
The PHEV or EV is the product that the car companies sell. This product is what is supposed to be improved by the addition of a inductive charging system, to increase charging convenience.

3.2.3 House with Installed Charging Station



This represents the charging system required for a customer with a private parking space. This private infrastructure is expected to be the primary infrastructure used in Europe and the US, until public infrastructure is constructed.

3.2.4 Public Charging Infrastructure



This picture represents public charging infrastructure or, more simply, the infrastructure for the customers who use public parking spaces for charging. Public infrastructure is one of the most important factors in enabling inductive charging to be implemented in China, because most of the population relies on public parking spots. [16]

3.2.5 OEM

Original Equipment Manufacturers (OEM) are the car companies that produce the car. OEMs are the crossing point of suppliers and customers. Therefore, quite often companies understand competitiveness as maximizing profit rather than analyzing interactions of stakeholders to gain a market edge. The growing environmental demands are causing changes in different parts of society, including the automotive sector. It does not matter whether car manufacturers actually care about the environment – even if car manufacturers do not care, they still need to understand the environment to remain competitive in the future.

Many car companies around the world are developing some type of wireless energy transfer system to charge PHEV and EVs. Although most companies keep their progress secret, it is clear that many companies see value in developing this technology. Even racecars, which have feared the switch to electric drive, now utilize this technology.

3.2.6 Suppliers

OEMs rely on many Tier 1 and Tier 2 suppliers to build their product. Tier 1 suppliers (Lear, Siemens, TDK) work directly with OEMs, bringing technologies or products from Tier 2 suppliers (Qualcomm, WiTricity). Similarly, Tier 2 suppliers bring technologies or products from Tier 3 suppliers, and so on. A company can be both a Tier 1 supplier for one product and a Tier 2 supplier for another.

The existence of Tier 1 companies is somewhat dependent on the existence of car companies. Tier 1 companies are the companies that deliver products directly to OEMs. Tier 1 companies are usually the companies that integrate technologies from Tier 2 companies (technology companies) into car designs. Tier 1 companies often dictate standards to automotive companies (?), but there are a few car companies so important that they are able to influence and even dictate Tier 1 requirements. Although Tier 1s have a high control over what gets produced and how, because they work with many different car companies, they depend on car companies to make the sales. Usually Tier 1 suppliers have the most control of the suppliers because they are the culmination and closest end product to the OEM.

3.2.7 Government and Policymakers

Governments and policymakers are decision-making bodies that influence the market through subsidies, tax deductions, or other benefits.

3.2.8 Power Plant

Power plants are what provide energy to the system. Switching to centralized energy systems makes it easier to regulate emissions and can increase efficiency.

3.3 Physical System

The physical system is the system that would exist when inductive charging is used by society. In this system, we have included energy flow and material flows because they impact the physical world. The following figure depicts the physical connections in the system. This figure shows the physical connections of the working system after implementation. The following, figure 2, is a system diagram of the flows within society, flows required for the usage of inductive charging technology.

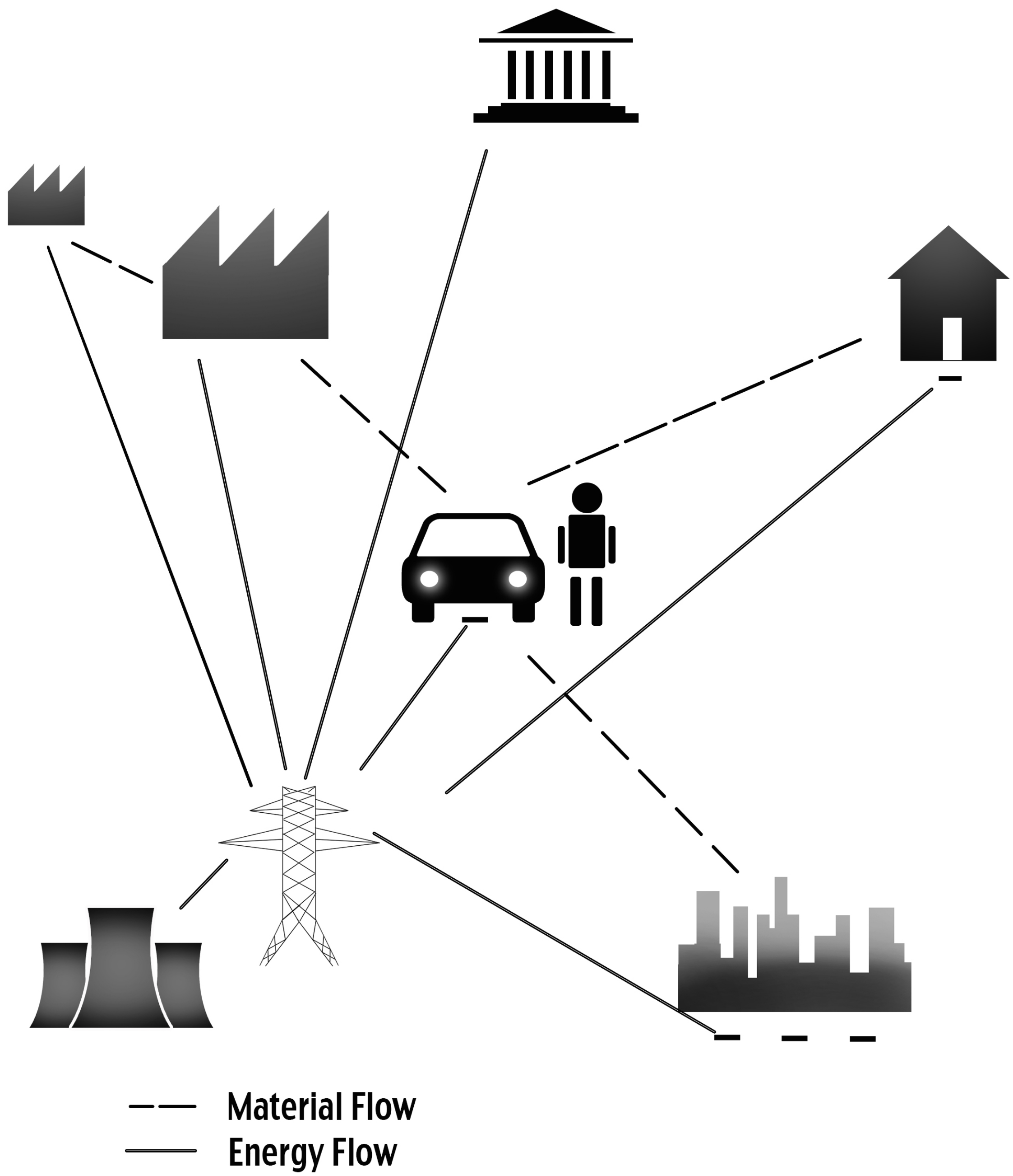


Figure 2 – Physical connections in the system

3.3.1 Constellations

The physical system and flow system presented in Figures 3 and 4, respectively, show general physical relationships between different stakeholders. Looking from a different perspective, the system is of course more complex – there are of course many subtleties, depending on company suppliers, technology suppliers, and other stakeholders. For example, the Toyota Prius PHEV is beginning to implement WiTricity's inductive charging technology [24], but the company producing and adapting the technology to the car is TDK. Although the general and specific systems have the same basic structure, we have used the term constellations for the network of specific companies that interact with each other. Analyzing one of these constellations can provide a business analysis usable by other constellations.
We analyzed all information we could find to build a web of interactions. This web means to visualize the impacts and technology development pathways, showing how stakeholders are influenced by other stakeholders.

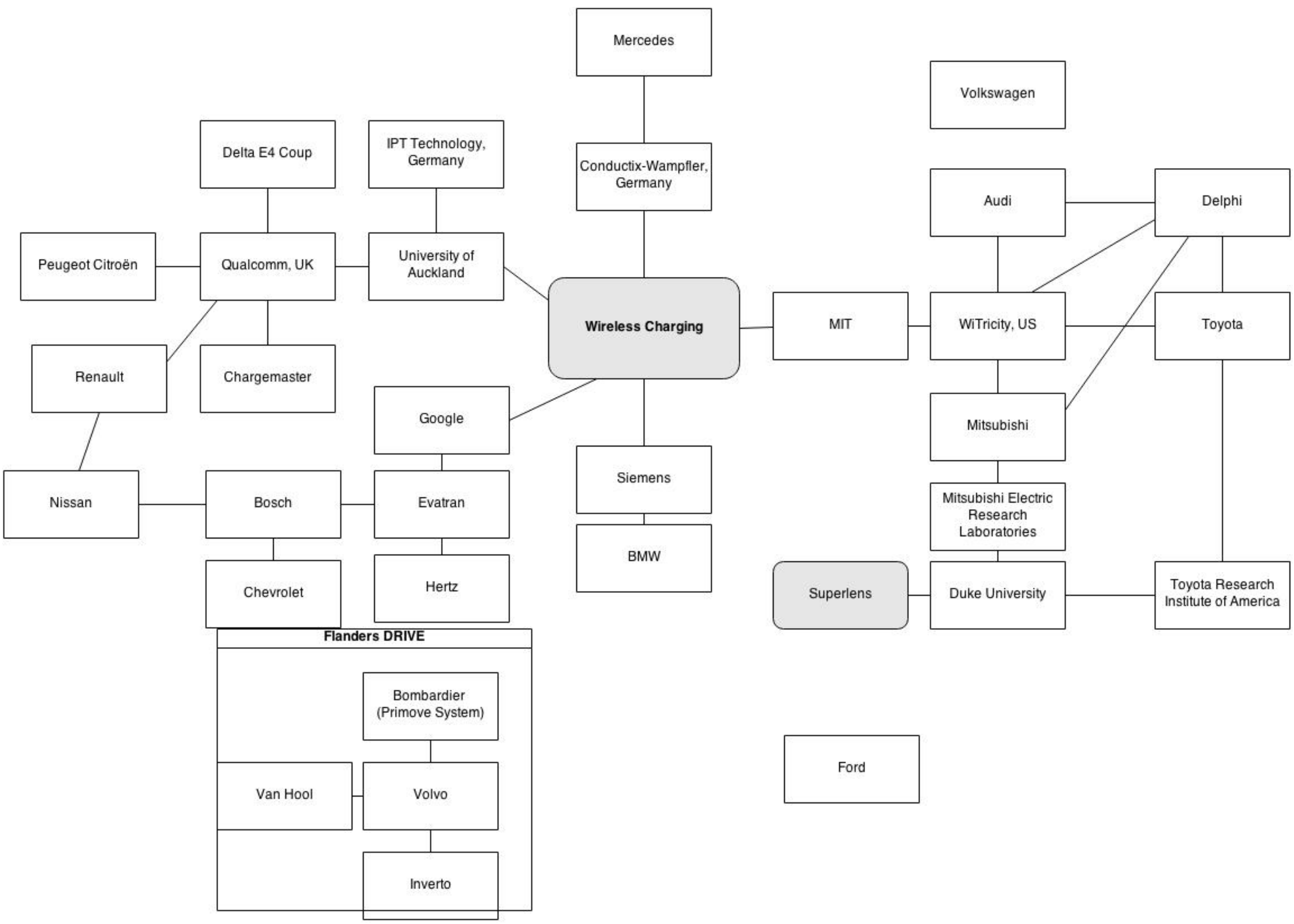


Figure 3 – Current company interactions

Looking at the above model, we broke it down to create a simplified model from a company perspective. The traditional business model is linear – Tier 2s work with Tier 1s, who supply OEMs, who sell to consumers. Our expanded system model includes other factors that are not included in the traditional model, factors that are vital to the healthy functioning of the business. Understanding this full system is what allows companies to create a comprehensive business strategy. The following figure depicts the expanded business model, as well as the traditional (the boxed).

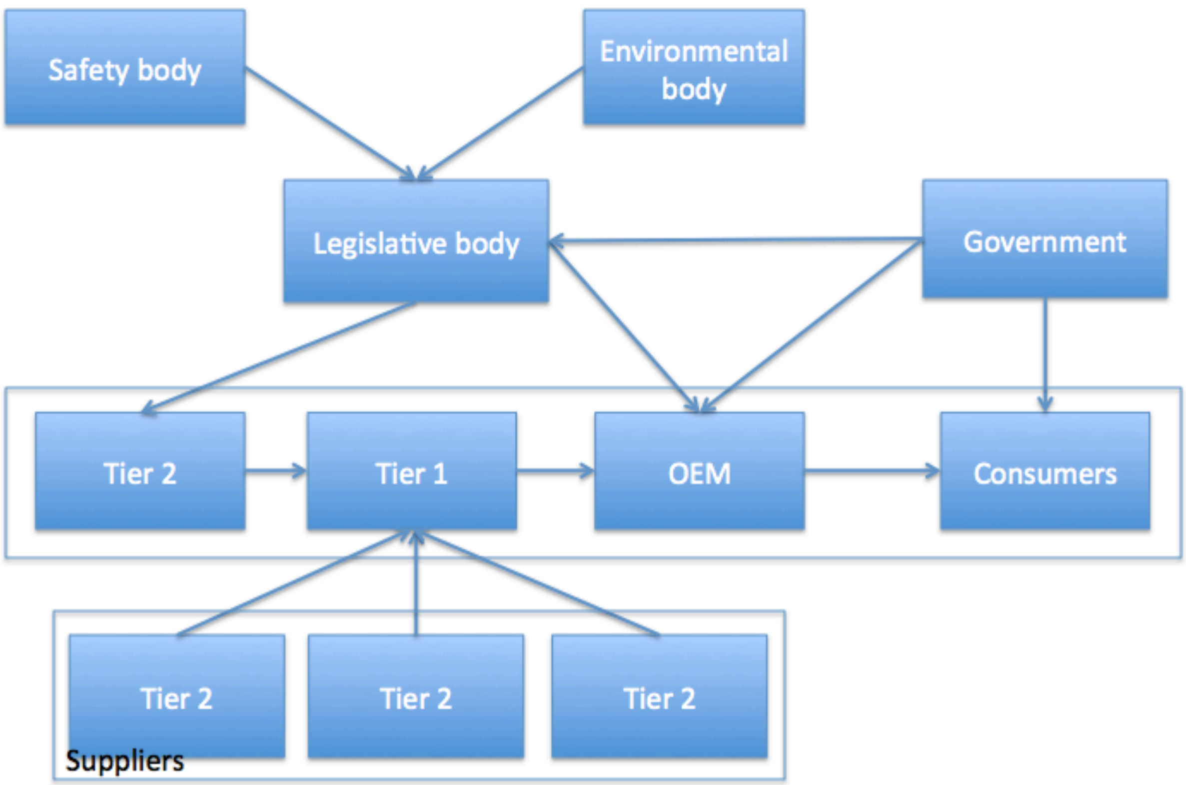


Figure 4 – System network[4]

3.4 Technology – Up Close

Because this technology is so new, understanding its development is essential in coming up with a good business strategy. Different technology companies market their technology differently, even using different terms. Throughout the thesis we were unable to find a definite answer to the question of whether or not the technologies were infact different. In the beginning, we understood that there were differences because of terms such as "highly coupled magnetic resonance", "wireless charging", and "induction charging". Throughout the thesis, however, our understanding began to sway to the thought that the technologies were one and the same, with a few small differences. However, we are still not convinced of either side. It's possible that the

[4] Environmental body and safety body entitles authorities, legislative bodies, NGOs as well as other groups.

technology is so new that it is difficult to compare the actual working technologies, or that, because the technology is so new, companies will not divulge information to make them comparable with others. The following is what we were able to put together from the research and interviews we carried out.

Inductive charging works by creating an electromagnetic field using a coil, and then transferring energy from one coil to another through inductive coupling. In essence, when you run a current through a conductor, an electromagnetic field is created. If another conductor is placed in this same field, the electromagnetic field created by the first conductor can induce a current in the second conductor.

For inductive charging of cars, one of the conductor coils is connected to power and placed under the vehicle in a pad or built into the road itself, and the other is placed inside the vehicle to pick up the energy from the electromagnetic field below the car.

This technology is called magnetic inductive charging, because the magnetic field produced by current flowing in one coil induces a current in the second. Similarly, there is another method of transferring energy called magnetic resonance charging, where the frequency of the magnetic field is picked up by the a receiver, transferring energy. They need to be tuned to the same frequency to resonate and successfully transfer power. It is important to note that the distance from the power coil to the receiver coil is what affects the efficiency in powers transfer.

There are also other methods of wirelessly transferring power, including the use of WiFi, microwave, and radio wave technologies. Unfortunately, these methods of transferring energy are affected by the inverse square law and the energy transfer is far too low to be implemented in vehicles.

Methods of wirelessly charging vehicles can be categorized into two groups, namely static and dynamic charging. In this thesis we only looked at static charging, but we felt it was important to mention the alternatives here. Static charging occurs when the vehicle is parked, while dynamic charging occurs when the vehicle is in motion. There is also a third option being tested in electric buses in the UK and Italy where buses are charged at each bus stop. Seoul, in South Korea, even has fully dynamic roads where buses charge while moving. One of the benefits of developing dynamic or semi-dynamic charging is that it reduces range anxiety. However, because dynamic charging technology does not yet apply to cars, it will not be considered in this thesis.

Static charging can be achieved through two methods, charging through a pad and charging through the air. When using a charging pad, the vehicle must be parked precisely over the correct spot, in order to charge the battery in the car. Typically, the given energy efficiency transfer is around 90%, some claiming even 95% (it is important to know whether this is the efficiency of the energy transfer in the wireless transfer coils, or if it is from the power source to the car batter – companies usually do not specify which it is, so we assumed it was the efficiency of the energy transfer and not the whole charging system). When charging through the air, the physical alignment between the charging and receiving units is much more forgiving than with the pad.

3.5 Safety

Safety is one of the most important focuses around this technology. For us as authors, safety was one of the most important aspects. Because technologies get locked in, meaning that the widespread implementation and use of a technology creates a dependence on it, it becomes very difficult to create a systemic shift away from them (this is one of the problems with fossil fuels and climate change). Assuming this technology would become widely used, we saw the safety of exposure to large electromagnetic fields as a key point when discussing the future benefits of this technology. According to Joel M. Moskowitz of University of California Berkeley, evidence shows that energy/wave technologies that we accept as safe could actually be having strong negative impacts on us every day.

We however, were not the only ones so interested in the safety aspect throughout this thesis. For some stakeholders, safety even seemed to be the most important topic. Safety has many aspects, all of which are discussed in this chapter.

The safety aspect can be separated down into two main categories, with two main methods of addressing safety concerns. The first category is operational safety, where the technology can interfere with other technologies. The second category is the health concerns of being exposed to the electromagnetic field.

3.5.1 Interference

The introduction of a new technology is made easier when it does not conflict with existing systems. It is important to analyze how the frequency used for inductive charging interacts with its environment.

3.5.1.1 Physical Interference

One of the topics of focus is that a physical object may enter the space between the charging pad and the receiver pad. The physical objects would only be affected if they have metal in them: however, they could heat up significantly and even catch fire. This problem is addressed by implementing a Foreign Object Detection system (FOD) to either turn off the field or reduce the transmission power until the object is removed.

3.5.1.2 Other Technologies

Technologies that transmit any sort of energy or information use specific frequencies to do so. These technologies must remain unaffected by the strong magnetic fields of the wireless charging system. This problem is addressed by choosing the appropriate operational frequency for energy transfer of the wireless charging system, making sure that it does not interfere with the others. All technologies decided to use the 85kHz range, while Siemens decided to use 145 kHz.

3.5.1.3 Pacemakers

This technology is singled out as a very specific operational and health risk. Pacemakers may be affected by the strong electromagnetic fields, resulting in dire consequences for the user that depends on it. The field may impact the pacemaker’s functions, which keep the users heart beating. This problem is being addressed by shielding under the car, ensuring that the field is not strong enough to affect the pacemaker in the areas a person can physically be (in the car, around it).

3.5.2 Health

The effects of electromagnetic fields (EMFs) on the human body are mainly decided by the frequency and strength of the field. At low frequencies the field will pass through the body, while at higher frequencies the body will absorb parts of the field.

The energy absorbed by the body at high frequencies will usually only enter the outer tissue. Absorbed electromagnetic energy, from fields over 100kHz, creates movement in the molecules, generating heat. At lower frequencies, the electromagnetic field induces circulation in the body. This circulation will, with adequate strength, also create nerve stimulation. Nerve stimulation can affect nerve signals, muscle activity, and cardiac muscles. [25][26]

The frequency[5] for wireless charging is between low and high frequency, meaning that it normally would not be classified as likely to cause heart- and vascular disorders or even be carcinogenic. [27] However, agencies such as the IARC (International Agency for Research on Cancer) and WHO classifies magnetic fields as possibly carcinogenic - research links exposure to alternating magnetic fields, exposure over normal levels of 0,1µT during childhood), with an increased risk of leukemia. [28] The warnings around EMFs is a result of the high degree of biological viability and multitude of EMF parameters, making it difficult to reach undeniable conclusions regarding effects on human health. [29]
However, our research found that it is unlikely that magnetic fields can cause heart- and vascular problems. The reference values are 1/15 of the value where negative health effects have been seen.

3.5.2.1 Short Term

The short-term health effects are the effects that the strong electromagnetic field can have on a person. One of these effects is nerve impulses caused by electrons being moved in the body. This could make people twitch and move in a sudden and uncontrolled manner. Another effect is if a person or animal gets in between the charging pad and the receiver. This could significantly heat up the person and result in burns or even death. To address this issue, Living Object Detection systems are incorporated into the wireless charging technology to detect living beings and decrease or stop the transmission of energy. The health effects are addressed in similar ways as the pacemaker issues, i.e. by containing the field strength in the charging area. (Not all companies have done this – the Plugless Nissan Leaf and Chevrolet Volt systems are placed in the rear of the car where it is very easy for someone to place their feet in between the charging pad and receiver, or for children to unknowingly reach in between to recover a ball, for example).

3.5.2.2 Long Term

The long-term health effects are unknown. The 85 kHz and 145 kHz frequencies used for wireless charging have not been studied much, likely due to the very same fact that makes them available for use – no one has used them before. However, several researchers such as Joel M. Moskovitch, from the University of California Berkeley, argue at the completely ignored negative health effects of fields and wireless energy and information transfer (such as WiFi). Because the link between the technology and effect can be hard to correlate, they are often ignored. Another reason is that the research that goes into these technologies is usually carried out by parties trying to show the safety in order to sell the technology, and therefore they dismiss the likelihood of long term effects in order to sell their products.

3.6 System Expansion

An important aspect that may not necessarily be obvious is the infrastructure needs of using a wireless charging pad. The pad's energy consumption significantly increases household consumption. Therefore, it is important to look at how a whole system could be affected by the implementation of this technology.

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[5] Frequency dictates what the field will affect, while the field strength impacts how severe the effect will be.

Average household electricity consumption varies significantly from country to country. Therefore, the percent change in household energy consumption will also vary from country to country. Also dependent on the country is the energy grids capability of accommodating this increase in electricity transmittance. The energy grid in Sweden is fully capable of accommodating electric cars for the whole population, while in the US, the energy grid is old and would need complete rebuilding. This also means that different markets have different opportunities.

To see impacts on energy usage, the next rough calculations show the percentage increase of electricity demand from the grid. For these rough calculations we assumed that an electric car has a battery of 20 kWh, that a Plugin Hybrid has a battery of 4 kWh, and that the battery is fully recharged every day. [30]

US average residential consumption per year is 10,837 kWh per year [31], which comes out to 29.69 kWh per day. This means that an increase in household electricity consumption of 20kWh (an EV) would be an increase of 67%. A PHEV would increase household electricity consumption by about 13.5%, but the total energy used would be larger because they would be using fossil fuels as well as electricity.

In Europe in 2009, the average household electricity consumption was roughly 1.5 toe, or 17.5 kWh per household. This would mean that household energy consumption would increase by 114%. [32] A PHEV would increase household electricity consumption by about 22.8%, but, similarly to the US, the total energy used would be larger because they would be using fossil fuels as well as electricity.

In China in 2011, the average electrified household used roughly 1,300 kWh per year, or 3.56 kWh per day. [33] A PHEV alone would more than double the electricity consumption of the household, and an EV would increase the consumption by 560%.

It is important to note that the less energy households consume, the better for the environment, but the more EV or PHEV use will affect their consumption. Also, the influence of EVs on energy use change is much easier to see because the energy source switches from fossil fuel to electricity, while the energy used in a PHEV is mixed. In most countries, using an electric car is still theoretically using a car that runs on fossil fuels because energy generation is reliant on fossil fuels. However, power plants that use fossil fuels are much more efficient and easier to regulate than combustion engines in cars. Additionally, many countries are increasing their renewable energy production, which would seemingly make EVs zero emission vehicles. In the strict sense of the meaning, this is not true because even if the cars use electricity from solar panels, the materials from the solar panels required some fossil fuels to be made. Therefore, no vehicles will be actually zero emission until the whole system has phased out fossil fuels.

3.7 Product Comparison

A key aspect when evaluating a new technology solution is benchmarking the technology solutions against each other. This allowed us to compare different companies from a different angle – their products.

The inductive charging market is increasing, in terms of suppliers. This makes it even more important to understand the differences between possible suppliers. Even though the principle and base technology is the same in all technology solutions, the networks and market dynamics make one choice better than another. The charging units of each company are built and operated in different ways, adding another angle of analysis.

The importance of understanding the current market for one's product is equally important as understanding the market situation for developing a solution. Hence, below is a comparison of the current EVs and PHEVs on the European market, displayed in table 3 and 4. The tables below are extracts from the full tables we have compiled, available in appendix 9.2 and 9.3.

Table 3 – EV car values, European market

EV's Europe							120 V	240 V	Wall-box		
Company	**Price €**	**Performance (Hp)**	**Torque (Nm)**	**Battery (kWh)**	**Range (km)**		**Charging Time (h)**			**Top Speed (km/h)**	**Acceleration 1-100km/h (s)**
BMW i3	30 493	170		18,8	160	190	7	4	3	150	7,2
Citroēn C-Zero	32 055	67		16		150	8		6	130	15
Ford Focus Electric	37 585	143	249	23	122	122	18-20	3-4.		135	
Mia Electric			58	12	125	129	3-5.			100	
Nissan Leaf Visia	26 101	107	254	24	117	135	20	8	4	150	11,9
Nissan Leaf Acenta (Tekna)	29 745		254		100	182			4	143	11,9
Renault Fluence Z.E.	57 166		226	24	160	185	6-9'			135	13,7
Renault ZOE	16 636	88	220	22	150	210	4-16'		2-8'	135	13,5
Tesla Model S	54 720			60	335	370				177	4,4
Tesla Model S	62 400			85	426	483				209	6,5
Volkswagen e-Up!	29 578			18,7		160	9			130	12,4
Volvo C30 Electric			220	24	150	170				130	

Table 4 – PHEV car values, European market

PHEV's Europe					120 V	240 V			
Company	**Price after policy**	**Battery (kWh)**	**Range (km)**		**Charging Time (h)**		**Efficiency (kWh/100km)**	**Top Speed (km/h)**	**Electric range (km)**
BMW i8		8	483	600	<3			250	35
BMW i3 extended range		18,8	340					150	
Chevrolet Volt	43 698	16		500		4	13,5	161	80
Mitsubishi Outlander	44 353	12		800		5			50
Opel Ampera	42 135	16		500		4	13,5	161	40-80'
Toyota Prius Plug-in	35 702	4,4		870	1,5			180	16-24'
Volvo V60 Plug-in	57 673	12		500	3,5			200	50

By studying the current EVs and PHEVs on the market, one can conclude that the charging time differs depending on the type of charging. However the same type of charging, e.g. wall-box, have similar charging time for the different brands. The ranges of PHEVs are quit even between brands, while for EVs Tesla has almost double the range compared to other brands. The average range of the EV is approximately 150km per charge, excluding Tesla, which is more than enough for ones daily average traveling distance of 43.5km. [34]

4 MARKET PERCEPTION

A key aspect when developing a business plan, especially a sustainable business plan, is to understand the perspectives of the current market in order to correctly assess the market needs and create the right value. One of the overall market perspectives of sustainable business models is that companies believe that a sustainable business plan is more costly, and so they are less likely to use one. Therefore, it is vital to locate concrete key points that prove the benefit of using a systems approach in business, one that would improve both the economic aspects and the environmental and social ones.

In terms of the technology itself, wireless charging is slightly less efficient than plug-in charging and is perceived as expensive, but still it would be marketed as a product that provides additional value. Fast in Charge, a EU funded wireless charging project, believes it creates "additional value in terms of user comfort and elimination of electric shock vulnerability." [35] Overall, wireless charging is believed to be on the verge of commercialization for private passenger vehicles, a technology that would be implemented in the next few years.

This section aims to give the reader a feel for the different stakeholders involved in the development and implementation of the technology.

4.1 Stakeholder Perspectives – Overall Picture

Implementation of a new technology solution in the current market may modify the perspectives of stakeholders.

The most positive perspective regarding inductive charging, and the one whose voice is heard the strongest, is the one of tier 1s and 2s. They believe that wireless charging is the technology that will enable the shift from combustion vehicles to EVs and PHEVs.

These voices are somewhat balanced by the OEMs, one of the stakeholders that, in our opinion, is more cautious regarding their opinion on wireless charging. They are eager to gain knowledge about the technology, and see its development but maybe not yet be ready to fully support the technology shift.

Somewhere in-between, there appear energy companies such as Vattenfall. They publicly support the technology and believe in its possibilities. They are however not pushing for it to happen, but rather considering how they can expand their market in this direction if it were to develop. The only energy companies fully opposed is fossil fuel companies, but they are opposed to the shift to electrification rather than the wireless charging technology itself.

The stakeholder group that has the most diverse opinions is researchers/consultants. On one end, they agree together with tier-1 and -2s that the technology will be a change agent for EVs [35], while others believe the exact opposite. There are also researchers/consultants, such as University of Canterbury Lecturer and CTO of an electronics company Hamish Laird, that don't see the technology as the only option, and not even the option to take. They see the limitations of the technology and believe that overcoming them might be benefit other technologies more. [37]

Counter-intuitively, the stakeholder group with the most power, consumers, barely has an opinion on the subject. This is most likely attributed to the fact that they don't have the knowledge or information needed to form an opinion.

4.2 OEMs

The perspective of the OEMS on inductive charging is a positive yet cautious one, when talking about wireless charging becoming the charging standard. Not knowing which technical aspects of wireless charging will become standard is keeping the OEMs reluctant in fully supporting the technology, because no company wants to put money and effort into a technology that will "lose".

However, because they see the possible benefits of the technology (often likened to keyless entry option, a technology that eased the unlocking of cars for consumers), they follow and work together with technology development. In the eyes of OEMs, inductive charging will appeal to the comfort-seeking side of customers. Not having to remember to charge your car, no cord handling, and no refueling of the car (for EVs) are all factors that would alleviate many inconveniences associated with an electric car. It is also seen as a solution for consumer range anxiety regarding EVs, [38] because a major focus of OEMs is to make EVs and PHEVs more in line with the traditional combustion vehicle, specifically regarding "refueling," namely its efficiency and range provided. [39] The technology is also seen as a possible enabler for increased EV and PHEV sales, giving hope to electrification because it is still only a very minor part of the car market despite its rapid growth.

The interest of OEMs for the technology is evident through their participation in the standardization work going on at SAE International, the Society for Automotive Engineers. It must be said that the motives behind the technology interest is that of business rather than responsibility for the environment.

4.3 Tier 1 and Tier 2

The stakeholder group that acts as the main driver for the development and implementation of this technology is the developer of the technology and those producing it, otherwise known as the tier 2s and tier 1s, respectively. The two were grouped together because of their linked business interest and relationship to others in the constellation.

This stakeholder group sees wireless charging as an enabler for a market shift and possible first step towards dynamic charging. Key benefits focused on are: convenience (drivers don't need to physically plug-in their cars), aesthetics (no more visible wires or charging towers), and improved reliability (less exposure to weather and handling issues). [40]

Siemens, a tier 1, sees (and sells) wireless charging as a technology that eliminates the need for cables. They present the technology as an easier way to charge a vehicle, "no more manual intervention needed to charge the battery." [41] It is seen as a time saver and enhancer of driving pleasure.

However a perception is that tier 1s, such as Delphi, Lear and more, are more cautious than Tier 2s and are being pushed by the Tier 2s. Tier 2s are technology developers and have invested in the technology, so it is clear they want their investment to have results. The reluctance of Tier 1's comes from the fact that they are technology integrators, and they have to combine the needs of OEMs and Tier 2s, instead of just pushing for sales – they need to know that what they invest in will sell on the market, while Tier 2s are simply convincing Tier 1s that it will.

One of the tier 2s, Qualcomm Halo states that wireless EV charging meets consumers' needs and increases the multiplicity of charging opportunities. Their points are summed up below:

- *Wireless EV charging meets our needs*:
    - Simple, effortless & convenient
    - Automatic hands-free charging
    - No cord to unplug or steal
    - Unaffected by water, ice, and snow
    - Simple to package on EVs

- *Multiplicity of charging opportunities*
    - Charge little, often and everywhere
    - Simple to deploy: no street clutter
    - Encourages intensive charging infrastructure
    - Reduces battery size and EV costs

A common statement, and viewpoint, of developers is that "humans are lazy and if there is a technology that lets us do less we use it". [38]

WiTricity, another tier 2 company, promotes wireless charging by saying it gives OEMs the ability to redefine charging for all existing and future electric- and hybrid vehicles, at a variety of charging points. WiTricity and Qualcomm, as well as a few other companies, see the charging of the car as a stepping-stone to using the technology to also wirelessly charge electronics inside the car, like a mobile phone. [42]

4.4 Customers

Essentially, the customer experience is the one that drives business. There are two methods of creating a customer experience. One of the methods is to cater to customer needs and wants, while the other one is to create customer's needs and wants. Regardless of which method is used to sell the product, the customer must ultimately feel that he or she wants or needs the product for the business to succeed.

However, in the case of wireless charging, the view of consumers is based not only on their view of the technology, but also on their view of EVs and PHEVs in general. The success of the wireless charging technology in cars depends on people being interested in EVs and PHEVs.

The Flanders Drive report concluded that charging via a cable is still preferred over inductive charging, and that inductive charging is just seen as an optional extra at the moment. The knowledge about and openness to the technology seems to be growing, because the report also stated that 64% of consumers would consider wireless charging as a possibility. However, currently only 37% preferred inductive charging to cable charging (see figure 10).

One of the reasons is that people are afraid of a lack of infrastructure and a lack of standardization, in addition to their range anxiety connected to EVs and PHEVs. The fear of losing range, as a result of forgetting to plug in the vehicle before the journey, is minimized by the implementation of wireless charging. [43]

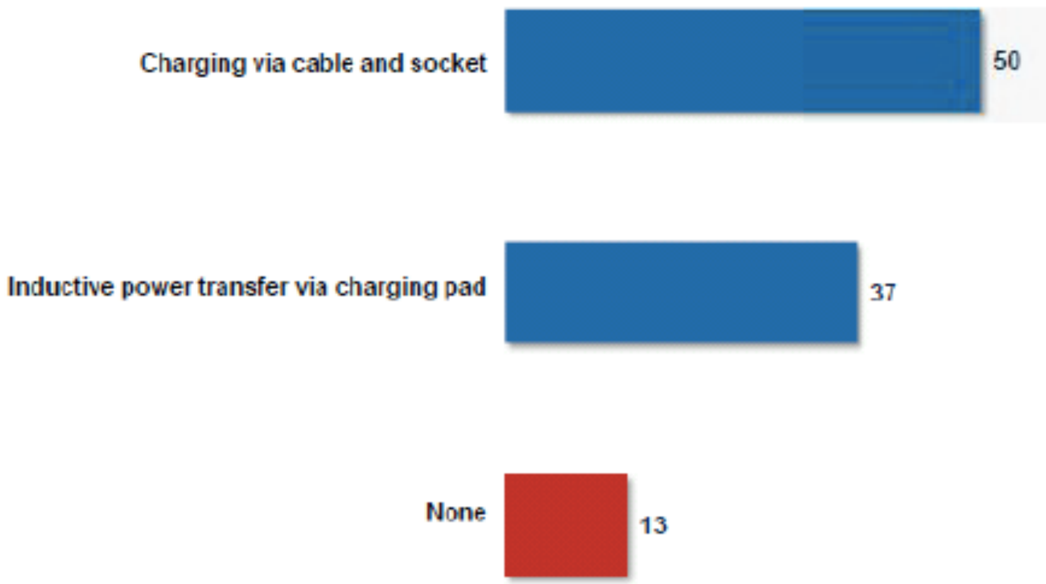

Figure 10 – International view on preferred charging technology [43]

Market predictions carried out by Navigant Research show how the interest of wireless charging is expected to increase exponentially in the next couple of years. The result is demonstrated in figure 11.

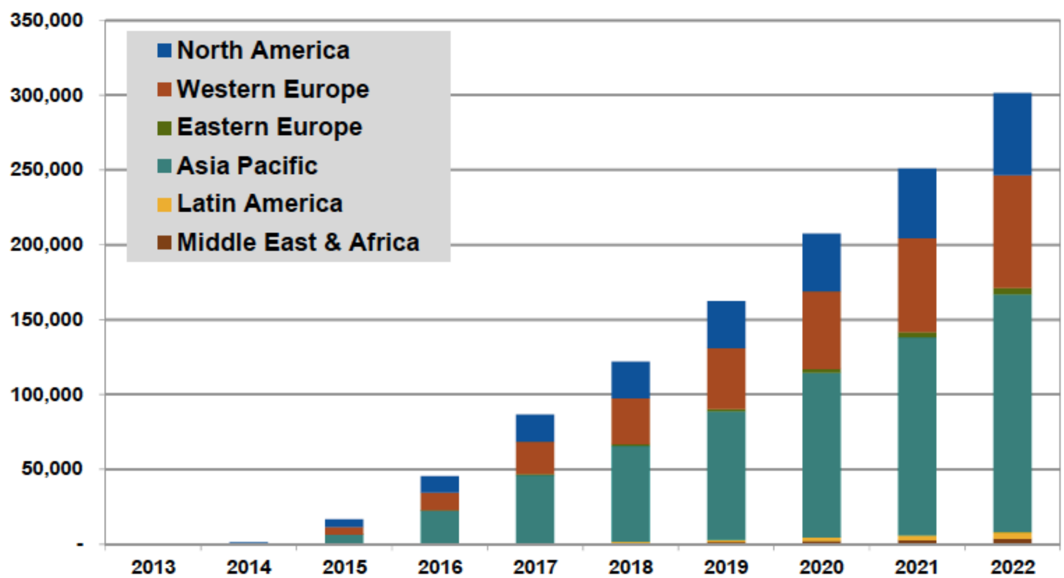

Figure 11 - Wireless EVSE Unit sales by region, world markets: 2013-2022 [45]

4.4.1 US Customers

The US customers are, at this moment, the only ones able to buy a working wireless charging unit and have it installed in their car, thanks to Plugless Power, a US-based wireless charging company. Despite the recent establishment of the company, its yearly revenue amounts to $430,000 [45], an indicator of the interest of the technology among American consumers.

American customers are seen as the ideal start consumers, by developers, researchers and industry representatives, because they have the infrastructure of private parking and a behavior of buying add-on features to their vehicles. The US customers seemed to be the most enthusiastic about EVs and PHEVs, while interest in other regions seems to be a result of beneficial policies. Comfort features are popular in the US.

4.4.2 Chinese Customers

The majority of the Chinese population regards EVs and PHEVs as expensive [46], making a luxury feature such as wireless charging even less desirable. Interviews with industry representatives with knowledge of the Chinese market, painted the same picture. The interest of the Chinese population and government lies in a cleaner environment and an infrastructure that enables the possibilities of cleaner technologies. The shift towards EVs and PHEVs stems more from a concern about the environment and wellbeing of the nation, rather than personal comforts. Even though wireless charging is considered an enabler for EVs and PHEVs, this may not apply to the Chinese market. Chinese cities are very congested, and people cannot find a parking place. In order for Chinese customers to see the benefits of the technology and be willing to pay for this extra feature, the basic needs of cars in general needed to be addressed, i.e. charging infrastructure and parking places. [47]

Nevertheless, Pike research indicated that largest market for wireless charging stations will be in the Asian pacific, of which China is a part (figure 12).[6] [48]

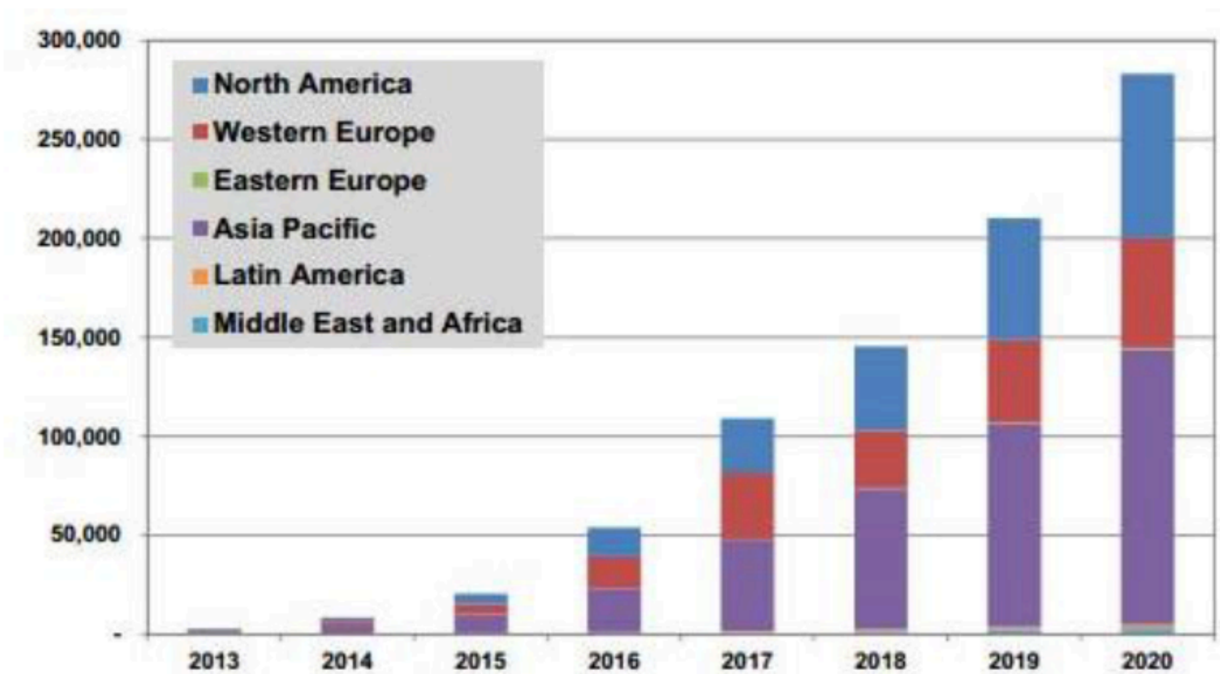

Figure 12 – Wireless Power Systems for EV Charging by Region, World Markets: 2012-2020 [48]

[6] It must be noted that this data does not specifically mean that China will have a large market – Japan and South Korea are very interested in wireless charging technology. However, China is now the largest car market on earth, and with the environmental problems and resulting policies, the shift towards electrification of vehicles in China is evident.

The perceived interest of the Chinese market, is mainly a result interest of the wealthy part of the society.

4.4.3 European Customers

A survey conducted in the Flemish parts of Belgium, concluded that the preferences of charging depends on the charging situation (see figure 13).

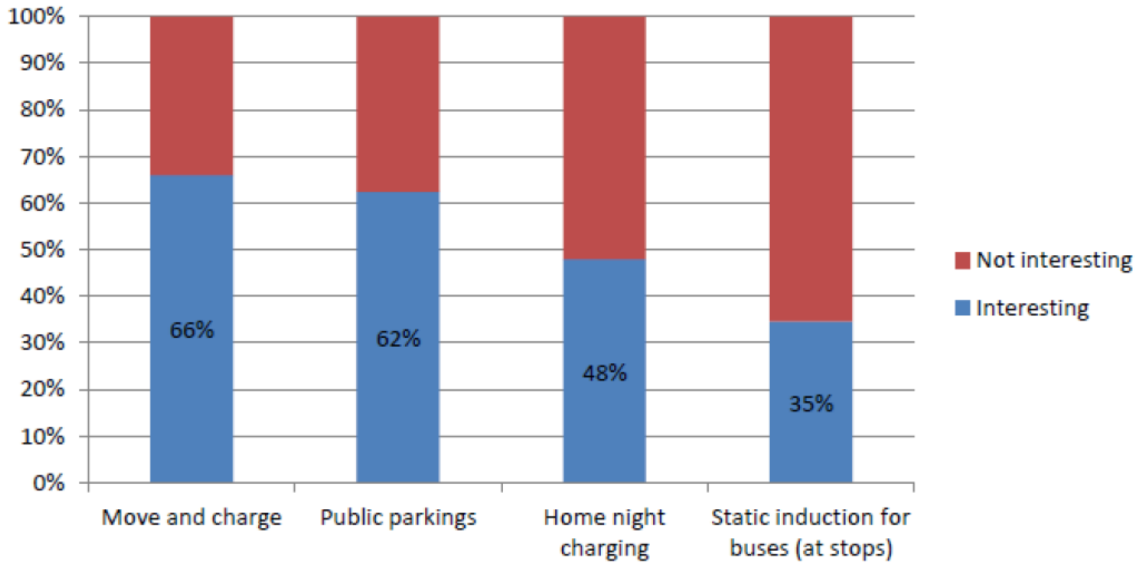

Figure 13- Flemish interest in wireless charging according to situation [43]

The results showed that the biggest customer interest for wireless charging is "move and charge" and public parking. The survey's results are a good indicator of the European customer's perspective on wireless charging – a high interest in dynamic and public charging. This goes in line with purchasing trends of EVs and PHEVs in Europe – they are clearly a result of public policies and subsidies.

4.5 Society/Governments

The interest of society and governments in wireless charging is founded in their interest in EVs and PHEVs in general. Governments and society want to improve public good, of which cleaner air is a very important part for the economy, society, and environment.

The increasing interests of governments and societies in reducing social and environmental costs and damages have lead to a series of incentives and legislations regarding clean transportation. These policies also have their limits, making space for other solutions to also shift society to electrified transportation. This helps promote technology solutions that will enable for cleaner vehicles to take a larger market share.

Wireless charging is one such technology, because it is believed to increase the usage of the electric drivetrain in PHEVs, and makes EVs more desirable. The technology also enables the possibilities for dynamic charging to occur, in the future. Dynamic charging is built on the same principles as wireless charging, but instead of standing still you charge while driving. This increases the range of EVs and PHEVs without the use of larger batteries.

Governments, experts, and industry representatives have come together with the IEEE (Institute of Electrical and Electronics Engineers) to develop some preliminary standards for the technology. The standards for wireless charging is developed by the governing body SAE, working group J2954. [49][50] The working group is composed of governments, experts, and industry representatives. On the global market, the standards set by SEA are the ones that carry the most weight. [44] The standards that exist at the moment are: [51]

- ISO/IEC 61980
- ISO/IEC 15118
- VDE-AR-E 2122-4-2-
- SAE J2954

The need for standardization is evident – companies, customers, and infrastructure developers would feel more comfortable investing in a technology that is integrated into a larger system, reducing the chance for it to become obsolete.

4.6 Hurdles

Implementing a new technology, or a new solution to an old technology, has its hurdles. The hurdles differ depending on market, product, and the maturity of the technology.

Most hurdles regarding wireless charging are, however, directly related to EVs and PHEVs, and are therefore documented in previous chapters. We also used historical knowledge of technology competition and market niches to enrich our understanding of overcoming hurdles for the development of our sustainable business case.

4.7 Public Acceptance

Public acceptance is very important in the success of a technology, although it is of course possible to guide public perception.

Wireless charging technology is not just competing on technological or physical characteristics, but also on public image. Currently, the public image has not yet been formed, or is very limited, because the technology is so new to the market. One of the main limitations for wireless charging, when it comes to public perception, is the possible health effects. In the last decade, the public has become increasingly aware of environmental health issues, especially when it comes to diseases and health conditions such as cancer, severe and lingering pain, and disabilities. [52]

The public's perception regarding wireless charging and usage level is directly influenced by their perception of electric vehicles. An undesirable view has developed on the global market, an image of EVs and PHEVs being too expensive, their limited range hindering daily life, and demanding charging procedures complicating daily life. This image persists even if an EV exceeds the average driving range of customers and subsidies reduce the price.

The OEMs going for wireless charging have to not only sell the technology, but also change the minds of reluctant customers who are uneasy about electrified cars and charging in an unconventional way.

The Flanders Drive report concluded that some of the weaknesses of wireless charging, in the eyes of customers, are: higher installation costs, lower energy-efficiency, and safety aspects. [53]

4.8 Resource Limitations

The world's resources are limited, a fact that needs to be taken into consideration when implementing a new technology. Resource limitation can be a very hard hurdle to work around, sometimes even requiring the development of new materials.

Wireless charging units are mostly composed of magnetic coils, coils usually made out of copper. Copper is a resource with high demand, yet it is often assumed to be abundant. However, copper is thought to be used up in the coming 25 years. [54] This is mostly due to the high demand, from developing countries such as China. At the moment China stands for 40% of the world usage. [55] The high dependencies on copper have made China prepare for a copper depletion. [56] This high demand and usage of copper indicates that a dependency on the material is a possible bottleneck/hindrance.

Therefore, although we did not assess the resource limitations of all the materials in the product, because of a lack of time and access to specific information about the technology, it is safe to conclude that resource limitations need to be considered when looking at this new technology.

4.9 Complexity Limitations

One of the limitations to wireless charging, according to researchers, is the level of complexity of the technology. The complexity does not lie in the technology itself, but in the production and extra technology needed to make it as efficient as possible. This will further increase the price of the technology. [57]

As described in the technology chapter, the basic principle of wireless charging is to have two plates close together in order for the transfer to occur. According to Laird, this will put restrictions on the usage of a vehicle. In order to align the pads directly above each other, which are needed for controlled transfer, automatic parking features will be necessary for the correct alignment wireless charging system. For the power transfer to be as efficient as possible, the pads have to be extremely close together, creates a possible hurdle for the technology. The impact of this efficiency dilemma depends in part on the standards set.

Overall, the amount of investments needed to develop wireless charging and make it work as desired may amount to a sum so large that developing other methods of automatic charging, such as automated conductive charging, may be better. [58]

5 A SUSTAINABLE BUSINESS CASE

Implementing a new technology is difficult; implementing an innovative technology can be even more difficult. A business plan is created in order to clarify and strategically set up a market implementation in the best way possible. A sustainable business plan[7] business plan includes social and environmental factors that are normally ignored, and makes the part of the business model.

5.1 Key Aspects

Several aspects of wireless charging its market stood out as factors that influence the system and the business case the most. The following list is comprised of these key aspects:

- Not enough public electric charging of PHEVs and EVs
- Lack of infrastructure – potential infrastructure
- Government initiatives
- Consumer convenience
- Standardization
- Costs
- Technology dependency on features such as automatic parking, FOD and LOD
- A luxury option
- Power companies want to enable control of home electric usage

These aspects cover the main idea of the technology, its hindrances, and main perspective of stakeholders. Some of the aspects are market specific while others are more general.
Global standardization is one aspect that could help alleviate the issues associated with most of the other factors. Setting a global standard would reduce fear for both industry and customers, as well as simplify the implementation of infrastructure.

5.1.1 US Market

The US market is perceived to be the best starting market for an implementation of inductive charging. [59] This is a result of the US social infrastructure, where the majority of the population lives in private houses with private parking, a requirement for the installation of a charging station. [60]
Still the US market has its limitation, such as no charging infrastructure at the moment, and a serious grid limitation. If the American population all came home after work and "plugged-in" their cars, while also turning on all household appliances as usual, a huge extra load would be put on the grid. This load would crash the grid, and, in order to prevent this, it must be understood that the US energy grid needs to be rebuilt for electric cars to be popular and used on a wide scale. However, the US energy grid needs to be rebuilt to accommodate renewable energies, and therefore this limitation may become obsolete in the future [61]. A national energy grid takes time to rebuild, and therefore this is likely more than a short-term limitation.

Even though the US grid may have limitations, the citizens seem to be the most enthusiastic and willing to purchase electric cars. The US market is at the moment the largest EV market, with its

[7] Sustainability is a business strategy that drives long-term corporate growth and profitability by mandating the inclusion of environmental and social issues in the business model.

beneficial housing infrastructure and subsidy benefits. Subsidies and tax benefits can decrease the price of an EV or PHEV by up to $7 500.
Companies will only sell the technology if it makes a profit for them. As stated in chapter 3.2.2, customers would be willing to buy the car for $26 000 (so companies willing to sell the car for $33 500). Therefore, if the price of the car and the wireless charging unit adds up to less than $33 500, the company will be able to include a luxury option in a price that customers would be willing to pay.
The target customer on the US market is the commuter, one who has a private parking space at home where it is possible to install a wireless charging station. Customers living in areas with sustained sunshine would have the possibility of charging their car using solar energy, which would allow for virtually cost-free charging after the installation of solar panels.

In order to summarize the key aspects, they are listed below:

- Have an infrastructure that eases implementation of wireless charging technology
- No public wireless charging infrastructure currently exists
- Grid limitations
    - Grid being rebuilt in e.g. California
- Largest market for EVs → Private houses
- Subsidy benefits
    - Companies can manage to sell their cars with wireless charging for a price customers are willing to pay
- Target wealthy homeowner commuters (charge at home and at work)
    - Especially California, which has specific policies aimed at increasing EV and PHEV sales
    - Run on solar electricity
        - Solar panel prices are decreasing, while fossil fuel prices are increasing (the oil is more and more difficult to extract)

5.1.2 Chinese Market

The Chinese market is a quick shift market, in the sense that a drastic change can occur quickly if the government decides to make changes. However, selling EVs and PHEVs is difficult on the current market because there is no infrastructure to support a market shift. What exists is social infrastructure consisting of skyscrapers and apartment buildings, with limited places to park. The question of finding a private parking space in the city is more or less irrelevant, and therefore wireless charging is impossible without addressing this serious issue [62]. However, the Chinese market and consumption pattern is highly affected by government influence, so if the government decides to switch to EVs and PHEVs, a fast shift could happen. Infrastructure will be quickly developed and customers will purchase EVs and PHEVs, likely purchasing the wireless charging option for convenience.

One of the main influences of the Chinese market is the increasingly polluted environment, creating a need for environmentally friendly products. Citizens of larger cities can feel the impact of increased levels of pollution - sometimes they are not even able to see the sun because of the thick layer blanketing the city. The environmental effects have started to create not only negative health effects, such as short term and long-term respiratory problems, but even economic impacts.

The Chinese government has developed incentives and subsidies in the last few years, in an effort to promote and subsidize EVs and PHEVs and to attract more customers towards green vehicles. [63] Furthermore, evidence for the government's commitment to a cleaner environment lies in its expansion of renewable energy power generation. Regardless, customers still prefer combustion vehicles rather than PHEVs or EVs. Perhaps developing public charging infrastructure would successfully encourage drivers to purchase EVs or PHEVs because they will have a place to charge (maybe the spots could even be reserved for EVs and PHEVs).

The key aspects of the Chinese market are listed below:

- No charging infrastructure (for both cords and wireless)
  - No place to park, makes it difficult to have private charging
- Government is pushing for green vehicles
  - Health problems have an economic impact
  - Push for green energy
- Subsidy benefits
- Government influence → what they say goes
- Aim for the car to be government car that uses wireless

A key aspect when discussing the Chinese market is, as stated above, government influence. One strategy for ensuring sales is by becoming the official car company of the government, like Audi was in 2012. Being the government's official car supplier guarantees sales and increases market opportunities: the car becomes the car of the people, it increases sales, and improves company visibility and popularity. The government spends up to $12 billion yearly on official vehicles, creating a very sizeable market. [64]

5.1.3 European Market

Europe is what we consider a reactive market – a market that will follow others but not be the first one to take the step. This description is accurate with regards to the European market's approach to wireless charging.

The European market lacks charging infrastructure, but it matches the basic needs for establishing it: social infrastructure in the form of private parking (regardless of housing situation) and good possibilities for public parking. This improves the possibilities for developing charging infrastructure to be developed and implemented in Europe. The process has already begun, and charging infrastructure is being implemented around Europe to provide good access to electric outlets near parking lots. [65]

A key aspect regarding the European market is the interest of the European commission to have low emitting vehicles on the road. This interest has created CO_2 restrictions for vehicles and increasing fuel prices, at a rapid pace.

Many countries in the European grid, such as the Swedish part of the European energy grid, will be able to handle the increased load on the grid without a problem, meaning that all vehicles could switch to electric drive without a need to rebuild the grid. The grid system is capable of producing more energy than it currently produces. [66] It must be added that it is difficult to assess the European grid in its entirety because not all countries are as developed as Sweden with regards to the energy grid.

Some countries have developed in such a way as to make electric vehicles even cheaper to use. A significant rise in the interest for renewable energy has created many renewable energy installations throughout Europe. This enables cheap charging of EVs and PHEVs: for example, private solar panels on roofs in Germany would allow consumers to charge their car for free because the solar panel produces more energy then used by the current average household.

One of the main obstacles regarding the implementation of wireless charging for EVs and PHEVs is limited subsidies. To be more precise, subsidies in Europe are country based and most of them are low or in the form of incentives. The incentive of road tax relief is the most common throughout Europe, which only allows people to save money in the future (it does not help them purchase the car), while subsidies are usually time-limited. This creates waves of sales rather than continuous sales and constant interest.
As a result, the high prices of EVs and PHEVs means that the target customers will be wealthier homeowners.

The key aspects of the European market are listed below:

- Lack of charging infrastructure
    - Available infrastructure for the implementation of wireless charging
- Developed grid in Europe, for example in Sweden
- High fuel prices
    - Implementation for renewable electricity → cheap charging
    - Private solar panels on roofs → free charging
- Subsidies do not necessarily extend into the future, hard to plan for companies
- Wealthier homeowners, families with two cars (one for long trips, one city car)
- Climate temperatures conducive to efficient battery use

Another user benefit of inductive charging is the fact you do not need to handle a charging cord in snow, rain, or cold weather. This is especially true in the northern parts of Europe, even though the weather conditions will not negatively effect the efficiency of inductive energy transfer. [67]

5.2 Aspects to Problem Solving

According to Hans-Göran Milding, from the Product Planning of Electrification Division at VCC, the two most important factors for successfully implementing a technology are technology maturity and commercial viability.

5.2.1 Technology Maturity

In a business case, an important aspect for successful technology implementation is its maturity. One of CEVTs concerns in going ahead with inductive charging is to make sure to reach the early majority instead of just early adopters. According to the Diffusion of Innovations, people are split into Innovators, Early Adopters, Early Majority, Late Majority, and Laggards. Innovators are the first 2.5%, Early Adopters are the next 13.5%, and then starts the Early Majority (see figure 14).

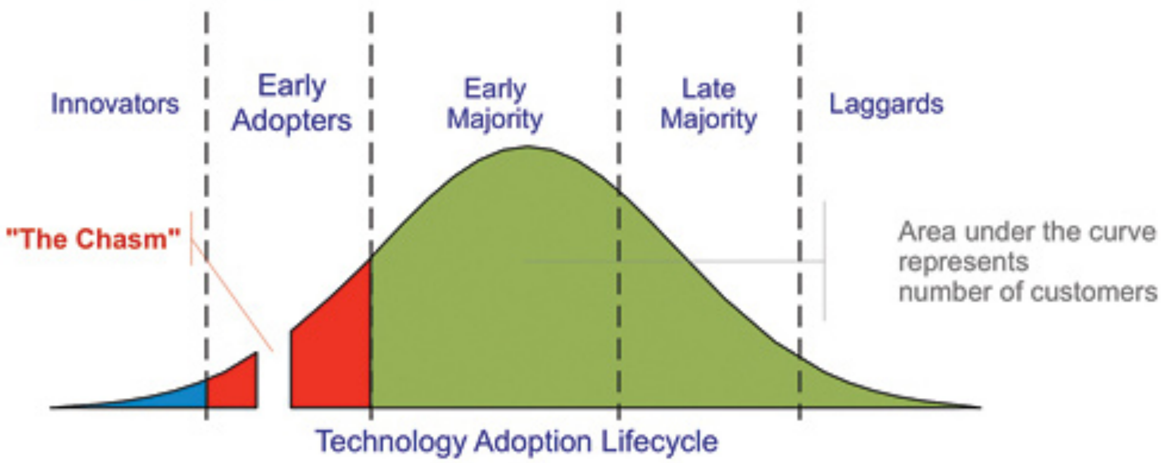

Figure 14 – Technology Adoption Lifecycle [68]

Currently, there is only one supplier selling a useable inductive charging unit on the current market - the market is still very open for technology developers. Before reaching a larger market, the technology needs to become a widely-accepted useable option. For this to happen, the standards for the technology needs to be set, and the effectiveness of the FOD and LOD safety systems needs to be proven. The fact that the technology is out on the market, with some companies investing millions, shows that some stakeholders are confident in its implementation – this is the first step in development of this market.

5.2.2 Commercial Viability

If a technology is developed enough to be used reliably, the next most important aspect is commercial viability. Commercial viability is important for the company to remain financially sound. To preserve the company, its foremost interest is to be financially viable, meaning that its decisions also need to be financially viable. This does leave some room for strategy – perhaps a decision that is not financially viable in the short run is financially viable in the long run. Therefore, commercial viability can be broken down into commercial viability of a product and the commercial viability of the company. The commercial viability of the product takes into account what is directly involved in the product, while the commercial viability of the company includes strategies aimed at gaining competitiveness. From a systems perspective, it is important to see how commercial viability of the product relates to system interactions. The system interactions can show advantages and disadvantages of approaches that may usually remain unnoticed. One fact about innovation is that successful technologies are not necessarily the best technologies, they have just been successfully implemented because of other circumstances. Therefore, seeing how a product plays into the larger picture is more important than just the product, its costs, and other attributes.

CEVT is focused on the commercial viability of the inductive charging unit. Because this technology is brand-new and innovative, it is important to look at shifts in the socio-technical system rather than consider it as just selling another convenience product.
One of the strongest indicators of this possible systemic change or paradigm shift is the wide range of important stakeholders involved. These include power companies, infrastructure and energy grid developers, urban and traffic planners, governments, citizens, and future generations. For instance, renewable energies are increasing at an increasing rate. Therefore, it is important to

include the system perspective to successfully analyze the market and perhaps even adjust the business model.

Long-term business strategies can allow for business decisions to not be commercially viable in the short run because they will pay off in the long run. This allows companies to knock-out competitors and become the dominant force on the market.

5.3 A Sustainable Business Case for CEVT

As inductive charging is an innovative technology solution, the strategy needs to be to develop an innovative business model, both internally and externally.
Out of all the methods of presenting a business plan, we decided that a business model canvas would be the most visual and clearest to understand. The business model canvas is a strategic management tool, consisting of nine categories designated by boxes. Even though the business canvas in itself was not expanded, we were able to fill it out more appropriately and completely because our systems perspective encompassed all business aspects. The categories are listed below.

Key Partners

i. The key stakeholder would be the Tier 1 supplier, perhaps in combination with a Tier 2 technology developer.
ii. A close partnership is necessary to have a well-developed and reliable product

Key Activities

i. Offer induction charging pad and receiver unit for PHEVs and EVs
ii. Activities require private parking, with access to electricity
iii. Activities would benefit from basic infrastructure such as public parking lots with electricity publicly available inductive charging stations (or a place to install a private one away from home)

Value Proposition

i. Customers are attracted by the convenience of the system. They can drive PHEVs and EVs without having to remember to charge it. All they do is drive.
ii. Always full range – never forget to charge
iii. Improving customer comfort (do not need to handle cord)

Customer Relationship

i. The car company helps the affluent customer gain a cutting-edge image.
ii. The relationship with customers will be through company dealers, ensuring a more personalized experience and relationship
iii. Company dealers are already in place (for VCC) and would not mean an extra cost or change in relationship dynamics

Customer Segment

i. The technology is meant for wealthier customers, with a plan to make it available for everyone in the future. The customers charge at home, but in the future public infrastructure will make it possible for everyone to use the technology.
ii. Value of convenience for upper and middle class.
iii. Focus on reaching the early majority.

Key Resource

i. The technology needs private space to set up an induction-charging pad.
ii. A key resource is copper, but also ceramic ferrites at a reasonable price
iii. Access to electricity is crucial for customers, as well as their interest and financial standing

Distribution Channel

i. The customers can be reached through dealers, and the inductive charging system can be installed either during the manufacturing of the car or as an aftermarket system.
ii. The customers are used to the existing channels of company dealers, no reason to change that.
iii. Company dealers are already existing and working, so by using them the cost can be kept down.

Cost Structure

i. The largest material cost for the system will be for the copper coils and specially manufactured magnetic materials used in the inductive charging system.
ii. A significant cost comes from the initial development and production/tooling cost
iii. Cost depends on quantity produced and the take rate of the induction charging unit (will the part be installed after the car is produced – does this require all cars in the production line to be modified even if they will not be fitted with the unit?)

Revenue Stream

i. The customers are willing to pay for increased convenience. If they are ready to pay more for a PHEV, then paying slightly more on top of that to forget about charging will be even more attractive.
ii. €2 200, ($3000), is perceived to be commercially viable [69]
iii. Currently, the only payment method is a one-time payment (for the Plugless unit, an aftermarket product, the only available inductive charging unit on the market). However, payment types for the charging unit need to be developed to match vehicle payment methods.

There are other aspects that the categories do not specifically include, such as market risks. The market risks involved in implementing inductive charging are: picking the wrong technology (no set standard yet), selling the units at too high a price, and both real and perceived health issues associated with the technology. These are factors that companies definitely need to keep in mind.

Because CEVT is a global company targeting a global market, the business model needs to be adjustable to match the needs of each specific market. In order to clearly communicate the attributes of each of the three markets we have researched and analyzed, we have divided the strategies by country. The strategies state the most important approach for each market.

5.3.1 Strategy for the US

The US market is mainly about convenience and selling the how the technology will ease daily life. This means to forget all about charging and refueling, and just enjoy driving. People already show interest in EVs and PHEVs, California has a special plan for having one million zero emission vehicles, and there is plenty of space both private and public to install inductive charging stations.

5.3.2 Strategy for China

The limits of the Chinese market regarding infrastructure indicate that one of the possible best first steps in entering the Chinese market is to focus on sales to the government. This would make the government develop charging stations for its own use, and slowly begin the process of developing charging possibilities for society as a whole and inadvertently expanding the market. By being the official government car, one will secure a sale of up to $12 billion as well as increase product visibility.

Another way to target the Chinese market would be through lobbying for basic infrastructure, such as parking lots with charging possibilities. The government needs to make space for charging infrastructure to even have a chance of making people shift to EVs and PHEVs.

5.3.3 Strategy for Europe

The key approach when targeting the European market is to present the inductive charging as an integrated solution, one that can be implemented with a system providing full control over household electricity consumption and its compatibility with solar panels on roofs. A good approach would be to market inductive charging as free or nearly free, comfortable, especially in winter weather, and promoting environmental customer behavior.

6 Key Points and Conclusion

In order to clarify the key points and conclusions of this thesis, we have decided to rephrase them below for clarification. The same points can be found in the preceding chapters, but perhaps without the conclusions resulting from an overarching perspective that combines them. This chapter represents how we see the situation as a result of studying it for months, while the previous were more of a presentation of the data.

6.1 Analysis

Implementing an innovative technology is difficult; implementing it on a new market can be even harder. Inductive charging is just that, an innovative technology that is being implemented in a new market. Even though this is considered very difficult, the significant majority of experts interviewed for this thesis seem to have the same conclusion - that inductive charging of EVs and PHEVs is the future.

License holders have invested large amounts of money in inductive charging and its development, and they are now pushing for its implementation. On the other side, OEMs are seeing it as a way to increase the perceived value of EVs and PHEVs in order to take a larger market share. Researchers and consultants, however, don't all agree on this being the way to go forward for EVs and PHEVs. Nonetheless, they see the way developers and license holders are pushing for it, possibly indicating future success.

However, stakeholders expressed concerns regarding safety, health issues, standardization, interoperability, and legislation. These concerns are mainly expressed by OEMs and researchers and consultants, and are rather focuses to overcome obstacles, as opposed to worries. The safety and health concerns are founded in the lack of knowledge of the effects of the frequencies used by the technology, i.e. the magnetic fields. Even if magnetic fields as a subject are considered to be well-researched, there is insufficient research on the frequencies used by the inductive charging systems. Because repercussions from negative health effects or safety issues can damage a company's reputation and even the market as a whole, the importance of standardization cannot be overly-emphasized – both a lack of interoperability and favorable legislation are reasons for why companies are unwilling to risk investing in the wrong technology. Choosing incorrectly can mean a loss of time and resources, likely making a company less competitive. A development of standards can reduce these fears by providing a clear direction and decreasing investment risk.

A key aspect regarding inductive charging and possible market approaches is the varying limitations and opportunities depending on the different markets, namely US, China, and Europe. This is important to take into account when selecting the first market to implement the technology. Stakeholders' opinions regarding implementation differ. One approach is to start with the US, especially California (its best market), because it has the necessary infrastructure as well as a tendency to select luxury options, but even more importantly because of a favorable attitude and policies geared toward pushing for EVs to take over the conventional car market. Another viewpoint is to target China, the largest and continuously growing car market in the world. This market is full of sales opportunities, but the lack of infrastructure needs to be thoroughly addressed for sales to occur in the first place.

The relationship between inductive charging and electrification of cars is hard to separate into two. It is possible for customers to purchase electrified cars without the inductive charging solution. However, the likely reason behind purchasing an electrified car is environmental friendliness, but the inconvenience of charging electrified cars everyday makes people not use them as intended. This means that they are actually decreasing the positive impact they were designed to have. Standardization is the focal point at which all problems meet and can be solved.

All interviewees made it clear that standardization is a key issue. They pointed out the importance of interoperability and guaranteeing that the investment will pay off.
Legislation is also seen as very important, both for companies and customers. Companies can be guaranteed worthy resource investments, for example by having some type of long-term guarantee of subsidies, while customers will enjoy benefits such as no tolls or using bus lanes. Although this stands for electric cars without inductive charging, creating public charging spots reserved for EVs or PHEVs with inductive charging systems is another way to increase EV and PHEV sales. One of the significant questions then is, who will invest in this public infrastructure? Will it be governments because it decreases emissions and therefore overall social costs, or perhaps energy companies because they can use this technology to install some form of smart grid systems? Industry sees beneficial legislation as a need for EVs and PHEVs to be competitive on the current market, specifically legislation regarding price and convenience of charging and refueling.

- *General stakeholder conclusion*
    - *Inductive charging is the future*
    - *Standardization, key issue*
    - *Concerns of public need to be meet*
    - *Global market solution needed*
    - *The convenience of inductive charging might boost EV and PHEV sales*

6.2 Putting it into Perspective, the Real Challenge for Car Companies

The current market for EVs and PHEVs has surpassed the feared chasm and reached the early majority in terms of interest - the view expressed throughout this thesis is the possibility of ensuring this shift with the introduction of inductive charging. The technology will likely make EVs and PHEVs more desirable to combustion cars.
Inductive charging is seen as a luxury option that increases the convenience of vehicle owners, but is the idea of increasing convenience for drivers misleading? Market trends and studies on commuting show that people are increasingly shifting away from cars towards the use of public transportation, and that fewer young people own cars or even get drivers licenses. This shift indicates a system shift regarding commuting patterns, a shift needing to be taken in consideration. A shift away from private vehicles would mean that OEMs and the car industry would have to rethink their customer and product. Inductive charging and its perceived added values could have a significant impact on the car market, but what about society as a whole? Car companies currently see EVs and PHEVs as competition with combustion vehicles. However, if car companies only look at the car market, marked by market share, they will not see the overall larger system perspective showing that perhaps it is not EVs and PHEVs fighting for a chance to survive in the world, but rather companies needing EVs and PHEVs to give cars a chance to compete with public transportation. Perhaps the entire auto industry is at risk here!
It is important to once again stress the importance of focusing on stakeholders and stakeholder perspectives. By working together with stakeholders and being aware of their thoughts, one will have a greater chance of having a successful business plan and long-term business strategy.

Understanding the full system is important not only when implementing a new technology, but also to understand its possible development. Interviewed stakeholders have mentioned the relationship between tier 1 and tier 2, and at times even expressed the curiosity regarding the relationships.
By understanding who is supplying who, one can understand the similarities between various technology options, see which ones operate in a similar way, and understand which ones are the most likely to be interoperable. Looking at who supplies who can also indicate which technologies are more reliable – a root technology used by many companies is more likely better developed than one used by only a few. Naturally, this needs to be analyzed because companies can make the mistake of assume a popular technology is better than a less known one.

A common perception in the industry is that inductive charging will increase the convenience of consumers. Inductive charging will allow drivers to forget about charging, and even refueling in the case of EVs. However, is this a desire of consumers? Is it needed? The aspiration to increase the convenience of consumers is founded in the belief that consumers are lazy, that if they have the option of not doing something they will pick that option.
The question remains whether or not increasing convenience by reducing the amount of things needed to be done is sustainable, or even the best option. Inductive charging will reduce the need of plugging in, but is this necessary? Vehicle owners of today are used to refueling their cars, i.e. to drive to a gas station, park, open the lid, fill the tank, put the lid on, pay, and drive away. Having to just plug in a car to a socket when parking at home, work, the grocery store, or public parking, can already be seen as increasing convenience. Plugging in just requires a different way of operating, perhaps even just a change in perspective.

- *Challenges*
    - *Shift in commuting patterns*
    - *Interoperability between suppliers/technology solutions*
    - *Necessity of increased convenience, real or not*

6.3 Conclusion

The key aspects of our proposed business model, regarding the implementation of inductive charging, are enabling-infrastructure, grid possibilities, and resource availability.
Enabling-infrastructure aims to focus on making sure that the basic infrastructure of parking lots is available. Without parking lots, customers will not even consider buying a vehicle, let alone an EV or PHEV with inductive charging.
The electricity grid is a possible limitation of the system – the European grid is developed enough in most countries to adapt to widespread EV and PHEVs usage, while the US grid needs costly rebuilding (the grid needs to be rebuilt to include renewables, so working together with that development can be a crucial strategy in gaining competitiveness).
Resource availability and scare resources affect the possibilities of technology lock-in, and need to be understood thoroughly for a successful investment in inductive charging. A technology dependent on a scarce resource can be a disadvantage from the start, especially if that resource cannot be replaced with another, more highly available one. One such focus material for inductive charging is copper.

Three areas were discovered to be vital throughout this thesis, namely: *importance of system thinking for business, technology and market maturity, and competing for convenience*.
The idea and importance of system thinking in business evolved around the idea of several revenue streams. In conventional business thinking, business is seen as a linear flow where revenues come from sales. By introducing systems thinking, more revenue streams come into play, creating the possibilities of multiple revenue streams for the business. Additionally, the authors conclude that using systems perspective is essentially what could be considered an enhanced market analysis, increasing the understanding of market relationships and likely future outcomes.
A good indicator of the strengths of an innovative technology is the development path of the technology. Inductive charging has been developed by several stakeholders at roughly about the same time, indicating technology maturity and suggesting that the technology is seen as the future.
The technology is not competing simply against plugin technology or even trying to make electrified vehicles more attractive than combustion. It is about competing for convenience overall, which means also competing against alternative methods of transportation. In other words, this technology can play a critical role in deciding the future of the auto industry, not just the technology itself.

Key aspects of the business model

- *Put focus on making basic infrastructure available*
- *Analyze grid development, look for possibilities to collaborate*
- *Make sure to not be locked in to scarce resources*

Key conclusions

- *Importance of system thinking for business → several revenue streams, enhanced market understanding*
- *Everyone sees this as the future → developed at several places at once (technology maturity)*
- *Competing for convenience → important for the future of the car not only this technology*

7 METHOD

The underlying mindset of our thesis is known as systems thinking. Systems thinking is a holistic method of looking at the parts of a system, as well as their dynamic interactions. This helps show indirect effects, as opposed to only direct relationships. As a result, our work had an underlying approach of including everything that would affect a system – we look at the overall picture in all scenarios. Often times this means including extra aspects and then eliminating the ones that are not related in the system: although the system may include these eliminated aspects, it is not important to study them if they do not affect the topic at hand.

In more practical terms, this means that we mapped out all stakeholders, not just the ones included in a traditional business model. This also gave us the opportunity to generalize our results and develop a simplified usable model (see 3.3.1 Constellations). This systems perspective also expanded the business model beyond the traditional relationships, and allowed us to develop a new business model, one that matches its environment instead of selected elements of it. To clarify the complex system interactions, we visualized the relationships as often as possible: this helped us find further research areas as well as see the direction in which the system is developing.

The thesis writing process started off by breaking down the problem into questions and research areas, to clearly define our task. We did this using a mindmap (see Figure 15). The mind map of market opportunities became the basic framework for the start of the thesis and the foundation of the time plan.

In terms of the actual thesis data, we started off by taking a closer look at the technology – we decided this was the factor that held all others together. The implementation of this technology was looked at from two different perspectives. One perspective was to understand the socio-technological changes resulting from this technology, looking at overall impacts on the society and stakeholder interaction. The second perspective was a more practical one, analyzing the technology implementation from a business strategy perspective.

The overall thought-process followed the following logic. In order to look for a competitive advantage, it was first necessary to understand the market and player dynamics, and the technologies involved. In other words, the first step was to focus on researching and gathering information about the technical aspects of the technology and company relationships. This provided us with a systems perspective of inductive charging technology, providing us with the ability to look where and how a company could gain a competitive advantage. This included company aspects such as financial viability and company-supplier relationships, as well as other stakeholders such as government and society. This resulted in an analysis of the stakeholders, as well as their perspectives, perspectives that may not be inherently apparent (such as distrust of a new technology). Building up a map of all stakeholders that could impact the implementation of this technology was time-consuming but necessary because stakeholders often conflicted each other.

It was important to look at the full system and see possible opportunities for gaining competitive advantage. This included both company dynamics, as well as analyzing different markets to see where the technology would likely be more successful. Research was also made in order to understand the structure of the current market interactions, drivers, and hurdles. The gained knowledge, in combination with meetings with our supervisor, showed which type of information was missing and indicated the areas where we needed to do more research.

This lead to one of the key aspects of this report, interviews with key persons within the system, persons such as Dr. Song (*Geely Automotive*), Hans-Göran Milding (*VCC*), Tommy Lindholm (*Vattenfall*), Bengt Axelsson (*CEVT*) and suppliers of the technology, e.g. Qualcomm, Siemens, and WiTricity. The interviews were usually taken down in the form of notes, but some were recorded and then transcribed later.

Before the creation of the business plan could happen, energy was put into researching tools for sustainable business plans and tools for analyzing the system. This third step was to obtain a thorough understanding of sustainable business models. After researching papers of leading experts, it was possible to see how regular business models could be adapted to be more sustainable and incorporate our possible competitive advantages into the already viable business plans. Ultimately, Porters model of the business environment and a combination of Boons, Breuer, and Bohnsack, Pinkes and Kolk was used for analyzing our research material and creating our proposed business plan.

The last step was the compilation of all the work into one comprehensive study that incorporates all aspects. The goal is combine the perspectives into a unified business plan that works both on company and society levels. This last step also ensured a unified report and that the paper was published in two versions: one that included proprietary information for CEVT, and one that included only the publicly available information for Chalmers University of Technology.

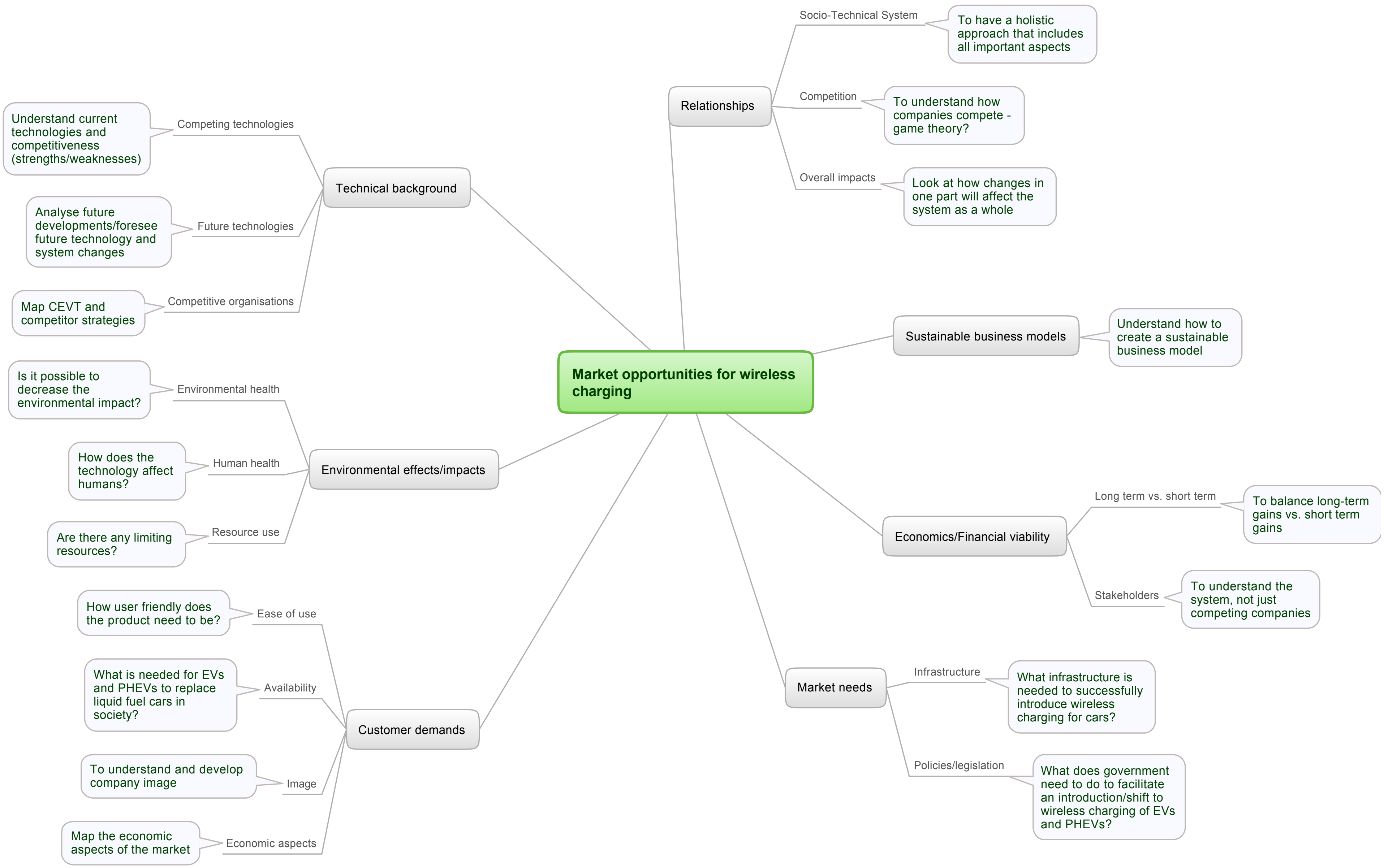

Figure 15 – Mapping market opportunities

7.1 Tools for Analysis

A well-used method for analyzing the external business environment and business strategy is Porters Five Forces Analysis. The framework is comprised of five individual forces that shape the overall level of competition in the industry. These forces are: threat of new entrants, threat of substitute products, bargaining power of buyers, bargaining power of suppliers, and the extent of rivalry among existing competitors.

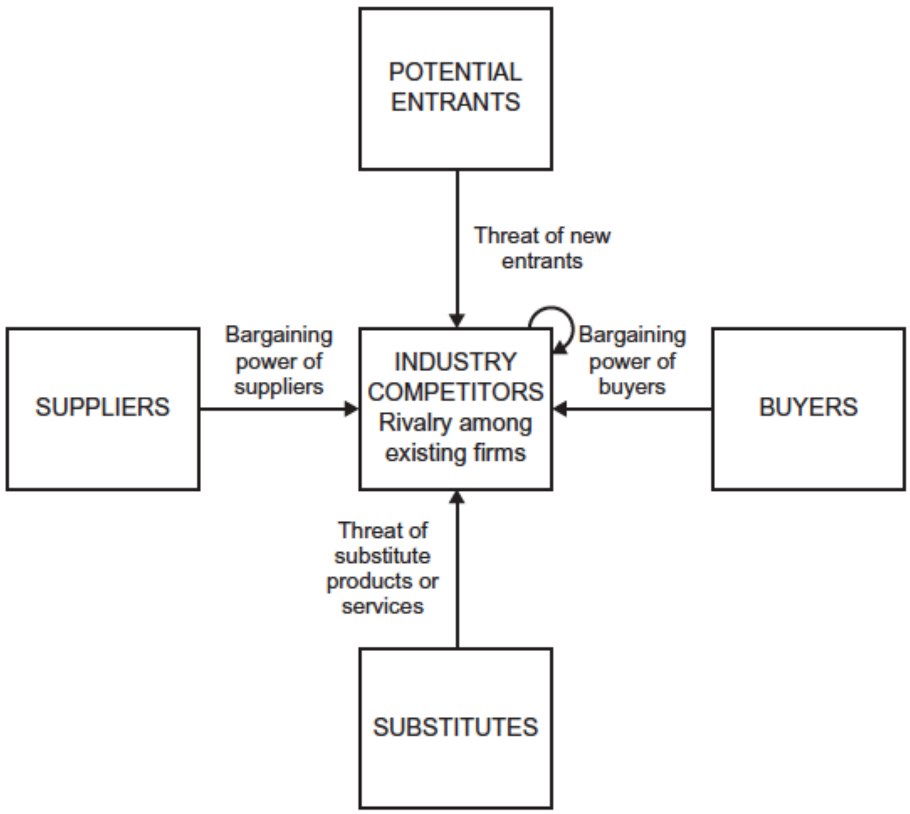

Figure 16 – Porters Five Forces Analysis [70]

The figure, figure 16, visualizes the interconnection between the five categories and their forces; [71]

- **Industry**
  What is the level of competition for the products or services in competitors: this industry? Is the organization in a good competitive position or is it a minor player? Are there several competitors that hold the power in the industry?
- **New entrants**:
  Are there barriers to entry, such as the need for large amounts of money or expertise? Is it possible to start up an organization offering these products or services without much financial support? What is the likelihood of new entrants coming into the industry?
- **Substitutes:**
  What is the range of substitutes available? What is the position of the organization when

compared to the suppliers of these substitutes?

- **Buyers:**
  How much choice do buyers have? Can they switch suppliers easily? Do they have the power in the relationship or are they locked in to the supplier?
- **Suppliers:** How many suppliers are available? Is this a competitive situation where the organization has a choice of suppliers? Do the suppliers have the power in the relationship because they operate in an area of limited supply?

The answers to these questions help to identify the factors that have the potential to impact upon the organization either positively or negatively.

7.2 Limitations/Boundaries

The following is a summary of the limitations of this thesis. CEVT is interested in this technology in the near future, and therefore the time boundary was the next 10-15 years (in terms of business). For health effects and social and environmental change, we used a larger time perspective.

This thesis was limited to static inductive charging. There are two other options, semi-dynamic and dynamic: these were looked at to gain a more holistic understanding of the technology development, but there were not thoroughly studied like the static charging.

One significant assumption is that people will use cars in the future. As technology progress and people shift towards public transportation, the role of the car in the future is unclear.

Another assumption is a continuation of the current perspective on ownership of cars – perhaps no one will own cars, and car sharing will be much more popular.

The last limitation is the time we had to carry out this thesis. We were studying 3 large, very complex markets and analyzing them using a systems perspective. During the interview with Qualcomm when we told them about our thesis, they wished us good luck saying, “We have a whole team working on this full time.” This really captures the enormity of this thesis. Although the conclusions may seem short and simple, understanding the whole system and breaking it down into simple components was what the majority of the time was spent on.

8 ANALYSIS OF SUSTAINABLE BUSINESS MODELS

The studied sustainable business models did not clarify many concepts. There seems to be a lack of definition of what a sustainable business is – one that sells a sustainable product or a business that in itself is sustainable. Also, is a business that is sustainable in the future one that eliminates its lasting environmental impacts or a business that can continue on in the future because of its strategy (financially)?

We argue that sustainable business models include social welfare, like the recently created Public Benefit Corporation concept in the US. However, this makes it seem like they are rather analytical, from an external perspective, rather than something companies can adapt.

8.1 Boons and Lüdeke-Freund

Boons and Lüdeke-Freund's aim of the paper was to advance research on sustainable innovation by embracing a business model perspective. The paper first presents a more generic business model, and then continues with a business model that is linked with sustainable innovations. [72]

A **generic business model**:

1. *Value proposition:* what value is embedded in the product/service offered by the firm;
2. *Supply chain:* how are upstream relationships with suppliers structured and managed;
3. *Customer interface:* how are downstream relationships with customers structured and managed;
4. *Financial model:* costs and benefits from 1, 2, and 3 and their distribution across business model stakeholders.

Normative requirements for **business models for sustainable innovation**:

1. The *value proposition* reflects a business-society dialog concerning the balance of economic, ecological, and social needs as such values are temporally and spatially determined.
2. The *supply chain* involves suppliers who take responsibility towards their own as well as the focal company's stakeholders.
3. The *customer interface* motivates customers to take responsibility for their consumption as well as for the focal company's stakeholders; the focal company does not shift its own socio-ecological burdens to its customers.
4. The *financial model* reflects an appropriate distribution of economic costs and benefits among actors involved in the business model and accounts for the company's ecological and social impacts.

However, this basic set of "normative principles for sustainable business models" does not in itself define a sustainable business model.

Boons and Lüdeke-Freund identified three aspects that appeared to be most significant in regards to sustainable business models: t*echnical, organizational, and social innovation.*

8.2 Breuer

Breuer and Lüdeke-Freund, [73] presents a framework and method for sustainable business model innovation for value networks. The method was applied and evaluated in a series of workshops in Germany.

Breuer differentiates between three levels of innovation;

1. *Normative management,* “deals with the general aims of the company, with principles, norms, and strategies which are aimed at corporate survival and development capabilities”
2. *Strategic management* aims to identify, achieve, and exploit a position for *strategic advantage*.
3. *Normative and strategic management/Instrumental management,* the economic processes of performance, finances, and information on a operational level.

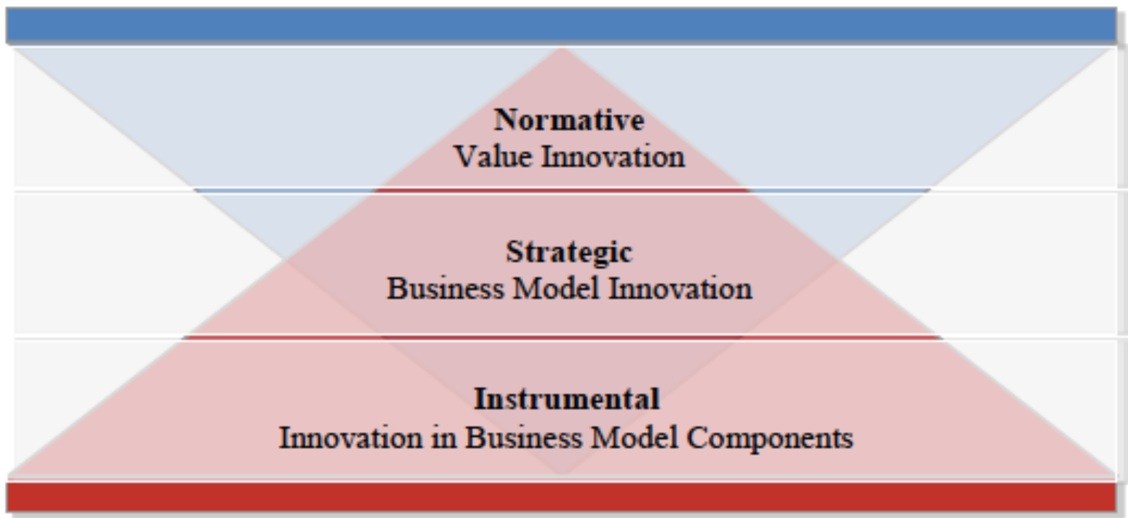

Figure 17- Three levels of innovation management, internally (red) and externally (blue) driven [69]

Breuer also stated that there are two important gaps in the literature on sustainable business models, namely: an “egocentric focus on single firms” and “a lack of reflection of the normative dimensions within value networks”.

8.3 Bohnsack [74]

The “Business models for sustainable technologies: Exploring business model evolution in the case of electric vehicles” paper looks at the impact of path dependencies on business model evolution. [74] Path dependencies are what keeps companies moving in the same direction as they are, an approach that is seen as rather conservative than innovative.
The paper recognizes the importance of creating economic value by using specific characteristics of special technologies. It defines two significant barriers: the first is that sustainable technologies challenge entrenched fossil fuel technologies, and the other is that sustainable technologies lack market attractiveness. Other factors also play a role, such as customer preferences. “Sustainable technologies often do not fit existing production methods, managerial expertise and customer preferences and the potential benefit of resolving environmental degradation in itself does not seem a sufficient condition to generate widespread customer acceptance.” The paper clearly states that environmental degradation is not a market driver. Therefore, new business models may be the only way of successfully introducing sustainable technologies. When developing new business models, it is important to make three considerations:

- product/services and segments targeted

- product development, production, and [after] sales
- revenue/cost model (payment and financing)

This list focuses on business elements rather than sustainability elements, suggesting that the difference between a business and a sustainable business is a sustainable product. "It is unclear, however, what an appropriate or 'right' business model is. In case of emerging technologies the right business model is not yet apparent and requires a process of experimentation based on several alterations." Although key business elements are selected, an appropriate business model is not evident. "'One needs to distil fundamental truths about customer desires, customer assessments, the nature and likely future behavior of costs, and the capabilities of competitors when designing a commercially viable business model' (Teece, 2010: 187)" In short, it still remains difficult to specify exactly what a business model entails.

Path dependency is an important aspect of looking at future technology and new developments in business strategy, but how do incumbents (companies already established on the market) and entrepreneurial firms affect each other in the creation of path dependencies?
Firm-specific conception
A repeating focus of firm-specific conception is that companies, even if they function within an overall similar business model, still have the space to "make unique choices to gain competitive advantage, implying a strategic perspective." Later, the paper also states that "While a business model is not the same as a business strategy, business model innovation provides firms with opportunities to gain competitive advantage." Clearly, the paper emphasizes that one of the key aspects of a successful sustainable business model, or any business model in general, is to gain a competitive advantage. It continues on to say that in the same way companies have several business strategies, "[they] can also employ various business models to create value for specific market segments." The strategic potential of a business model is new sources of value creation based on innovations and different interactions in the business model.
Firms create value through:

- efficiency (cost leadership)
- novelty (differentiation)

These two often play a role in new technologies that successfully enter a market.
However, different companies have different approaches. Path dependent behavior is completely different for incumbents and entrepreneurial firms

- incumbents usually stick close to original business
- entrepreneurial firms can be very creative, but it may be hard for them to stay on the path they choose (financially, etc)

This is a result of established companies usually being larger and having developed a working method – changing it requires change on many levels. Entrepreneurial firms enter the new market and, because they are so small and still adjusting to the market, they are often much more flexible with the business model or strategy. Firms usually get stuck in a path because of a combination of:

- historical background and resource endowment
- contingent events
- self-reinforcing mechanisms

The paper describes incumbents mainly using one factor – that they are usually more conservative. Entrepreneurial firms on the other hand are defined with much more:

- can be more radical, do not have cognitive constraint

- expected to go after novelty
- may have problems with legitimacy/potential customer acceptance of their business model
- people may expect it to remain innovative/use novelty in the future
- constrained by limited resources

The main difference is that incumbents are established on the market, which means that the largest problem is the fact that they are established so it will be difficult to then ask them to change and risk the stability they achieved. Entrepreneurial firms on the other hand are not yet established, so their issues center around making to that level of stability incumbents enjoy. What influences a business model's evolution? Three main factors are listed to breakdown what affects the pathways:

- cognitive constraints of dominant logic
- complementary assets
- contingent events

In order to assess these factors, the researchers searched automotive magazines for three aspects of a business model:

- value proposition
- value network
- revenue/cost model

The result was the development of four business model archetypes for electric vehicles.

The four archetypes are discussed below:
1) Luxury specific-purpose
The Luxury specific-purpose car is a car for affluent customers with a specific goal, whether it be leisure or urban commuting. It is both expensive and meant for a specific-purpose, meaning that the target customer is very specific. One sentence that characterizes the approach is, "Tesla decided to sell the Roadster in flagship stores designed by the creator of the Apple stores." They were creating a specific brand for people looking for a product with a certain image.

2) Luxury multi-purpose business model
The Luxury Multi-purpose business model also targets customers with low-price sensitivity, but the cars need to be more robust and functional. Two car companies are specifically mentioned in this section, the Fisker and Tesla. The paper makes an interesting point about company strategy:

> A case in point is Fisker, a new entrant from California that pursued the luxury multi-purpose business model by building the Karma, a sedan with plug-in hybrid technology. In contrast to Tesla, Fisker designed the car itself but purchased the technology from outside partners. It bought the batteries from A123 which were supposed to be safer and easier to pack into a car than Tesla's approach of using laptop batteries, but also more expensive. From General Motors, Fisker purchased the plug-in technology which meant that the Karma had two propulsion technologies on board, making it less agile and less spacious. Valmet Automotive, a contract manufacturer with a focus on specialty low-volume cars, assembled the car. Due to Fisker's specific choices, the Karma became relatively heavy, more costly, whereas its driving capabilities were dependent on outside partners' expertise and development.

What is perhaps not explicitly said, yet clearly evidenced by this paragraph, is that a company's overall strategy is made up of layers upon layers of strategy. Although the car company is clearly entering the luxury market to be competitive with an EV, Fisker developed the car in such a way that it did not control the most important aspects but rather outsourced them.

3) Economy specific-purpose business model
The economy specific-purpose business model targets a different customer than the two previous models, customers that are price-sensitive. Therefore, the company needs to make their product desirable by providing a focused value proposition. Because EV companies couldn't reduce range anxiety, time needed to charge, and initial investment costs, these companies instead adjusted their business model to:

- focus on decreasing the price to the customer and selling to people who can plan car usage (car fleets, postal service, or utilities)
- add a service component
- sell electric cars and batteries separately
- develop car-sharing programs

Even though the companies could not invest in battery technology to reduce range anxiety, for example, they managed to change their business model to reduce the problem.

4) Economy Multi-Purpose Vehicle
This segment had some of the most significant hurdles in developing a car: they had to both reduce the large investment cost associated with developing a multi-purpose vehicle, making it heavier, and also increase the range. These companies found additional sources of revenue, and changed the revenue/cost model to make their product more competitive.
This segment is mainly made up of those who have tackled conventional car commercialization and began tackling electric cars and their problems, problems such as range anxiety and charging time. One innovation that resulted from this was the range extender, a method of reducing range anxiety with increasing the weight and cost required for using batteries to do the same.

8.3.1 Bohnsack Conclusions

Overall, most EV business models target economy cars. A few factors in the value proposition played a key role in making a viable product: "The importance of compensating the customer for the high initial investment costs, limited driving range and uncertainty about battery lifetime were particularly significant." The EV business models used services to overcome problems that would require large investments, making the car no longer affordable.
On the other side, "business models for the luxury segments were not only less concerned with these higher costs, but also depended less on a service component related to the need for regular recharging." One strategy helped a luxury car bring down its costs, using its environmental friendliness and the California Emissions Trading Scheme to gain a business advantage. Large car companies are required to sell a certain amount of environmentally friendly cars in the US in order to be able to sell at all. Tesla capitalized on this, and sold environmental credits gained from creating its Zero Emission Vehicles to companies that were not able to reach their needed quota in order to continue selling cars at all. Selling credits or licensing technologies could be a way for companies to improve their EV business models. Many large car companies took yet another approach - they tried adapting their conventional cars to accommodate new drivetrains in an effort to reduce costs.

Once new business models began to surface, many companies began to adopt new models they perhaps would not have considered before. “Nissan offered a program for free recharging and inspections at Nissan dealers and a discount on rental cars when longer range was needed.” Nissan was not the first company to develop a lending program that would extend a customers driving range by physically offering them a car when needed, but when another company began implementing the idea they took advantage of it. Nissan also picked up other innovative business models. “In 2009, Nissan started a joint venture with Sumitomo Corp., which specialized in trading used batteries. Another change in the revenue/cost model had to do with creating a better fit with the lease market that is particularly important in the US; a change that was further accelerated by government incentives that applied to the lease market. As Nissan stated: ‘We could arrange it so that they apply the tax credit to the cost of the lease, which would bring down the total ownership cost.’”

One of the reasons established companies may seem to be conservative is the fact that decisions have to go through a much longer and complex process than in entrepreneurial firms. “While the business models in the economy segment witnessed an evolution towards additional services, the changes were fairly incremental in the period of our study. One of the reasons why incumbents did not make large adjustments seemed the lengthy approval process.” Incumbents’ decision processes are a consequence of ensuring stability to continue development in the direction known to be successful, and changing these processes to look for new opportunities can take time.

Many of the business model changes were not a consequence of business decisions, but rather the business decisions were a consequence of the market situation. “Taking a more aggregate perspective, several contingent events occurred within and outside the industry that influenced the evolution of business models; these included regulation, customer preferences, competitive moves of rivals, technological developments, and the emergence of best practices.” Policies and other external forces encouraged companies to reexamine and ultimately adopt and develop new business models.

8.3.2 Contingent Events

Different companies use different business models for EVs, and during the writing of the paper there was no clear evidence towards a shift to a unification of business models.

8.3.3 Influences from outside the industry

Ironically, the global financial crisis helped the EV market. Governments developed bailouts and incentives to prevent job losses, and many required sustainability requirements to be eligible. In retrospect, governments used the financial crisis to further sustainability goals by requiring the inclusion of sustainability in business in exchange for financial support. The policies and incentives made EVs competitive with conventional cars in the economy segment, less so in the luxury segment. It was easier for established companies to use the support instead of entrepreneurial companies – they had more experience knowing how governments will react to a situation.

Retail is usually very competitive and hindered the entrance of EVs on the car market, but the policies helped the market adjust and make its first step towards E-mobility. Another significant benefit that made it easier to adopt was the development of Plugin Hybrids because they could use existing infrastructure.

8.3.4 Influences from Inside the Industry

Tesla made the electric luxury sports car popular. This created a shift in many other car companies:

- Longer warranty period from other electric car manufacturers
- Others began leasing batteries separately from cars
- More companies focused on development of batteries

In the beginning, battery technology was usually outsourced to companies, but then as the importance of battery development for EVs became more apparent companies started developing batteries themselves.

Another inside influence was limitations. Limitations often resulted innovations. The fact that many car companies didn't control battery innovation made them come up with ideas such as a substitute vehicle for longer trips, battery swapping options, or car sharing.

8.3.5 Discussion of Findings

In general, companies were conservative when approaching the EV market. Naturally, there were exceptions: Daimler created the Car2Go program and BMW created its BMW i Project. As the authors of the paper expected, most companies focused on efficiency for value creation. They were driven mainly by cost reduction requirements, for e.g. lowering the purchasing price by changing the revenue/cost model.

Rather unsurprisingly, entrepreneurial firms found new ways to overcome barriers. Later, all EV companies adopted these models. This demonstrates the sustainable benefit of entrepreneurial EV companies on the overall market, even if they do not end up being successful themselves.

Several factors helped companies enter the EV market. One of the largest assets in introducing EVs was an established dealer network. The network seemed like it could play an important role in delivering the new service-based components of the company's value proposition. Although many incumbents could rely on internal revenue streams, many also used government subsidies to finance EVs. However, businesses unfortunately only focused on one business model – the one that involved launching a new product on a limited scale, instead of one that would be up scaled to a large-scale business model.

Outside factors did also play an important role in the development of the EV market and the relevant business models. The paper found that business models were more resilient in cases with contingent events. Rather surprisingly, some companies continued producing EVs even after having gone bankrupt - one reason could be that they needed to meet sustainability requirements to get bailed out. Other companies canceled their EV program, such as when Chrysler got bought out by Fiat.

Overall, it seemed like EV projects suffered during internal cost cutting when in tough financial situations. This indicates that although car companies did invest in new business models and EVs, they still felt more comfortable with internal combustion engine cars. Incumbents did however react better than entrepreneurial firms because they were better at predicting government reactions to situations. Entrepreneurial companies were also able to benefit from government programs if they had entered the market early enough – in fact; Tesla and Fisker were able to broaden their business models.

In terms of influencing business model evolution, it seems that all factors are closely related with one another. "All three factors that tend to drive path-dependent behavior – i.e. the dominant business model logic, complementary assets, and contingent events – seemed to work in close alignment, creating a self-reinforcing mechanism." The current system stops itself from achieving its full business potential.

In terms of the specific archetypes, the economy- and luxury-specific purpose models seem more promising than the multi-purpose economy model because of battery drawbacks. The least promising is the luxury multi-purpose because of technology impediments: fast acceleration is

compromised by high weight needed for multi-purpose functionality.
The impact of path dependencies on business model evolution is evident. However, even conservative business models seem fluid, perhaps because they are in the early stages of introduction. The authors expect the business models to become more stable as the EV market and companies become more established. Overall, most business model changes came in the value proposition and the revenue/cost model.

8.4 Our System-Based Sustainable Business Model

Traditional business models are centered around revenue streams, resulting in them incorporating only stakeholders that directly affect revenue streams, streams from selling a service or a product. Sustainable business is traditional business, but expanded and enhanced through the use of systems thinking.
Systems thinking analyzes all possible impacts and relationships to a gain a full understanding of interactions, it means taking a step back to see how different parts interact to make a whole. This helps foresee and prepare for normally unexpected scenarios, as well as gain competitive advantages on opportunities that traditional businesses fail to take into account. It is also important to differentiate between systems thinking and sustainable business to better see how they interact. Systems thinking is an approach that maps out relationships and helps quantify flows in a system. Sustainable business, on the other hand, is the overall goal that should be achieved, one that is measured using a systems perspective.

We argue that it is impossible to use systems thinking without being sustainable. By successfully understanding a system, one will automatically become sustainable as a result of understanding the business benefits of working towards a healthy system, rather than simply a healthy business. It is impossible to assess one's level of sustainability without using systems thinking: therefore, it is impossible to be sustainable without systems thinking.
We have defined the factors we believe make a sustainable business. These concepts are based on our research of sustainable business models, our experiences throughout our thesis, and our Industrial Ecology education at Chalmers, among others. The different aspects are described below, coming together as a whole to describe what we consider to make a sustainable business.

Expanded scope: The expanded scope resulting from systems thinking provides companies with a deeper market understanding, as well as possible rebound effects from the system. The scope helps the company see the real market, and see opportunities that would otherwise be missed.

Holistic: A holistic approach includes all sustainability aspects in a business model – a systems perspective allows a company to see the real dynamics of the market, revealing opportunities for being sustainable in the long run. Holistic also includes a degree of honesty where the sustainability effort is all-inclusive and aimed at improving rather than compensating for impacts or creating an image. Compensation does not improve environmental conditions, only avoidance does. A holistic approach means that you consider all aspects, even though you may only be able to deal with a few at the moment. Systems thinking shows how a holistic approach actually benefits both the self and others.
Another aspect of a holistic approach is to look at all aspects equally. This may mean treating all customers equally, but we also see it as process equality. For instance, traditional companies focus on cash flow. We believe that cash flow is important for every company, but that still a

sustainable business treats cash flow, material flow, energy flow, etc equally. This brings a sort of balance to companies that is missing from the traditional approach.

Collaborative: Sustainability issues are unlikely to be solved by one stakeholder. Systems thinking shows not only why understanding interactions is important, but also how the specific interactions can affect a company. Therefore, collaborating with stakeholders is key, both with those that are going in an agreeable direction and those going in the opposite direction. This collaboration can open up new business opportunities or reduce costs, ultimately leading to new types of revenue streams, streams not available in traditional business models.

Integration: In terms of value organization, sustainability should not be a department of the company but rather an integral part of the company. Doubtless, it is easier to have a department with sustainability specialists rather than an entire company with people knowledgeable in sustainability issues. However, this leads to the sustainability department cleaning up after the impacts of business-as-usual. Sustainability needs to be integrated into company operations, product and service design, its use, and its end of life – this is best achieved by integrating sustainability into the company as a whole.
Sustainability is important because of the approach it creates, rather than simply the data is based on. Similarly to systems thinking, sustainability is an approach to considering effects throughout a working process rather than part of a product or service – it is something that results from being embedded in every part of the process, from design to end-of-life. Additionally, cross-disciplinary thinking (as opposed to compartmentalization) leads to a deeper understanding of the product and increase efficiency through solutions that could otherwise be missed.

Beneficial: What makes a company sustainable is that it is beneficial. Through this we mean that it works to improve the status quo, rather than benefit itself. Systems thinking shows that benefiting others also benefits oneself, because the system is improved and healthier.

Dynamics: One key aspect of a sustainable business model is the dynamics of the system. Modeling a system shows the different actors involved, but what is perhaps even more important and revealing is the dynamics of these actors. Systems thinking therefore reveals opportunities in a dynamic system, rather than simply presenting an artificially static representation of business environment.

To be sustainable, you need to be completely sustainable and fully aware of your impact on your surroundings. We believe a shift in society's understanding of sustainability is necessary to show the real achieved level of sustainability. This means that, instead of calling companies sustainable for reducing their carbon footprint, you put everything into perspective to show how little a step carbon reduction is towards actual sustainability.

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9 APPENDIX

9.1 Interviews

All interviews are compiled from interview notes; any direct quotes are clearly displayed as a direct quotation.
As the thesis was carried out under an NDA, all data and interviews used for the thesis are not available. Bellow lists all interviewed, however the NDA stops us from publishing them all.

9.1.1 Hans-Göran Milding 03/04/14

Deputy Power Pack Director 15D at Volvo Car Corporation.
Hans-Göran has a long background at VCC regarding product planning.

9.1.2 Siemens AG 03/04/14

Siemens AG is a patent holder and developer of inductive charging, as well as being a tier 1, i.e. a supplier to OEMs. Siemens AG is a German industrial corporation, founded in 1847.

9.1.3 Dr. Jing Song 04/04/14

VP at Geely Automotive Research Institute for New Energy Vehicles.
Dr. Song has a background of 22 years in the US, where 19 years were spent with Ford Motors working within electrical, hybrid and fuel cell vehicles.
Geely Automotive is one of the biggest Chinese vehicle producers, and is a joint venture between Zhejiang Geely Holding Group and Geely Automobile Holding Limited.

9.1.4 Qualcomm 08/04/14[8]

Qualcomm Incorporated was founded in 1985 by seven industry veterans, and is a semiconductor company that designs and markets wireless telecommunications products and services.
In 2011 Qualcomm Inc. acquisitioned HaloIPT, creating Qualcomm Halo, a developer and license holder of Wireless Electric Vehicle Charging (WEVC).
The interviewees were James Semple Director, Business development, European Innovation Development and Edward van Boheemen. Patent innovator.

Qualcomm started with wireless charging years ago, where Nigel Power LLC were the first high power company they acquired. They state that they are trying to build a long-term market, where the vision is to have wireless cars, especially EVs, by 2050. According to them, electric vehicles are the solution for sustainable transportation, and wireless charging is the solution for supplying energy to electrified vehicles.
The Qualcomm technology center is located in Munich, Germany. When it comes to standardization, health, and safety measures, they rely on the Qualcomm knowledge. They are a part of SIE, ISE, and FCC.

Qualcomm's wireless charging system operates on 20kW, but mainly 6.6/7kW and 3.3kW for cars, with an efficiency of over 90%, (16 amps -230V (90%) and 32 amps, single phase, 7.2kW (90%)). The 3.3kW or 6.6kW is the value one will use when plugging the car into a wall-socket.

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[8] The points made is from our, the authors, understanding of an interview with Qualcomm, and has not been verified.

The system uses flat coupling and an alignment of 150 mm in both X and Y directions, balancing losses will appear. However, alignment will be matched to meet OEM requirements.
The ideal goal of Qualcomm is to be able to always get out at least 90% efficiency regardless of how you park, and to be compatible with different car models. A way to do this will be via a controlling system, i.e. the design of the magnetics. Reduced tolerances saves money and space, but they can also mean losses in efficiency.
Cars with an aluminum shielded battery are better for the system, because aluminum does not get heated and therefore does not decrease efficiency. Iron, on the other hand, can absorb the energy, leading to high amount of heat and a decrease in efficiency of up to 4% (which would add up to hundreds of W in losses). Because of the receiver pads exposure, it will have to go through similar tests as wheel arches, to ensure that it lasts as long as the car.
In Japan and China, parking is usually performed in reverse, which means that the design CEVT has chosen (with the receiver pad in the rear of the car) is the better choice. However, it is important to keep in mind that the further back the receiver pad is, the harder it is to align the system.

Qualcomm is trying to solve opportunity charging, which means being able to always be in the top level of the battery capacity (which is better for the battery). Qualcomm sees this as a solution, which is integrated with the infrastructure because being integrated with infrastructure means you can dynamically control electricity loads. If you consider charging the cars with wind power, when you have high levels of wind power, you can charge the car batteries more, storing the energy. Qualcomm does not believe charging schemes work: people forget to charge and leave the cables on the ground.
Qualcomm sees wireless charging as affecting society in the long run, both in Vehicle-to-Grid and Vehicles-to-Home systems. The VTH system is already present in Japan. However, Qualcomm's agenda is not to sell products – they develop the technology solution and sell it to a tier 1 supplier (technology supplier), who then in turn sells it to an OEM. Regarding the differences in technologies at the market, they state that the difference is marketing that they all use the same system.

The best way to market electrified vehicles is as a consumer electronic device rather than the old-school view of a car – wireless charging will help support this perspective. Humans are lazy, and if there is a technology that lets us do less we use it. "The best technologies start as premium solution and then become standard."
Qualcomm is in contact with infrastructure builders, governments, and legislation bodies in order to deploy this technology. The point of view of others that the new technology needs to be compatible with old technologies is not shared with Qualcomm. They see wireless as a cleaner technology than plug-in "old technology," – wireless technology cleans the environment visually because you do not need charging posts, cords, etc, just a small pad on the ground.

The ICNIRP, International Commission on Non-Ionizing Radiation Protection, put up recommendations, from which standards usually are developed. They claim that no heating of the tissue can be correlated to the electromagnetic fields used by wireless charging, that the only possible effect is instant effects on the nervous system. Simulations are being made in order to find all hot spots.
Research is being done to look at interference with other systems, effects on human tissues, and biomedical implanted advises in humans. The issue is around magnetic fields in general.

At the moment Canada is the only country to have legislation to protect animals, like e.g. cats. But what do you define as a living object?

9.1.5 Mats Williander 10/04/14

Research manager at Viktoria Swedish ICT.
His research focuses on business model innovation, on the characteristics of eco-sustainable business models, but also on similarities and differences between cooperative systems and Social-Ecological Systems (SES).

Eco sustainable business models are about a business model where, from an environmental point of view, the products in the value proposition last for a long time. They join together profit maximization and resource efficiency, in comparison with linear business models where high volume is often linked to high margin.

Sustainable business models, at Viktoria, are focused on environmental sustainability plus financial sustainability. The fundamental difference between eco sustainable and "traditional" is "who owns the product". Williander explain it as, the one who designs the product should have incentives as if they had kept ownership, or because they do actually keep the ownership. It's all about profit maximization; if you own the product you are more likely to make the product last as long as possible. A linear business model creates profits by sales, which creates incentives to keep delivering products (i.e. having a lower life length).

Williander explains that we have lock-in effects in organizational function. The core functions can become hindrances for the organizations: if they do not reflect on what they are doing, they continue doing things because of routine. Companies are part of a network, and changing a business model affects the value chain. Therefore, switching to a circular business model may require convincing of suppliers and their suppliers. Traditional business models have been in place and evolving for 100 years, making it hard to change to a circular system now. This has much to do with the fact that even if you prove the profitability of a business model, it cannot be changed easily because the whole system has to change.

When discussing market shifts, Williander states that in order to shift the market, one needs to meet the early majority's needs. The early majority is more egocentric than innovators and early adopters, in the sense that they shift from one value position to another only when they see the clear benefit for them (most likely financially).

The shift to EVs is highly uncertain according to Williander, but if it will happen, there will also be a shift to wireless charging. A key reason is that the cord seems to be a likely hindrance for the success of EVs and PHEVs.

The change agents, the ones urging and possibly facilitating the shift (eg Tesla Motors), encourage change as a result of business, social, and environmental reasons. The question is though, why would a traditional car company want to see this shift, to plug-in vehicles, happen? Many automakers sell EVs as a result of regulations: they have to sell them in order to sell combustion cars on the California market, for example. There is no business reason for producers to engage in the shift to EVs, at the moment. It's enough for them to produce both combustion and electrified vehicles, and then sit back and see how the market evolves.

The implementation of PHEVs would probably not have happened if it were not for European legislation on carbon emissions. However, for a shift to happen, the price of plug-in vehicles needs to decrease while governments need to implement more developed bonus systems as a trigger, and then higher volumes will reduce the prices. One of the reasons EVs and PHEVs are more expensive than combustion vehicles is the high battery cost (mainly for EVs).

The Swedish government gave out incentives to all EV buyers in an effort to encourage EV sales, a policy that cost the government and taxpayers up to 200 million SEK. Williander believes that a bonus-vale system would have a stronger impact, i.e. a system where an additional CO_2 tax would be implemented on grams of CO_2 produced over a specific threshold, while cars below the limit would in essence gain money for producing less CO_2 than the specified limit. In other words, polluting cars provide the subsidies for clean cars.

The rapid increasing cost of electricity, compared to fuel prices, is working unfavorably for the implementation of EVs and PHEVs. The energy cost cap needs to remain in place.

PHEVs are easier to sell to the consumer than EVs, because they are able to completely replace the internal combustion cars

According to Williander, for a shift to happen, you need to bundle technology with matching customer needs: PHEVs can be clean and useful for long distance trips, while if you purchase an EV you also need access to a combustion vehicle to go on longer trips. This bundling makes it possible to convince users to either get a PHEV for all-around use, or an EV for daily use together with a combustion car for long trips. The product needs to meet the use requirements of customers, unless customers needs shift in a new direction.

Combining wireless charging and PHEVs is an example of bundling to increase benefits. A PHEV has a smaller battery (lower charging times), and in combination with wireless technology a driver would be much more willing to charge more often. Free and frequent charging spots will be beneficial, while electric roads will increase the incentives for EVs.

Williander stresses the fact of thinking about "the value for customers", i.e. what is needed for them to get as much value as possible. For wireless charging and EVs/PHEVs, this would be hassle-free charging, frequent charging spots, and have perks such as keeping the car warm or cooled while parked.

However, wireless is far away from a mature technology. Concerns of consumers regarding magnetic fields, such as "can you be in the car while it's charging", need to be addressed, and the eco-system that accepts wireless charging needs to be built. The eco-system needed to facilitate implementation is composed of adopters and charging stations. The network effects also need to be taken in consideration, i.e. both the business model when the technology is being implemented and then also the business model after the technology has been successfully implemented.

The selling price of $3000 for a wireless charging unit seems to be commercially viable for Williander. The emotion of buying a vehicle is greater than the price, and proven perceived benefits of the technology are also considered to be worth the price. A way of reducing the price even more is by making everyone use wireless instead of the power cord – an increase in production and units sold will bring down the price. Maybe it is possible to decrease the price of wireless charging below the price of the cord by using the system to find other revenue streams. Alternatives to this could be to create a different business model, to reduce the upfront cost and spread out the rest of the cost over time or other stakeholders.

9.1.6 Mats Josefsson and Crister Lunde 22/05/14

Mats Josefsson, Systems Responsible HV Charging and Power supply at Volvo Car Corporation. Crister Lunde, HW Designer Power Electronics at Volvo Car Corporation Electrical Propulsion Systems.

9.1.7 Bengt Axelsson 26/05/14

System design manager at CEVT (Chin- Euro Vehicle Technology AB).
Geely Automotive (China) owns CEVT, with the aim of developing the new C-segment platforms.

The main problem with integrating wireless charging in the EVs and PHEVs lies in finding that volume needed in the car. "It's not an electrical problem, rather the physical area needed", Axelsson.
The interview with Axelsson started off with a dive into the differences or lack of differences between technology solutions on the current market. Our background research hade showed us that different suppliers claim to have lots of patents, bur over what? Axelsson stated that his understanding is that they are using the same technology, that the physics of the technologies are the same. However differences clearly exist as they have different efficiency values;

- *Plugless*, uses IGBT transistors as inverters, which limits the frequency. They also have a higher value of copper that is lowering their efficiency.
- *Bombardier*, have a different philosophy, a three-face coil system. It is believed that the system can reduce the external radiation, as the external field can cancel themselves out. The system was first used for high power systems, and is now used for lower powers, e.g. used in a 20 kW system in C30 in the Flanders Drive project. However it is hard to understand how their technology works, or how the magnetic flux looks, according to Axelsson.
- *Siemens,* have a double coil and a "twist coil" around a ferrite at the top. The D-shape of the coils keeps them closer, making it easier to focus the radiation and keep it inside, i.e. make it possible to more easily concentrate the flux.

In other word, the differences between supplier technologies are more of a design difference than a technology difference. They should also be compatible, e.g. if you park a Plugless car over a Siemens pad, you could just use one of the coils and transmit power. This is however not the case with the three-phase system of Bombardier which, which is uses another technology. Axelsson also stated that the two-coil system is the easiest to control.

As a new technology solution enters the market, the question of system integration of mass-produced parts, evolve. In a general viewpoint the more integrated the solution is, the lower the system cost, Axelsson. It will however depend on the take-rate (the cost), a higher take-rate means that the product should be more integrated.
Axelsson believes that wireless will be introduced in the homes first with systems that aren't compatible with each other. The second step will be public parking, with compatibility. Add on systems usually become standards and standardized. For wireless the first accepted standard at the moment is the 85kHz limit.

One of the main questions in the wireless discussion is the energy efficiency difference between wireless and plug-in. When looking at the full system, i.e. grid to drive, conductive will always have better efficiency, Axelsson believes. Flanders Drive, report, has the measurements as well as specific for the different steps. (*Flanders Drive concluded that wireless have an efficiency up to 90%, 4% less than with a cable.*)

The concerns regarding radiation have lead to all developers to develop a living object detection system, as well as a forging object detection system. But how effective is the system? According

to Axelsson, the system if still under development, and that's why they don't have values for the preciseness. The system can be a camera or a infrared system in the car. For metal detection you can have small coils picking up if the metal is disturbing the field.
The health effect of the field is said to be instant and not long-term, in the sense that it can affect nerves and synapses.

9.1.8 WiTricity and TDK 04/06/14

WiTricity is a technology developer, a manufacturer of devices for wireless energy transfers and license holder. The company originated as a project at MIT. TDK, or ***T****okyo* ***D****enkikagaku* ***K****ogyo, is a multinational electronics company that manufactures mainly electronic materials and components. TDK is also holder of the WiTricity license for wireless transfer.*
Interviewees; David Schatz, Director of Business Development and Marketing at WiTricity; Kazushi Watanabe, Section Chief, Energy Device Development Section at TDK; Kaoru Matsuoka, Senior Vice President at TDK

WiTricity is the license holder of the base technology TDK have for inductive charging, a technology they have combined it with a ferrite coil to improve efficiency. For example Evatran has no ferrite, which makes them demand a strict alignment. A small un-alignment of 5 cm will create great leakages in power transfer.
They have built structures where breaking of ferrite won't affect the system. They have tested their system for dynamic charging in small cars, where the coil transmit was 2kW and 70*70cm. The efficiency of AC to DC transferee is 91% for 3,3 to 6,6kW. A screen/shield have to be integrated in the car.
At the moment they are comparing the highest transfer efficiency and the leakages. As the most efficient placement in nor always the one with the highest efficiency.

TDK would provide the whole power transfer system, including e.g. FOD system, wireless communication, amplifier unit, transmitter coil and connector, receiver coil and connector, position detection and rectifier unit. At the moment they supply DC-DC and chargers to Honda. They participates in the standard organizations for EMC and EMF, i.e. ISO, SAE, JASO and IEC. TDK have employees in Japan, Europe and US, and sees this, as a way to make sure that any product they sell will be adaptable in all markets.
By this year, 2014, they plan on developing their standard in order of the SAE and IEC. They don't have a serious production contract, however they believe that the only one who have a serious production for the technology is Toyota. They say that a lot of people have patents, but who have license patens.

9.1.9 Tommy Lindholm 09/06/14[9]

Stakeholder power generation/distribution, Vattenfall.
Tommy has also worked as vehicle and electric vehicle expert at Vattenfall, Sweden. Vattenfall is one of Europe's leading generators of electricity and heat, owned by the Swedish government. Vattenfall started the mobility department in 2002.

The role and believes of Vattenfall when discussing wireless charging of EVs and PHEVs, is according to Tommy Lindholm, to inform the public of their opportunities. They are promoting

[9] The interview is in general for the case of Sweden and the Swedish market

inductive charging, as they don't see the EV to be a mass market if the cable is there. The vision for the future, according to Vattenfall and Tommy, is renewable energy together with inductive charging.

The pressure on electric companies are said to increase as the amount of EVs and PHEVs increases, however this won't be the case for Vattenfall according to Tommy L. As if all the Swedish cars, around 4.5 million where EV cars, would charge at the same time, they would need between 8 and 9TWh of electricity and there is approximately 160TWh production capacity in the Swedish net work.

They are talking about smart grid system for houses, so that they can put priorities on charging in the house. The interest of smart grids will enhance so the end customer can get information from the network when the washing machine can start to utilize the lowest kWh price. They want to give the costumers the ability to se all the levels of charging in the house, possible through the app/webpage Energy Watch. A wireless charging system would be possible to integrate in the system, and then able to control so the charging of the car happens when it is the cheapest tariff price of the kWh.

Tommy states that they, Vattenfall, will promote and start up, as well as educate regarding the charging at specific locations for charging. Vattenfall is building up 12 fast charging stations for EVs in Stockholm this year. And there are plans to build up 3 fast charging station in Gothenburg in 2015. And this activities shall be seen as a promotion to strengthened and build up confidence for the EV market. They see themselves as a catalytic company in the question.

The discussion around storing solar and renewable energy in car batteries, by the smart grid, is an OEM and political question, says Tommy Lindholm.

The main limitations for the EVs at the moment is the battery cost, the costs are approximately 550-900 \$/kWh, as well as the range problem. In his point of view all electric will never be the only car, unless they can reach 400-500 km range.

The CO_2 limitations have generated in the OEMS building amazing cars. Cars with amazing efficiencies and performances, that creates a threat to pure electric vehicles as micro hybrids, mild hybrids and hydrogen vehicles. According to Tommy Lindholm, this has evolved into two main problems for EVs and PHEVs, namely price and government subsidies. In his point of view, political incisions are needed for electric vehicles to compete. Policies are needed to bring down the price, to a level so the EVs can compete with combustions in order for the public to buy. There is a political discussion ongoing to introduce a malus bonus system where the vehicle with fossil fuel will have a high tax and vehicles with low CO2 will be compensated.

However, even if the price comes down the EV will have a hard time competing. As most people like big cars, and the premium vehicles have still a high degree of attractiveness to the end customer. One shouldn't underestimate the power of statues profile. You need to offer something that gives value to the car.

The look of the current market, indicate that a clear replacement wont be successful, we will most likely get a more diverse market with more options. The amount of sold pure EVs in Sweden is less than 10 000 and the vision for Sweden is to have 600000 EVs to 2020.

Nevertheless, he believes that this time the EV will succeed in taking the mass market, (have failed 3-4 times before). Mainly thanks to the CO_2 limitations, which have driven the OEMs to have a number of different hybrid vehicles as micro, mild and full hybrids that rake down the consumption/emissions as well as offering a option in all price classes. In the US you also have a

law about having a EV in the portfolio in order to be able to sell cars in the US, this type of law is unlikely to happen in Europe or China. If we want the car to be a mass product it needs to fulfill customers expectations, as design, performance, convenience, quality and safety.
The way for EVs in big cities is smart mobility, according to Tommy. When it comes to specific markets, Tommy doesn't see the EV taking the market in China, except in Beijing and other big cities with polluted air and water. In colder countries, such as Sweden an additional limitation is the fact that the cold climate can decrease the battery capacity up 30- 50%. He therefore believes that California and other warm markets it is easier to find satisfied customers regarding range.

Make it so cheap that people will buy it, NOT buying down the cost so people can afford it. Need to make it something special, like inductive charging.

When discussing the hard technical aspects of wireless charging, the perception is that all (or almost all) suppliers have resonance charging system they just use different words. You can only do it in one way, but then you can couple it. Tommy stated that an aluminum shield under the car is necessary in order to keep the radiation within the standardized values.
That you have higher losses with wireless in comparison to a cord is only a myth according to Tommy. In resonance you can have around 95% efficiency, all is above 90% and inductive might be one or two percent less. The price of the wireless is believed to be lower, as the cord for coils are much simpler and therefor a lower cost. A normal cord for a EV or PHEV cost around $700-1 000.
Bidirectional charging is a tricky problem, mainly due to uncertainties. Who will be the owner of the battery? If it brakes, what happens? Who takes the warranty claims? This will not be an option until we know more about the lifetime of the battery. For battery swapping, a company that tried it and got bankrupt (Better Place).

9.1.10 Hamish Laird 01/07/14[10]

Hamish Laird, CTO and Founder of ELMG Digital power
ELMG is a power electronic and embedded control of power electronics specialist, located in New Zealand.

Inductive charging is presented on the current market under different names, namely highly-coupled resonance and inductive charging. However, the technology is the same in all solutions, otherwise it wouldn't work - all use the principle of magnetic coupling, whether it be more or less magnetic. Some operate on a frequency that makes them seem to be electromagnetic, but when you look at the dynamics of the system there is no electrical coupling. They may operate at different frequencies, but the technology is the same because they all generally use some sort of tuned circuit (resonance) and generally all use impedance matching for control. They all work using the maximum power transfer theory principle, which says you get maximum power transfer when the impedance is matched. However, the rule of maximum power transfer is not necessarily the most efficient.

The predictions for car IP, four years ago, were that there would be no growth in the auto industry. Personally, Laird does not see the benefits of inductive power transfer, and asks, "What is wrong with the cable?" The pads are not able to be directionally focused – you can make a

[10] The interview is paraphrased and in many places word to word.

magnetic field go where you want, but you need to do more than just wind a coil, it would require something like a magnetic lens. Because the pads are not focused, half of the energy goes in the direction away from the car pad (down) and, if there is steel reinforcement in the cement floor below, is absorbed by the steel. Additionally, if the charging pad is closer to the steel rods in the floor than the receiving pad on the underside of the car, the pad will not work. So it seems that the technology can work in some circumstances, but not all. Also, because the energy transfer is so dependent on correct alignment, I think the car battery will be dead in the morning, making this a showstopper for the technology.

My conclusion is that there's a tradeoff between how accurately you park you car and how much the charging mat and receiver in the car costs. Tolerance of 15 cm would cost a fortune, but reducing it down to 2 cm would reduce the cost by a factor of about 3. This will be the undoing of any sort of wireless charging – you need to invest too much in the mat or the energy transmitter if you cannot control their location. I think the price point will drop when you begin using automatic parking to park the car very accurately over the mat. But if you are going to park automatically over the fixture, why not have an automated socket? You will be as accurately aligned for a passive/conductive charging technology. The investment required in the mat and receiver to control the alignment is too large to overlook. A few wise words on the topic are, "If its possible to do it without magnetics, then do it that way." However, I do not know why no company offers automatic conductive charging, and all offer inductive charging. I think it will be the simpler solution that disrupts the inductive power transfer, which does not mean inductive power transfer will not take off, and I'm not saying that it would be good or bad.

In the case of dynamic inductive charging, when you have movement and distributed transmitters, this technology has a significant advantage – the world where you have distributed power availability is what makes wireless power useful. This is pretty much the semiconductor industry, where you have to move stuff and power it at the same time. I think that as soon as you have self-drive cars that can follow a track, this will be an obvious solution. This technology can have advantages for public transportation, because of the high capital costs of the vehicle – you can have smaller batteries to use the vehicle. The ability to drive in a certain position in the road will be the enabling factor for wireless charging that will make it more useful than conductive charging.

I think what will help quantify the usefulness or wireless charging is calculating the drop in power transfer resulting from a difference in alignment. If you have a transmitter coil and a receiver coil and they are perfectly aligned, and you have minimal lens, you can work out the coupling between the two. Then you can move the receiver and work out what the coupling drops to. Basically what you trade is effectiveness for perfect alignment to drop in effectiveness – it is a straight geometric problem. If you have a directional transmitter (beam transmitter), as you move the receiver the coupling drops, and so the stability of the whole system changes and this control problem is not overly difficult to solve. However, the maximum power you can get across drops, which means that all your systems need to be bigger in order to compensate for unaligned operation. The cost of this unaligned operation is one of the key drivers in economics of this technology.

The cost difference between plugin technology and wireless technology does not come from the cost of the cable, because cable is inexpensive. The cost comes from reliably making contact.

Plugs in your house reliably make contact in your house for a certain current rating. If you go up in current rating, in order to make reliable contact the connector technology becomes more and more complicated and the force between the plug and the socket needs to increase. So the key question is, who much current do you want to put in your electric vehicle? A 3kW cable is incredibly cheap for from a connector and cable point of view, and you would be able to plug it directly into your house. The build cost of that cable is probably less than a dollar, maybe 10 dollars, even if they sell it on the market for a few hundred.

If you want a very fast charge, as in lots and lots of current, definitely inductive power transfer starts to become competitive. This is only because you save money on expensive contact. The idea that you would remotely charge and transmit a lot of power will not work, what you would have is an inductive transfer that would look like a conductive socket. You would control the location, in an electric toothbrush charging kind of way. This technology is available in Detroit since the 90's, but they decided it was not worth continuing.

To answer what makes companies charge so much for wireless charging… the response is they paid way too much. For what was on offer, I do not understand why they paid as much as they did. Also, everyone else in the room was saying they don't want to buy. So one of the reasons could be that they overpaid for the technology. Another reason could be that they are paying for using the patents, and they are paying per unit. Others invented their own technology, but if others are getting a high price for it, why would you sell yours for less? You wouldn't want to collapse the market, would you? What makes this technology desirable is the possibility to drive without needed to stop for extended periods of time for the vehicle to recharge. However, if fast charging is the goal, then inductive is competitive and will save money on the contact technology needed for charging.

Following how a technology is picked can be very revealing: when it comes to the automotive industry, the successful technology is often the one that venture capitalists pick, the one that's capitalized the best. However, for all that America is a great free market place, the thing that America does best is standardization, which is done on an ad hoc basis. There are many examples where the technology that won was a compromise that the industry body managed to sell to others, the one they managed to convince everyone to adopt. The automotive industry is relatively small, so this should happen relatively quickly, but I'm not sure that it will. At the moment there are four types of public charging standards in US (California), and there is a fight between them. But what will happen is that when there is money to be made, they will standardize very quickly. In the US, they will just get together and try to solve the problem – you can just show up and be a part of it. In Europe, would likely be more regulated.

Another surprising thing is to watch out for homegrown Japanese technology. Keep an eye on what the Japanese are doing at home, that is very good strategically. Because all of a sudden the Japanese car manufacturers will get together and agree on a standard, they will have had it deployed in Japan for four years, it's completely field tested, and it's ready to go, and they sweep the world. They will just go to the standards meeting and say we're done, we have the technology, you can have it if you want. I think the Japanese be surprisingly collaborative, in the sense that things can suddenly move forward much faster than you expected.

I think one of the largest problems with wireless charging is that you can never get what you want. You can make a system that is relatively insensitive to misalignment, but then the maximum transfer will be lower than a system that is more sensitive to alignment. If you can have a very focused narrow beam, you can focus a lot of energy or power, but as soon as you go out of alignment the loss of transfer capability will be very large. The thing that defines your transfer capability is the ability to keep the system stable, so all the transmitters generally try to manage their broadcast power, and they use the absorption of your receiver. Because they are coupled, they can look at the absorption of the receiver and manage the power so that it is just on the verge of becoming unstable. So there's an interesting control problem that all comes down to how well aligned you need to be to be in control. This is the key issue with the technology. You can have diffused power transmission, but you get very little power transfer, or you can have very focused power transmission, but you lose almost all of that ability as soon as you're out of alignment. This is one of the reasons there is a lot of material work being done to develop magnetic super lenses.

I don't know too much about the adoption of technologies by the auto industry, but I have noticed two things. The first is that the price curve for vehicle technologies, such as inductive charging, seems to be very lumpy: either everyone adopts, or no one adopts. It's probably a geographic thing, such as everyone in China adopts, or one adopts, geographic in the market sense. The second thing is that…there's a very good model of technological adoption, which has a very strong tipping point behavior point in it. Cars meet the needs of people: they go fast enough, they're comfortable enough, they are economical enough, and so they have been mass adopted. Previously, however, very few people had cars, and then suddenly there was a large adoption. The reason I chose my car was not because it was reliable, or any other fundamental option, but because it was a hybrid. Now, there's always a tipping point on the market where everyone has the same thing because that's all they can afford, that the utility of the product is the most important thing. Then suddenly you reach a point where the products become very diverse across the market, and you have a lot of specialized options. Now, you have to decide, in terms of your adoption, whether wireless charging is a fundamental thing that is an improvement across the entire car industry, or is it just another one of those things like having a CD player. It will be one of those things. I know that the people who have invested heavily in the technology will think it is the first, but my feeling is it won't be. In terms of adoption model, you have to decide if this thing is fundamental for cars, or if it's like intermittent wipers or side-impact protection. Is this a feature or fundamental for cars, my guess is it's a feature.

I don't really know what will help the EV and PHEV market develop faster. I think one of the key things would be the repeal of the dealer protection laws in the US. That would be a fundamental shift that would shake auto industry in the US. In 40 states, you have to buy a car from a dealer. New cars can only be sold by the dealer – the car company cannot sell you the car directly. This is the problem Tesla is having. If you go to the Michigan government and say you want to cut out all the dealers, they wouldn't do it, because that's where the auto industry is. So I think it's a policy issue. Also, one of the fundamental things that would enable it would be the EU's focus on tailpipe emissions. However, what I understand from that is that the combustion engine companies are trying to push energy measurements to total lifetime energy, which probably most hybrids would lose on. The other thing I would add is to move away from permanent magnet machines.

The frequencies at which people transfer with magnetic fields are relatively low, so the size of the field is rather low. You could go faster, but the beams would get narrower, and the alignment issues would increase. I do think miniaturizing is great for electronics, but that it would be difficult with this technology so you need to take resources into account. A Chinese company said, “Number of people in China, one meter of internet cable each, not enough copper.” I said really? They said yeah, work out the tons. I think it means that the amount of Copper China controls is not enough, that they are already considering the copper shortage. So I asked, why copper? What about aluminum? And they said “Not enough of that either.” So China is already looking at a copper and resource shortage of material in the world…which scared me actually, being an electrical engineer.
If you’re going to need a certain amount of energy to be transmitted, you’re going to need a certain sized wire. You can look at the amount of material needed per kW of energy transferred to find the final price. You would be able to find the final market cost of the technology will be, after everyone has paid for their IP paid for their manufacturing plant, etc… then you get to a Return on Capital type of business. Yes, it’s just kilograms of material.

In terms of China’s charging infrastructure, I think you cannot think of China being homogenous. You can be in a developed area, drive 20 mins, and be in a completely undeveloped area. So, I think you should break it down into three things. What does the Chinese government want to happen? What can the Chinese government make happen? What will the Chinese people accept? I was talking about this with my friend in Shanghai, who says that every day for the last two months at least the air pollution has been over 200 ppm, and one day he couldn’t see the ground from his window (100-something meters). So, I’m sure the Chinese government wants to get their pollution down. I’m sure they can enforce cleaner cars in the middle of the city. What will the Chinese people accept? I think that in the wealthy bits, they would be happy with hybrids, and in the less wealthy bits its not even an option. What I’m saying is that charging will be in the behest of the state, that it will be public, at a surprisingly low rate (if you’re offering 3kW, they will have 1 kW), I can’t tell what they will do, but I think their air pollution is becoming more of an issue they are acknowledging. So, the copper shortage I think was more about using copper when it cannot be replaced – if we can use plastic for internet, we will not use copper. I’m not saying they will necessarily constrain copper in all applications, but that they already have a solution. So, all data over fiber, because there’s almost an unlimited amount of plastic around the world. A copper shortage will also affect plugin cars, but I think the Chinese solution is different from what we’re all imagining, the Chinese solution will be a planned one.

A possible showstopper for IP is the cost of magnetic material, which is generally ceramics. Ceramics need to be shaped, which is extremely difficult and expensive. Ferrites are not the solution, because if you look at a ferrite’s magnetic lens properties and compare it to an optic lens, it does the opposite. That is, if you have a ferrite in the shape of an optic lens, it will refract light instead of focus it. It is still possible to make ferrites focus a magnetic field, but you need completely different principles than used for optical focus: using materials that focus magnetic fields like how glass lenses focus light would make it easier to work with the technology. For extreme focus, you would need a lot of expensive ferrite materials or make the coils bigger, flat coils mounted on aluminum. A flat coil you can probably do pretty good coupling with, with almost no focusing. However, what you end up with is a lower limit for the power transfer, so it is fine for small powers but not larger power needs. Most of the offered options now are flat coils, because it is the cheapest at the moment. The optimal solution is that you put in too much wire, too much power electronics, and don't do any focusing…but if you could do some focusing with a reasonable material, you would do much better. Some companies did a huge amount of research on focusing a magnetic beam, and focusing them so you could drive a bus: a huge amount of research was done not only on focusing, but also adjustable focusing. They did a lot of research on manipulating a magnetic beam to drive a bus: they wouldn't try to control the beam, they would instead try to control the point at which the receiver was most coupled, so they wouldn't adjust the focus of the transmitter but rather the receiver (not the geometry, but electrically adjust the receiver so that you could optimize the transfer). They worked on the receiver part to control the beam, so that when it's in a different place, it's still a focused beam. It becomes fairly obvious when you sit down and look at the math and the physics of this, that the fundamental flaw of the technology is the idea that you have the charging pad and receiver pad some distance apart. The fundamental idea should be that you get them as close as possible, that maybe the pad jumps up and touches the receiver pad.

The key issue with power flowing backwards through the grid is that all the transformers are wrong, so you get over-voltage on the high voltage lines, and it's not tamable. The option of vehicle supplying energy to the grid is all politics.

*Laird explains that his Prius Hybrid, with a good fuel economy, is highly dependent on the temperature of the battery, and that Mitsubishi surprisingly does not mention anywhere in their sales material that if you plug it in you will not use any fuel (that it can run solely on electricity).

9.2 Current Market – EVs in Europe

Europé										120V	240V	Wallbox	Fast charger	Batteryswap												
Company	**Market**	**Price €**	**Price after policies**	**Performance (Hp)**	**Torque (Nm)**	**Battery (kWh)**	**Battery Type**	**Range (km)**		**Charging Time (h)**			**min**	**min**	**Charging in %**				**Charge in km**				**Efficiency (kWh/100km)**	**Top Speed (km/h)**	**Acceleration 1-1**
BMW i3	All	30 493		170		18,8	Lithium-ion high-voltage	160	190	7	4	3	<30		100	100	80	80	130-160	130-160	104-128	104-128		150	
Citroën C-Zero	All	32 055		67		16	Lithium-ion		150	8		6	30		100		100	80						130	
Ford Focus Electric	All	37 585	32 124	143	249	23	Lithium-ion battery pack	122	122	18-20	3-4.				100									135	
Mia Electric	Belgium, Netherlands, Luxembo		26 735		58	12		125	129	3-5.					100									100	
Nissan Leaf Visia	All	26 101		107	254	24	Lithium-ion	117	135	20	8	4	30		100	100	100	80						150	
Nissan Leaf Acenta (Tekna)		29 745	22 687		254			100	182			4					100							143	
Renault Fluence Z.E.	France, UK, De	57 166			226	24	Lithium-ion	160	185	6-9'			<60	5	100			80					17	135	
Renault ZOE	France	16 636		88	220	22	Lithium-ion	150	210	4-16'		2-8'	30		100		80	80					14,6	135	
Tesla Model S	All		67 322			60		335	370				20,0	1,5	100			50	335	370	483	426		177	
Tesla Model S	All		105 364			85		426	483				20	1,5	100			50	167,5	185	241,5	213		209	
Volkswagen e-Up!	All	29 578	23 480			18,7	Lithium-ion		160	9			30		100			80	160			128	11,7	130	
Volvo C30 Electric					220	24	Lithium-ion	150	170															130	

9.3 Current Market – PHEVs in Europe

Europé											120V	240V	Wallbox	Fast ch	Batteryswap					
Company	**Market**	**Price €**	**Price after policy**	**Engine**	**Performance (hp)**	**Torque (Nm)**	**Battery (kWh)**	**Battery**	**Range (km)**		**Charging Time (h)**			**min**	**min**	**Efficiency (kWh/100km)**	**Top Speed (km/h)**	**Acceleration 1-100km/h**	**Capacity**	**Electr**
BMW i8				1,5 three litre cylinde	349	550	8	Lithium-	483	600	<3		3	<30			250	4,4		
BMW i3 extended range		32 483		two cylinder engine	34+		18,8		340								150	7,9		
Chevrolet Volt			43 698				16	Lithium-ion		500		4				13,5	161			
Mitsubishi Outlander			44 353				12	Lithium-ion		800		5								
Opel Ampera			42 135				16	Lithium-ion		500		4				13,5	161	9		40-80
Toyota Prius Plug-in			35 702				4,4	Lithium-ion		870	1,5						180	10,7		16-24
Volvo V60 Plug-in			57 673				12	Lithium-ion		500	3,5						200	6,2		
US																				
BMW i8	Noth america	97 521		1,5 l turbocharged th	357	569	7,1	Lithium-ion			3,5	1,5						4,2		

9.4 Vehicle Electrification Standards - SAE

[75]

SAE Standard	Standard Title	Objective
J537 (RIP)	Storage Batteries	Specifies testing procedures of automotive 12 V storage batteries and providing information on container hold-down configuration and terminal geometry.
J1495 (RIP)	Test Procedure for Battery Flame Retardant Venting Systems	This SAE Standard details procedures for testing lead-acid SLI (starting, lighting, and ignition), Heavy-Duty, EV (electric vehicle) and RV (recreational vehicle) batteries to determine the effectiveness of the battery venting system to retard the propagation of an externally ignited flame of battery gas into the interior of the battery where an explosive mixture is usually present. NOTE: At this time 1998, there is no known comparable ISO Standard.
J1634 (RIP)	Electric Vehicle Energy Consumption and Range Test Procedure	Establishes uniform procedures for testing electric battery-powered vehicles. Provides standard tests which will allow for determination of energy consumption and range.
J1711	Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, Including Plug-in Hybrid Vehicles	Establishes uniform chassis dynamometer test procedures for hybrid-electric vehicles (HEVs). The procedure provides instructions for measuring and calculating the exhaust emissions and fuel economy of HEV's.
J1715/1 (RIP)	Hybrid Electric Vehicle (HEV) & Electric Vehicle (EV) Terminology	Contains definitions for electric vehicle terminology.
J1715/2 (WIP)	Battery Terminology	Define common terminology for automotive electrochemical energy storage systems at all levels; component, sub-component, subsystem and system-level architectures including terms pertaining to testing , measurement and system function related to energy storage
J1766	Recommended	The purpose of this document is to define test

(RIP)	Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing	methods and performance criteria which evaluate battery system spillage, battery retention, and electrical system isolation in Electric and Hybrid Electric Vehicles during specified crash tests.
J1772 (RIP)	Electric Vehicle and Plug in Hybrid Electric Vehicle Conductive Charge Coupler	Defines a common EV/PHEV and supply equipment vehicle conductive charging method.
J1773	Electric Vehicle Inductively Coupled Charging	Establishes the minimum interface compatibility requirements for electric vehicle (EV) inductively coupled charging for North America.
J1797	Recommended Practice for Packaging of Electric Vehicle Battery Modules	Provides for common battery designs through the description of dimensions, termination, retention, venting system, and other features required in an electric vehicle application.
J1798 (RIP)	Recommended Practice for Performance Rating of Electric Vehicle Battery Modules	Provides for common test and verification methods to determine Electric Vehicle battery module performance.
J1850 (RIP)	Class B Data Communications Network Interface	Establishes the requirements for a Class B Data Communication Network Interface applicable to all On- and Off-Road Land-Based Vehicles.
J2288	Life Cycle Testing of Electric Vehicle Battery Modules	Defines a standardized test method to determine the expected service life, in cycles, of electric vehicle battery modules.
J2289	Electric-Drive Battery Pack System: Functional Guidelines	Describes common practices for design of battery systems for vehicles that utilize a rechargeable battery to provide or recover all or some traction energy for an electric drive system.
J2293/1	Energy Transfer System for Electric Vehicles--Part 1: Functional Requirements	Establishes requirements for Electric Vehicles (EV) and the off- board Electric Vehicle Supply Equipment (EVSE) used to transfer electrical energy to an EV from an Electric Utility Power System (Utility).

	and System Architectures	
J2293/2	Energy Transfer System for Electric Vehicles - Part 2: Communication Requirements and Network Architecture	Establishes requirements for Electric Vehicles (EV) and the off-board Electric Vehicle Supply Equipment (EVSE) used to transfer electrical energy to an EV from an electric Utility Power System (Utility)
J2344	Guidelines for Electric Vehicle Safety	Identifies and defines the preferred technical guidelines relating to safety for Electric Vehicles (EVs) during normal operation and charging.
J2380	Vibration Testing of Electric Vehicle Batteries	Describes the vibration durability testing of a single battery (test unit) consisting of either an electric vehicle battery module or an electric vehicle battery pack.
J2464	Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing	Describes a body of tests which may be used as needed for abuse testing of electric or hybrid electric vehicle batteries to determine the response of such batteries to conditions or events which are beyond their normal operating range.
J2711 (RIP)	Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles	Provide an accurate, uniform and reproducible procedure for simulating use of heavy-duty hybrid-electric vehicles (HEVs) and conventional vehicles on dynamometers for the purpose of measuring emissions and fuel economy.
J2758 (RIP)	Determination of the Maximum Available Power from a Rechargeable Energy Storage System on a Hybrid Electric Vehicle	Describes a test procedure for rating peak power of the Rechargeable Energy Storage System (RESS) used in a combustion engine Hybrid Electric Vehicle (HEV).
J2836-1	Use Cases for Communication Between Plug-in	Establishes use cases for communication between plug-in electric vehicles and the electric power grid, for energy transfer and other applications.

	Vehicles and the Utility Grid	
J2836/2	Use Cases for Communication between Plug-in Vehicles and the Supply Equipment (EVSE)	Establishes use cases for communication between plug-in electric vehicles and the electric vehicle supply equipment, for energy transfer and other applications.
J2836/3 (WIP)	Use Cases for Communication between Plug-in Vehicles and the Utility Grid for Reverse Power Flow	Establishes use cases for communication between plug-in electric vehicles and the electric power grid, for reverse power flow.
J2836/4 (WIP)	Use Cases for Diagnostic Communication for Plug-in Vehicles	Establishes diagnostic use cases between plug-in electric vehicles and the EV Supply Equipment (EVSE).
J2836/5 (WIP)	Use Cases for Communication between Plug-in Vehicles and their customers	Establishes use cases between Plug-In Vehicles (PEV) and their customer.
J2836/6 (WIP)	Use Cases for Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid	Wireless charging use cases
J2841	Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using Travel Survey Data	An equation describing the portion of driving in battery charge-depleting mode and battery charge-sustaining mode is provided resulting in an aggregate "Utility Factor" (UF).
J2847/1 (RIP)	Communication between Plug-in Vehicles and the Utility Grid	Establishes requirements and specifications for communication between plug-in electric vehicles and the electric power grid, for energy transfer and other applications.
J2847/2 (RIP)	Communication between Plug-in Vehicles and	Establishes requirements and specifications for communication between Plug-in Electric Vehicles (PEV) and the DC 0ff-board charger

	off-board DC Chargers	
J2847/3 (RIP)	Communication between Plug-in Vehicles and off-board DC Chargers	Establishes the communication structure between plug-in electric vehicles and the electric power grid, for reverse power flow.
J2847/4 (RIP)	Diagnostic Communication for Plug-in Vehicles	Establishes the communication requirements for diagnostics between plug-in electric vehicles and the EV Supply Equipment (EVSE) for charge or discharge sessions.
J2847/5 (RIP)	Diagnostic Communication for Plug-in Vehicles	Establishes the communication requirements between plug-in electric vehicles and their customers for charge or discharge sessions.
J2847/6 (RIP)	Wireless Charging Communication between Plug-in Electric Vehicles and the Utility Grid	Wireless charging messages, signals, etc.
J2889	Vehicle Sound Measurement at Low Speeds	Develop a test procedure to determine the sound output of electric and hybrid-electric powertrain vehicles at certain low-speed conditions.
J2889/1	Measurement of Minimum Noise Emitted by Road Vehicles	Specifies an engineering method for measuring the minimum noise emitted by road vehicles.
J2894/1	Power Quality Requirements for Plug In Vehicle Chargers - Part 1: Requirements	Provides guidelines and standards for the quality of the charging voltage and current at the vehicle itself.
J2894/2 (WIP)	Power Quality Requirements for Plug In Vehicle Chargers - Part 2: Test Methods	Address automatic charger restarts after a sustained power outage, as well as the ability to ride through momentary outage
J2907 (WIP)	Power rating method for automotive electric propulsion	Test method and conditions for rating performance of electric propulsion motors as used in hybrid electric and battery electric vehicles.

	motor and power electronics sub-system	
J2908 (WIP)	Power rating method for hybrid-electric and battery electric vehicle propulsion	Test method and conditions for rating performance of complete hybrid-electric and battery electric vehicle propulsion systems reflecting thermal and battery capabilities and limitations.
J2910(WIP)	Design and Test of Hybrid Electric Trucks and Buses for Electrical Safety	Covers the aspects of the design and test of class 4 through 8 hybrid electric trucks and buses.
J2929 (RIP)	Electric and Hybrid Vehicle Propulsion Battery System Safety Standard - Lithium-based Rechargeable Cells	Defines a minimum set of acceptable safety criteria for a lithium-based rechargeable battery system
J2931/1 (RIP)	Power Line Carrier Communications for Plug-in Electric Vehicles	Establishes the digital communication requirements for the Electric Vehicle Supply Equipment (EVSE) as it interfaces with a Home Area Network (HAN),
J2931/2 (WIP)	Inband Signaling Communication for Plug-in Electric Vehicles	Establishes the requirements for physical layer communications using Inband Signaling between Plug-In Vehicles (PEV) and the EVSE.
J2931/3 (WIP)	PLC Communication for Plug-in Electric Vehicles	Establishes the requirements for physical layer communications using Power Line Carrier (PLC) between Plug-In Vehicles (PEV) and the EVSE.
J2931/4 (WIP)	Broadband PLC Communication for Plug-in Electric Vehicles	Establishes the requirements for physical and data-link layer communications using broad band Power Line Carrier (PLC) between Plug-In Vehicles (PEV) and an EVSE, DC off-board-charger or direct to the utility smart meter or Home Area Network (HAN).
J2931/5 (WIP)	Telematics Smart Grid Communications between Customers,	Communication protocol including V2V, V2I telematics

	Plug-In Electric Vehicles (PEV), Energy Service Providers (ESP) and Home Area Networks (HAN)	
J2931/6 (WIP)	Digital Communication for Wireless Charging Plug-in Electric Vehicles	Wireless charging communication protocol
J2931/7 (WIP)	Security for Plug-in Electric Vehicle Communications	Electric Vehicle communication security protocols
J2936 (WIP)	Vehicle Battery Labeling Guidelines	Labeling guidelines for any electrical storage device at all levels of sub-component, component, subsystem and system level architectures describing content, placement and durability requirements of labels.
J2946 (WIP)	Battery Electronic Fuel Gauging Recommended Practices	Recommend practice associated with reporting the vehicle's (hybrid and pure electric) battery pack performance details to the automobile user.
J2950 (WIP)	Recommended Practices (RP) for Transportation and Handling of Automotive-type Rechargeable Energy Storage Systems (RESS)	Recommended Practices associated with identification, handling, and shipping of un-installed RESSs to/from specified locations (types) required for the appropriate disposition of new and used items.
J2953 (WIP)	Plug-In Electric Vehicle (PEV) Interoperability with Electric Vehicle Supply Equipment (EVSE)	Establishes the interoperability requirements and specifications for the communication systems between Plug-In Vehicles (PEV) and Electric Vehicle Supply Equipment (EVSE) for multiple suppliers.
J2954 (WIP)	Wireless Charging of Electric and Plug-in Hybrid	Establishes minimum performance and safety criteria for wireless charging of electric and plug-in vehicles.

	Vehicles	
J2974 (WIP)	Technical Information Report on Automotive Battery Recycling	This SAE Technical Information Report provides information on Automotive Battery Recycling. This document provides a compilation of current recycling definitions, technologies and flow sheets and their application to different battery chemistries.
J2981(WIP)	Starter Battery Identification and Classification	To provide the industry with the means to apply a set of rules for identifying and providing a common numbering system for lead acid starting batteries.
J2983 (WIP)	Recommended practice for determining material properties of Li-Battery separator	This SAE RP provides a set of test methods and practices for the characterization of key properties of Li-battery separator. It is not within the scope of this document to establish criteria for the test results, as this is usually established between the vendor and customer
J2984 (WIP)	Identification of Transportation Battery Systems for Recycling Recommended Practice	The chemistry identification system is intended to support the proper and efficient recycling of rechargeable battery systems used in transportation applications with a maximum voltage greater than 12V (including SLI batteries). Other battery systems such as non-rechargeable batteries, batteries contained in electronics, and telecom/utility batteries are not considered in the development of this specification. This does not preclude these systems from adapting the format proposed if they so choose.
J2990 (WIP)	Hybrid and EV First and Second Responder Recommended Practice	This RP describes the potential consequences associated with hazards from electrified vehicles and suggest common procedures to help protect emergency responders, recovery, tow, storage, repair, and salvage personnel after an incident has occurred with an electrified vehicle
J2991 (WIP)	Range Test Protocol for PEV (Plug-In Electric Vehicles) Small Task Oriented Vehicles (STOV)	This test protocol is being developed to create a voluntary guideline for manufacturers of PEV Small Task Oriented Vehicles (STOV's) to use to validate the range of their vehicles. The intent is to develop a laboratory test protocol for range testing that is repeatable and can be conducted using common dynamometer testing facilities.
J3097 (WIP)	Standards for Battery Secondary Use	To develop standards for a testing and identity regimen to define batteries for variable safe reuse. Utilize existing or in process standards such as Transportation, Labeling and State of Health. Add to these reference standards the required information

		to provide a safe and reliable usage.
J3004(WIP)	Standarization of Battery Packs for Electric and Hybrid Trucks and Busses	Identify existing standards and provide recommendations on design criteria and future standardization opportunities for battery packs on electric and hybrid truck and bus applications.
J3009 (WIP)	Stranded Energy - Reporting and Extraction From Vehicle Electrochemical Storage Systems	The intent of this document is to consider the type of information reported by the battery management system (BMS) and recommended discharge level dependent on a collision or vehicle fire. The document does not describe how the energy should be extracted.
J3012 (WIP)	Storage Batteries - Lithium-ion Type	This document will focus on (1) product and functional definitions that describe the uniqueness and similarity of lithium-based technology versus conventional lead-acid, and (2) development of new test procedures for performance and life cycle evaluation to establish new baseline for future non-conventional storage technology.