How can Electric Vehicles become the Dominant Design?

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Abstract

Due to technological developments and raising environmental concerns, vehicle industry is in a transformation process. Current dominant design in the industry is the internal combustion engine vehicle but there are already different alternative vehicles like electric vehicles (EV), hybrids, and vehicles running on ethanol or hydrogen. These alternatives started to expand and they are competing to have a strong position in the market. The question is which technology (EV, hybrid, ethanol) will have an important position in the future. This study focuses on the progress of electric vehicles towards being the dominant design in the vehicle industry and aims to give advices and suggestions to electric car manufacturers what they should develop and concentrate on in the future. To achieve this aim, interviews with Renault and Stockholm Municipality is conducted and analyzed in detail. Many manufacturers are interested in EV technology and started to invest in the technology to have a strong position in the future. Although EVs are ready to expand, there are still some obstacles in their way. Some of these problems can be solved in a short term, while others, mostly technology related improvements still require time.
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1. Introduction

In the followings decades, a big revolution is expected in the vehicle industry and the general expectation tends towards the idea that conventional cars using combustion engines will finish their golden era. In the near future, the decrease of oil production [4] will contribute to a much faster increase of oil and gasoline prices that we can perceive now. Also, several environmental regulations emerged concerning on the limitation of greenhouse gas emission for conventional cars. Soon, the whole industry needs to be changed in order to prevent a really big recession in the vehicle industry. There are several new vehicles which use new technologies and some can be listed as hybrid vehicles, plug-in hybrid vehicles, fuel cell vehicles and electric vehicles. However the crucial question is which technology will penetrate into the market and will be the dominant design in the future replacing nowadays dominant combustion engine vehicles.

Electric vehicles use clean power; they do not emit any pollutant substances to the atmosphere, referred as zero emission vehicles. Actually, these vehicles have as long history as conventional cars, but never succeed to really penetrate into the vehicle market. Recently the electric car market started to expand and many big car companies like Renault, Nissan, Mercedes, Peugeot and Toyota have started their innovative processes. It is expected that they will invest huge amount of money in the development of the electric cars.

Predicting the emergence of electric vehicles is not a new idea. There were several researches already in the 70s concluding that electric vehicles will penetrate to the market within decades, but it never happened. There were several reasons behind it, but electric cars could not reach a competitive level against conventional ones. There are many factors that can influence electric cars competitiveness including technology developing, new regulations and policies, customer behavior changes and economical reasons as prices or costs. These changes can contribute to the appearance and after the emergence of a new dominant design in the vehicle industry.
2. Scope

In this research paper, the previous and recent progress of electric vehicles will be analyzed regarding some facts that can contribute to increased competitiveness of EVs in the future. In this evaluation the dominant design theory can help us to understand better the market opportunity of electric cars. A deeper examination of the advantages and disadvantages of electrical vehicles compared to the recent conventional cars will be conducted. Also, it is crucial to do an investigation about the main factors that are the main reasons for changing the old dominant design. We will analyze customer behavior, how it changed recently, and we also consider the customer benefits of electric cars. Hence, we will be able to do suggestion what is the adequate future development way that EVs should follow to be able to become more competitive, then the dominant design.

To achieve this goal we will analyze the electric car industry in the past and present as well. We will also write about what factors that can contribute to the penetration of electric vehicles. On the other hand, the risks and the real difficulties of transforming a well established old industry will be considered carefully. Thus we will explore the opportunity of electric cars using the dominant design theory which can lead us to a stable conclusion what should electric car manufacturers concentrate on in the future. The related literature helps us to understand the recent and past situation, and to explore previous related researches. In the research part, we focus on the manufacturers regarding their predictions and strategies and on the local authorities supporting EV’s penetration in different ways. Although the dominant design is usually used as a global theory, we think that we can have a realistic approach and conclusion when we focus our researches on Renault’s recent EV strategy, on Sweden and the Nordic countries.

3. Problem

There are several factors showing that the vehicle market has to transform during the next few decades. First of all, the peak oil will have a big impact on the whole market. As the global demand of petrol increases year by year, the production needs the follow it. The demand will increase in the future as well, but the production will start to decrease soon. This scissors will lead to the fast grow of prices and to a big recession in the vehicle market that can influence the whole economy. This recession is preventable if we change the petrol demand to another fuel demand, for example to electricity. Another factor is the increasing importance of
environmental thinking. The environmental regulations are becoming stricter which can facilitate the penetration of new environmental friendly technologies. The future vehicle industry needs to change; the transformation will be slow, but finally total. The most important question is which technology can emerge as a new dominant design.

4. Purpose
There are several solutions to replace the petrol and gasoline car engines like natural gas engines, hydrogen fuel cell engines, hybrid engines and electric engines. The belief behind this research is that electric cars have better opportunity than the other technologies listed. In the recent years a new interest started to expand among car manufacturers and they begun to invest in electric vehicle technology to maintain their competitiveness in the future. The purpose of this thesis is to give advices and suggestions to electric car manufacturers what they should develop and concentrate on in the future regarding EV technology to make electric cars more competitive and push them towards the dominant design role in the vehicle industry. Researches among manufacturers and local authorities supporting EVs can provide us sufficient data to be able to get a relevant conclusion. The dominant design future cannot be surely predicted, but it can be analyzed in what areas EVs should be developed in the future in order to gain more competitiveness against conventional cars and other emerging technologies.

5. Aspects of the thesis

5.1 Perspective
The problem will be studied from the perspective of Renault as car manufacturer and companies related with deploying the necessary infrastructure, and their major problems that are important factors for the industry. These companies conducted already several researches focused on potential EV customers and on industrial technologies. Hence, their view about the future expenditure and development is really relevant. Finally, some analysis will be done from the perspective of local authorities (municipalities, government and organizations concentrating on EV market) focusing on an electric vehicle tender in Stockholm where decision makers have huge influence on the electric car market penetration. Detailed interviews with both parties will be analyzed to draw conclusion and reach some results about the future of electric vehicles.
5.2 Delimitation

Although the research mainly focuses on Sweden, analyzing the expansion of electrical vehicles requires considering many factors, and some limitations should be set for this research. When looked from the perspective of the society, using electrical vehicles instead of conventional vehicles is a change with a large scale. Calculating and analyzing the environmental and economical costs of this expansion is not the major concern of this research. For example, it is assumed that the long term environmental benefits of electrical vehicles are acceptable compared to the pollution caused when producing all the required electrical vehicles. In addition, another assumption is that there will be enough methods and resources to produce sufficient electricity to run these electrical vehicles in the future.

The vehicle market has already started to change. Regarding the engines; there are natural gas engines, hydrogen fuel cell engines, hybrid engines and electric engines. It means that new technologies started to expand, and in time there will be a new dominant design in the market replacing nowadays conventional car. Regarding the recent prediction, the combustion engine vehicles will still be dominant in the next 20-30 years, and only after we can talk about a new dominant technology. Also Wickelgren and Sprei point out those consumers in automobile industry are changing their preferences while buying vehicles very slowly [26]. Thus, this research has a clear limitation in time and as a result it will focus mainly on the fact what should be developed and changed in electric car technology in order to gain more competitiveness and the opportunity to become the dominant design. Focusing on the adequate way that EV’s manufacturers should follow.

This research is conducted from the perspective of car manufacturers and local authorities. Even though there are many other stakeholders in the expansion of electrical vehicles like the individuals, environmental organizations and governments, this research will not mainly focus on their benefits from the expansion.

Since electrical vehicles requires charging or changing of batteries, demand on these vehicles and their market expansion strongly depends on the price of electricity. In this research, it is assumed that the shifts in electricity prices have no negative effect in electrical vehicles technology.
6. Literature review

To better understand the actual and the possible future situation we will look into the history of electric cars, and we will explore the reasons that can contribute to the change in the dominant design in the vehicle industry. These are the oil prices that really depend on the future peak oil, the possible gain in greenhouse gas emission, the concerning regulations, the cost saving of electric car usage and the most curtail point the batteries. After that, the research will focus on the dominant design theory for explaining its different phases and approaches, then on other previous researches in this area.

6.1 History of Electric Vehicles

The invention of electric vehicles preceded the combustion ones and they were more attractive and popular at the end of the 19th century [1]. During the turn of the century, there were three main lines in the vehicle industry: steam, electric and petrol versions. At that time, electric vehicles showed the most convenient ones, because it was easy to start, it did not have a vibration, and it was not necessary to use the gear. Although they could only drive 50-60km, it can be considered enough at the time regarding the road coverage that concentrated only into the cities. The real peak in sales of electric cars was in 1910, but at that time there were much more vehicles with combustion engines due to fact that most of the combustion engines’ problems had been solved. From 1911, the start of the petrol engine was already easy and safe as the need of cumbersome hand crank was eliminated. Their range was already much longer compared to the electric ones. Due to the discovery of lots of oil fields, the fuel prices went down and finally the mass production (introduced by Ford in the 1920s [2]) decreased dramatically the price of nowadays conventional vehicles. From the start of the mass production they used to cost two or three times less than their electric rivals. These were the main reasons why electric vehicles disappeared until the 30s.

In the 70s new projects started in several countries to develop and produce electric cars. The main reason behind this interest was the OPEC oil embargo which resulted to the fast increase of oil prices. From 1972 to 1974 the oil price went up from a stable 20$ per barrel to 80$ [12]. The other reason was the air pollution caused by conventional cars that could be reduced by using electric vehicles. Also researches predicted that the battery technology will develop in a fast way if they start to do more research in that area, thus electric vehicles can be real competitors of conventional cars. In France some public firms formed a network supported by state founding to create a market for electric vehicles. It included EdF (energy producer), French Post Office, Paris airport, SCNF (train transport company) and the local public
transport company in Paris the RATP [5]. The aim was to clarify these companies’ needs as potential users regarding electric cars, but it was realized soon that technical solutions are far away from customer demands. Japan started a redevelopment program of electric vehicles in the early 70s. During five years they spent 19 million dollars in a national project conducting researches of electric vehicles. They constructed around 300 vehicles, but the main goal to build up 200,000 until 1986 was never reached [5]. USA also spent millions of dollars in electric vehicle project that begun in 1976. They developed electric vehicles and batteries as well. Their initial expectation was really optimistic (reaching 50,000 yearly vehicle production [5]), but soon in the early 80s the program was ceased.

In the 90s an increased interest came back for electric vehicles. In California, the legislation of Zero Emission Vehicle Mandate put the focus back on electric vehicles. They wanted to solve the pollution problem in the inner cities. The goal was to lower the pollutant emission of cars by reaching 10% of zero emission vehicles among new cars sold by 2003 [1]. Some car companies started their electric car development, but they never reached a high quantity, and finally all companies stopped their development projects. Meanwhile in Europe some new legislation sponsoring electric vehicles were formed. In Switzerland the local regulations reduced the conventional vehicle transport in inner cities promoting the usages of electric vehicles. Also JOULE I and II European programs contained expectations about electric cars [1].

In the past years many discussions and researches focused on the climate change and the CO₂ emission of conventional cars. Now, in many countries there are more taxes and restrictions on high CO₂ emitting cars. Those factors contributed to the investments in electric cars by car manufacturers. Almost all bigger firms have an electric car strategy for the future as Renault, Nissan, Mercedes, Peugeot and Toyota [9]. Renault will launch its first two electric cars this year, and will increase it by two new types in the following years [10]. Recently, the European Commission accepted a new transportation strategy (Transport 2050) concerning to Europe. The goal is to create a more competitive transport system by increasing mobility, to reduce the oil dependency of transportation and to decrease CO₂ emission by 60% by 2050 [11]. That will facilitate the penetration of alternative vehicle solutions like electric cars.

Electric vehicles were there already from the beginning of the vehicle industry. But they could never be able to be enough competitive against gasoline cars. The battery capacity limited the range of the cars, and the missing infrastructure made the fueling difficult for electric cars. The advantages of conventional cars were huge in the past, but nowadays new
regulations, customer’s behavior changes towards more environmentally friendly technologies and the upcoming improvements can redesign the vehicle market in the future.

6.2 Reasons for change in dominant design

There are several reasons behind a change in a dominant design in the field. The following chapter will focus on the future changes which can influence the whole vehicle industry. These reasons can be listed as the change in oil prices, the interest for a more environmental technology in form of new policies, the customer acceptance regarding the technology economy and the most crucially the improvement in battery technologies.

6.2.1 Peak oil

When the production of the oil reaches its maximum, it is called the peak oil that is a crucial point in the vehicle market. From the beginning of the oil production, the demand for oil increased year by year. Until now, the production could follow this increased demand. When the production will decrease and the demand remains still increasing, it will create a bigger and bigger scissor that can cause a huge increase in the oil prices. To avoid it, the increasing demand should be satisfied by another type of fuel.

There are several researches about the peak oil [4]. The most pessimistic ones estimate the peak oil for the current years, but the optimistic estimations are also close to 2020. It does not mean that after the peak oil conventional cars will disappear, but the faster increasing oil prices can lead to the penetration of new technologies. Oil prices are really dependent on crises. During the oil embargo in 1973-74, the crude oil prices went up to 80$ per barrel from a stable 20$ [12]. After that, prices stabilized around 30$ per barrel. The recent recession from 2008 had a big impact on the oil price as well. It reached its maximum in 2008 with more than 140$ per barrels. Today the actual price is more than 100$ [13].

A big recession in the oil industry like the decreasing production could cause the huge increase of oil prices that can facilitate the penetration of alternative fueled cars.

6.2.2 Greenhouse gas emissions

A major advantage of electric vehicles against the combustion engine vehicles is the amount of greenhouse gas released into the atmosphere. Wickelgren and Sprei points out that a study by Swedish Road Agency shows that when compared a new car in EU to a new car in Sweden, it emits 18% more CO₂ per kilometer [26]. In addition the car fleet in Sweden is larger and heavier than the average in EU and this has a bigger affect on the environment
According to the same research, although the average CO₂ emission rate for each car is decreasing, the increase in the sales resulted with a total of 30% raise in the emission rate between 1990 and 2008 [26].

The following researches by T&E in UK and Germany are two examples to show how much this pollution can be prevented while using electric or hybrid vehicles in the following years and they will be analyzed in further detail. The saving rate is not so high in the short run due to small numbers in the market however it is expected to grow dramatically over time [3]. When considering the effect of greenhouse gas emission regarding the change of dominant design in the market, it is assumed that the consumers are, or will be, aware of this fact and consider it when deciding on buying an electric vehicle.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV</td>
<td>PHEV</td>
<td>EV</td>
<td>PHEV</td>
</tr>
<tr>
<td>Business as Usual</td>
<td>3,000</td>
<td>1,000</td>
<td>70,000</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>4,000</td>
<td>1,000</td>
<td>600,000</td>
</tr>
<tr>
<td>High-Range</td>
<td>4,000</td>
<td>1,000</td>
<td>1,200,000</td>
</tr>
<tr>
<td>Extreme Range</td>
<td>4,000</td>
<td>1,000</td>
<td>2,600,000</td>
</tr>
</tbody>
</table>

**Figure 1 – Number of EV and PHEV in UK [3]**

This figure is included to show different scenarios for the number of EV and PHEV’s in the near future in UK. According to this research some calculations for CO₂ emission in UK is done considering the growing number of vehicles, and the results are shown in the figure below [3].
This research shows the expected saving in CO₂ emission in percentages in four different scenarios. As it can be seen from the figure, the savings can start from 2% in the current situation and it can even reach 15.77% in the best scenario. There are currently a total of almost 5000 EV’s and PHEV’s in UK. [3] In the business as usual scenario it can go up to a total of 3 million cars by 2030. Moreover in the extreme range scenario, this total number is expected to achieve the number of 20 million. [3] It is possible to conclude from this research that transition to electrical vehicles can have a huge effect on the environment if their expansion is supported and fastened.

### 6.2.3 Regulations and policy

An important factor that can lead to a new dominant design in the vehicle market is the regulations and policies that are designed by authorities due to the public pressure and environmental concerns. New regulations and policies related to the environment and new engine types can be grouped into two categories. One of these categories can be described as policies that encourage the community to buy vehicles with engines that are different from combustion engines, while the other group can be described as regulations designed to discourage people from buying vehicles with combustion engines and discourage manufacturers from producing these vehicles by that way.

To encourage the community to use electric vehicles, various countries propose important tax incentives or credits to their citizens. Wickelgren and Sprei indicate that in average, cars in Sweden are among the heaviest and most fuel consuming vehicles in Europe [26]. According to this information we can see similarities between the car fleets of Sweden and USA. To start with, Internal Revenue Service (IRS) of United States Department of Treasury, which can be described as the tax collection agency, provides credits up to 7500$ when purchasing an...
electric vehicle after 31st of December, 2009 [19]. In addition, to encourage conversion from combustion engines to electrical engines, IRS also offers a credit up to 4000$ for electric vehicle conversion kits [19]. Moreover, Swedish Ministry of Environment indicates that greenhouse gas emissions should be kept in a level which has no harmful effect on the environment or on the people [20]. To achieve this objective, government allocated almost 400 million Euros for the period 2009-2011 to address the environmental concerns [20]. Starting from 2007, the Swedish government introduced a green car rebate of 10000 SEK to encourage people to purchase fuel-efficient vehicles [21]. A research conducted by Lindfors and Roxland showed that introduction of this rebate had a positive impact on the market share of green cars, both EV’s and PHEV’s. They also point out that there would already be an increase on the market share of these cars, and the increase in the market share got higher with the help of this rebate [22].

European Federation for Transport and Environment AISBL conducted a research due to environmental concerns and indicated that electric and plug-in hybrid vehicles will be useful in reducing oil consumption and CO₂ emission. In addition, they point out the following three aspects in EU legislation that need to be changed in order to achieve that goal. First of all, they conclude that long term CO₂ standards for cars should be decreased and it should be 80 g/km by 2020, and 60 g/km by 2025 to hasten the penetration of electric vehicles to the market [3]. Moreover, they state the following two points: “Quantity and quality of electricity used in electric cars must be measured.” and “The power sector has to be decarbonised.” [3]. As indicated in the delimitations part of this research, these two points are not within the scope of this research.

On the other hand there are regulations that try to force manufacturers to design and produce vehicles with a higher level of energy efficiency and lower greenhouse gas emission. An important example for these regulations is the Cars and CO₂ regulation adopted by EU in the year 2008. According to this regulation, car manufacturers should adopt their fleet in a way that the average level of greenhouse gas emission of their fleet should decrease almost 15% by 2015 [3]. In addition, a higher level is planned for the year 2020 and it will be reviewed in the near future [3].

European Commission is also trying to decrease the dependence on oil and the level of greenhouse gas emission due to transportation by 2050. In March 2011, the commission
adopted a new strategy called Transport 2050 regarding this subject. In this strategy, it is stated that Europe’s transportation system should be transformed by 2050 and one of the major points to achieve this goes through “having no more conventionally-fueled cars in cities” [11]. This strategy also includes decreasing conventional vehicles by 50% in cities by 2030 [11]. Other important goals are the reduction of oil dependency of transportation and to decrease CO$_2$ emission with 60% by 2050. Moreover, this strategy is not only concerned with cars in urban transport but also concerned with air and ship transportation. This report shows that European Commission is aware of the current high emission rate and will take action for the reduction.

6.2.5 Batteries

A crucial part of electric vehicles is clearly the battery, since the power, the range and a huge part of the cost of electric cars depend on the battery. In the past, the battery technology could not develop fast enough to compete with petrol engines, thus electric cars could not stay into the market. From 1910 until 1990, the capacity of the batteries only doubled which can be considered as a really slow improvement compared to other technologies. Considering for example computer chips where the capacity doubles approximately every second year (Moor’s law). One of the reasons of this slow development was the lack of technological interest. As batteries were used only for small energy storage with relatively low power, the technology was more or less stuck in the same level. The increased demand for portable electronic devices (mobile phones, laptops, GSP) pushed the technology to a development direction from the beginning of the 90s. Thus, new battery technologies started to emerge.

There are several important factors for batteries; the capacity (stored energy per kg), the power (produced power per kg), the weight, the cost and the lifetime. Those are usually used to compare the different battery technologies.

One of the oldest battery technology is the lead acid battery invented in the middle of the 1800s [3]. It was used in the first electric cars. It provided enough power and range (50-60 km) in the first decades, but soon from the turn of the 1900s, conventional cars became more competitive. While combustion cars increased their range and reduced their cost, the battery technology could not develop so fast and provided less range for a higher price. Lead acid batteries are still used nowadays. We can find them in all conventional cars (giving power to starter motors), and in large backup power systems (i.e.: computer labs). Lead acid batteries are really cheap, but both their power and energy density is low. Thus they are not adequate to be used in electric cars.
Nickel-cadmium batteries - invented in the beginning of 1900s - give more power and capacity. It is also used for backup system for power trains or airplanes. But its weight compared to the provided energy is too large to be used in electric cars. Also, lead and cadmium are toxic materials; they are more harmful to the environment than other battery technologies.

Nickel-metal hybrid batteries provide more power and capacity on the same weight, but they cost much more compared to lead-acid or nickel-cadmium batteries. Their lifetime is also better then the two previous ones reaching 8-10 years. They can gain power during regenerative braking (when the braking power charges the battery) [3]. Most of the problem with this technology is the difficult charging method and the cost. Nickel is ten times more costly than lead that is not supposed to be reduced much in the future. Also, it cannot be charged safety over 50 Celsius, hence a built in cooling system is needed for charging [14].

From 1991 lithium-ion batteries started to appear [3]. Nowadays this is the dominant technology for portable devices (mobile phones, laptops, mp4 players). They have much better energy density compared to all previously mentioned batteries (that is the crucial range factor for EVs), and their power density is similar to nickel-metal hybrid battery. Lithium-ion batteries do not loose capacity during charging when they were not fully depleted, but they tend to be unstable by overheating, overcharging. Another big advantage of Li-ion batteries is the possibility of fast charging. Using a common lithium ion compound the full charging time can be 30 minutes compared to 7-8 hours with normal charging method [3]. From 1991 the cost of Li-ion batteries went down from 3.17 $/Wh to 0.28 $/Wh until 2005 that is 11 times reduction, while the capacity increased from 88 Wh/kg to 202 Wh/kg [15]. Although this development in the past 15 years was faster than in the previous 100 years in battery technology, Li-ion batteries are still very expensive for EVs (10 – 15 000 $), and the cost reduction slowed down from 2000. According to Renault their batteries will last 8-10 years with normal usage [18]. That lifetime is around the same as for Nickel-metal hybrid batteries.
Regarding all the factors, lithium-ion batteries seem to be the best technology for electric cars as it provides higher range and faster charging method than the other technologies. Although the cost of these batteries is still quite high, the capacity development can cut down the prices as well.

Another interesting long-term point of view is the availability of Lithium, the most crucial part of Li-ion batteries. According to the US Geological Survey there are 13 million tons reserves on the Earth which is only estimation; it can grow in time [16]. The overall lithium production reached 25 000 tons in 2011 from which 26% were used for batteries [15]. If the production stayed in the same level, reserves could provide enough lithium for hundreds of years. Although it seems to be enough time, considering the fast increasing demand for lithium it can be a weak point of Li-Ion technology. However, the possible new reserves’ discoveries and an efficient recycling method could prolong the lifetime of lithium on Earth.

6.3 Frame of reference

In this research the dominant design theory will be used to understand better the future of the electric cars. To narrow down due to time constraint, the research will mainly focus on Sweden and the Nordic countries, where we will use the dominant design theory to find relevant conclusion about the crucial areas of EVs where they should develop the most to be more competitive. More precisely, the dominant design theory provides us sufficient information to understand the competitive disadvantages and possible advantages of EVs in the past and nowadays as well. Thus, it gives us a better opportunity to analyze and find out
the crucial factors that need more technological development. For that reason, the dominant design theory and its phases will be explored in detail in the following part.

6.3.1 Dominant Design

The dominant design is the leading technology that is followed by the market [6]. The dominant design usually has many advantages compared to other alternative technologies. By the time many infrastructure elements and intellectual knowledge accumulates around the dominant design which leads to the fact that all competitors use the same technology in the specific industry. It is not necessary that the dominant design is the only alternative solution, but they are well established standard products. A good example is the QWERTY keyboard we use for all computers [7]. It followed the early typewriters then it became the standard keyboard used by everyone. Although there are other kind of keyboards that can increase the writing speed by 20-30%, the QWERTY keyboard is so well established that no one can think about its replacement.

However dominant designs can change, when new and better technologies emerge. In the mobile phone market, almost every three years there is a new dominant design that is now the Smartphone. When a new technology is developed it can attract more and more scientists and entrepreneurs. Thus the technology can improve and new products can appear in the market. In time this new technology can be the dominant design.

Regarding the past 100 years the internal combustion engine was the dominant design in the vehicle industry. We have already explained how it could become the leading technology from the three alternatives (steam, electric and petrol engines). We can also think about how well established is the infrastructure within the industry. Petrol stations can be found almost everywhere. It is really easy to buy a car; there are huge amount of choices and many retailers. The maintaining, repairing, recycling system is also easily available for all customers. There are a lot of events connected to this technology, from car and motor races to car and motor festivals. We can conclude that it is not only the technology advantages that give dominancy to the dominant design, but also all the physical and intellectual establishments around it [7]. Thus, a new technology needs to be much better than the dominant one in order to become the dominant design.

6.3.2 Phases for an emerging dominant design

The Abernathy and Utterback model is about how an emerging technology becomes a dominant design regarding the competitive environment [8]. In this model, product and
process innovation, competitiveness and organizational structure are all used together. The model consists of three phases, the fluid phase, the transitional and the specific phase. These phases have different impact on companies, on the market and on resources regarding the innovation.

In the fluid phase there are uncertainties regarding the technology and the market. The way of manufacturing is mostly dependent on the high-skilled labors. There is no clear idea about how and where will the market develop and about new way of process innovation. Usually there are many small firms, using their differentiated products in the competition. Companies use different materials for the production, thus suppliers have no important bargaining power. The main threat comes from the old technology, but new entrants with radical innovation can be competitive as well. Firms can follow two kinds of behaviors. They can wait for the new dominant design in the market and then they can take advantage of their already established customer contacts, distribution channels, suppliers and value added services. The other possibility is to establish the dominant design in the market and to use the time advantage against the others.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fluid Phase</th>
</tr>
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<tbody>
<tr>
<td>Innovation</td>
<td>Product changes / radical innovations</td>
</tr>
<tr>
<td>Product</td>
<td>Many different design, customization</td>
</tr>
<tr>
<td>Competitors</td>
<td>Many small firms, no direct competition</td>
</tr>
<tr>
<td>Organization</td>
<td>Entrepreneurial, organic structure</td>
</tr>
<tr>
<td>Threats</td>
<td>Old technology, new entrants</td>
</tr>
<tr>
<td>Process</td>
<td>Flexible and inefficient</td>
</tr>
</tbody>
</table>

**Figure 4 – Fluid Phase**

By the time, manufacturers start to know more and more about the new technology. The innovation spreads out, and the market starts to grow and standardization appears in the use of the new technology. That is already the transitional phase. The new technology becomes the standard technology referred as the dominant design. The dominant design is a product design within a market where different products have the same characteristics and main components.
“The dominant design product has features that competitors and innovators must adhere if they hope to command significant market share following” [6]. Companies who can react fast can establish their products as standards gaining some types of monopoly in production. Firms usually follow two strategies: consolidation of their product positioning or increasing the production capacity in order to reach a mass production.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Transitional Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation</td>
<td>Major process changes, architectural innovations</td>
</tr>
<tr>
<td>Product</td>
<td>Less differentiation due to mass production</td>
</tr>
<tr>
<td>Competitors</td>
<td>Many, but declining after the emergence of a dominant design</td>
</tr>
<tr>
<td>Organization</td>
<td>More formal structure with task groups</td>
</tr>
<tr>
<td>Threats</td>
<td>Imitators and successful product breakthroughs</td>
</tr>
<tr>
<td>Process</td>
<td>More rigid, changes occur in large steps</td>
</tr>
</tbody>
</table>

**Figure 5 – Transitional phase**

During the specific phase the dominant design has already emerged. The competition focuses on changes from differentiation to product performance and cost effectiveness. The companies know better the market and they try to be specialized to different market segments. Production machines are high-specialized, thus the high-skilled labors are less important. As the materials used for the production is concentrated and consumers have better knowledge about the products, both suppliers and customers power increase. To maintain the competitiveness, companies can use their supplier’s contacts, distribution channels that are also barriers to other entrants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Specific Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation</td>
<td>Incremental innovations, improvements in quality</td>
</tr>
<tr>
<td>Product</td>
<td>Heavy standardization in product designs</td>
</tr>
</tbody>
</table>
## 6.4 Previous researches on dominant design in the vehicle market

When it comes to consider the level of expansion of vehicles with different engines in the future, it is possible to come across various researches on the subject. Two important researches were conducted by Greenpeace and Boston Consulting Group (BCG) recently. These researches consider different scenarios and they give important clues about the expansion of the hybrid and electric vehicles in the market. To understand the future of
electric vehicles it is important to look at the results of researches conducted by different organizations with different points of view. Comparing a research conducted by an environmental organization like Greenpeace which tries to decrease the level of pollution in the environment, and a research conducted by a consulting group which is mostly hired by companies to increase their profits can give us better clues about the subject.

In the analysis conducted by BCG, the options for efficient and low CO₂ emitting power trains are grouped into three categories which can be listed as alternative fuels, advanced internal combustion engine technologies and electrification [23]. However, this analysis also indicate that these three options are not totally away from each other but coexist partially in different models [23]. An example for this classification and the level of connection between these options can be found in figure 7.

![Image: Classification for Power Train Technologies, BCG, 2009 [23]](image)

Figure 7 - Classification for Power Train Technologies, BCG, 2009 [23]

After categorizing the vehicles, three different scenarios were set by BCG to analyze the future of electric vehicles. These scenarios include variables from oil prices to public concerns and regulations. Acceleration scenario (scenario 3) includes very positive affects for electric vehicles expansion while the slowdown (scenario 1) includes negative effects. The results of this research can be found in figure 8. BCG concludes that in the four regions explored, (Western Europe, North America, Japan and China) the vehicles with internal combustion engine will still be dominant in all scenarios although the market share for the other vehicles increases [23].
The results of another research conducted by Greenpeace also comply with the BCG research explained above. Greenpeace similarly categorized the vehicles into five categories and conducted research for ten regions in the world. The details of this research can be found in figure 9. Greenpeace reports also shows great increase in the market share of electric vehicles by 2050. Despite the dramatic raise in the market share, this report also points out that there still won’t be an electric or hybrid vehicle dominancy in the world [24].
7. Research

7.1 Methodology

Our thesis will focus on qualitative approach methodology to collect sufficient information in order to answer our research question, to give suggestions and advices about the crucial factors of electric cars that need to be developed in the future to make EVs more competitive. We drive our qualitative methodology by interviews with actors who have important roles in the future EV market expansion. The surveys will be analyzed empirically taking into account the dominant design theory. We use qualitative research strategy that provides us deeper analysis opportunity regarding our research purpose than a quantitative methodology could give us. We are interested in the opinion of the interviewed persons that suits better to our qualitative strategy. The analysis of qualitative surveys should be done carefully; we will also compare them in an adequate way to be able to draw our overall conclusion.

There will be two part of our research surveys. One is focusing on the manufacturer side and the other one on an electric car tender that takes place in Sweden. Both surveys are concentrating on the Nordic countries, mostly on Sweden. The method of the research is driving interviews with the project leaders of the specific area. Our manufacturer research is focusing mainly on the customer’s benefits and disadvantages from the EV manufacturer point of view. The possible development strategies, market penetration plans and the necessary infrastructure are also part of the survey. The EV tender survey is focusing mainly on the same areas as the previous one, but as a plus the local authorities’ (government, municipalities) influence on the market is taking into account. Both actors have already analyzed the EV market opportunity and the current EV technology that gave them a realistic approach about the future development direction. Hence, we can compare both side opinion, and use it with the dominant design theory to be able to provide a relevant conclusion.

7.2 Research questionnaire

We conducted two longer interviews, one with the Product Manager of Renault’s electric cars if the Nordic countries. The other interview we made with the Project Manager of an ongoing electric car tender in Sweden. Renault will put into the market two types of EVs in this year 2011 (Fluence Z.E. and Kangoo Van Z.E.), and two more types in the upcoming 2 years (Twizy and ZOE). Renault tries to cover a wider range of customers with these different types of EVs that can be an important factor to become the market leader. Renault Fluence ZE is
described as a safe, quite, comfortable, easy to use with automatic transmission and environment friendly family car [17]. In the light commercial vehicle category, Renault will introduce the Kangoo Van ZE [17]. It is mostly attractive for the companies and government institutions which want to give a message about their care for the environment. Another model introduced by Renault is the Twizy [17] that is expected to be on the market at the end of 2011, beginning of 2012. It is expected to cost similar to a scooter with three wheels and has only two seats. It is a model that targets just city use where traffic or parking space is a problem. Thus, Renault is a serious future actor in the EV market. Their experience and market view could give us really relevant information about the present and future opportunities and the weakness and advantages of EV. The manufacturer questions concern mainly to Renault’s strategic decision, its market view, to customer behavior, technological advantages and disadvantages, possible development directions, expansion strategy, related infrastructure and agreements with local authorities. In the other interview about the electric car tender, we were focusing on the purpose and the possible results of the tender. We also asked about the advantages and disadvantages of EVs from a customer point of view, about the possible technology improvements, and about the possible given support from the government or local authorities. We will analyze the two surveys carefully in the following parts, and also compare them while we take into account whether these factors are accordance with the dominant design theory.

7.3 Analysis of the results

In the appendices the detailed answers can be found. In the following chapters we analyze these answers while we also consider the concerning part from the dominant design theory and its phases.

7.3.1 Renault survey

What are the most important reasons of Renault electric car investment?
The main reason is the environmental responsibility as the vehicle market has a large influence in the CO₂ emission. It is accordance with the environmental regulations and trends that are more and more strict. These regulations can encourage manufacturers to develop EVs. Thus it can contribute to the acceleration of the fluid phase of the dominant design.

Why does Renault invest in electric cars and not in other alternatives (like Plug-in hybrid or Fuel Cell Vehicles)?
Here, the environmental fact got again the main importance. Electric cars can have the most positive impact in the environment. PHEV is not a full solution. But Renault did not analyze the fuel-cell as a possible solution. They think they have better chance in EV market. According to the dominant design theory, in the fluid phase firms can follow two strategies. They can wait for the new dominant design in the market and then they can take advantage of their already established customer contacts, distribution channels, suppliers and value added services. The other possibility is to establish the dominant design in the market and use their time advantage against the others. Renault chooses the latter one. Also, we see the emergence of different technologies that is specific for the fluid phase. However, the technological experience in electric cars is bigger than in fuel-cell technology (it is really new). On the other hand, hybrid cars gained increasing market share in the past years. It means that besides conventional cars, there are other technologies that are considered as threats against EV technology.

*What do you think, what are the most important reasons for customers to buy an electric car?*

The two main reasons mentioned in the answer are the environmental thinking and the new way of driving. The former one is again about the environment that is a new way of thinking that can accelerate the emergence of EV technology and accelerate the step from fluid phase to the transitional. The new way of driving can be also a really important factor. If customers prefer to drive EVs more than other type of cars, it is a big technological advantage that can be important during the technological selection.

*What are the main disadvantages of electric cars nowadays compared to conventional ones?*

The range was mentioned as a disadvantage. It is around 160km with a fully charged battery compared to 600-700km for a conventional car. Here we talk about one of the biggest threat from the actual dominant design. According to the dominant design theory radical innovation can help to make new technology more competitive. In that case it is obvious that this innovation is needed for the batteries. The other mentioned disadvantages were the soundless driving, and customer fear from high technology. We think that it is much easier to solve both previous factors than to solve the battery problem. It is interesting that the price was not mentioned as a negative factor. This is because of the new way of handling the batteries. Renault will rent out the batteries, and customers do not have to pay the huge initial cost for EVs that sometimes is the double compared to the price of conventional cars.
What do you want to improve in the future among these disadvantages to make electric cars more competitive? How do you want to improve them, do you have a strategy?

The range was mentioned as a crucial factor that can be improved by battery technology development or by using better the energy (energy consumption optimization and better charging). During the fluid phase of the dominant design a radical innovation can be really competitive. A radical innovation in both areas (better batteries or better energy usage) can increase the competitiveness of EVs. Such an innovation was for example the regenerative braking that charges the battery during the braking of the car. Renault wants to focus on a better usage of energy then on the battery technology. Our opinion is that the battery improvement is more crucial than the energy consumption optimization. The other important factor mentioned was people’s education about driving behavior. Averagely we drive less than 60km per day that really fits to electric cars. Here an important factor is the proper marketing to reach potential customers with this important message. That can be achieved by using the already established customer contacts.

Who are Renault's biggest rivals?

Almost all big car companies invested in electric car technology. Mitsubishi, Peugeot, Citroen will have one common electric car. Volvo and Mercedes will have their own EV. These manufacturers have only one type of EV, while Renault will have 4 different types. That gives a competitive advantage to Renault. A quite big Chinese company (Build Your Dream) will produce EVs in a larger scale, but they are not in Europe yet. Thus, in Europe it seems that Renault can be the market leader at least at the beginning. That refers also to one of the dominant design strategy where the company tries to use its time advantage (more types in the same time) against the others.

What is your calculation, how bigger is the price of an electric car compared to a conventional one from the same category?

The cost of an electric car without battery is 5000-6000 Euros more than a conventional car. Considering that the battery can be 8000-12000 Euros, the overall price can be the double of the gasoline car’s price. In some countries there are government subsidiaries that can compensate the surplus price without battery. But Renault takes advantage from the high battery prices. Instead of selling the battery to the customers, Renault rents it out for about 80 Euros per month. According to Renault their batteries will last 8-10 years with normal usage [18]. Calculating with 80 Euros monthly cost, it is 7680 – 9600 Euros in 8-10 years that
means the renting strategy can be manageable. Producing batteries is a huge initial investment that only returns after 8-10 years. We think that investment is a really big risk. It means that Renault has to finance always the complete battery production and only will gain back the invested money after 8-10 years. In long term this financial sustainability is really questionable, mostly when the number of EVs will grow quite fast. On the other hand it is a really big market advantage considering the fact that driving more than 12000 km per year with a Renault EV will cost less than using a gasoline car while the maintenance costs are expected to be also less. The battery rental question points out also a related part of the dominant design fluid phase when there is no clear idea about new way of process innovation. Maybe the leading way will be the battery leasing.

Do you think customers are open for electric cars here in Sweden? On what kind of customers will you focus in the near future, and on what kind in long term?

Several positive factors were enumerated. Swedes are really open minded and environment friendly. It shows a change in the customer behavior that is advantageous for electric cars. The already established car heating infrastructure can be used for battery charging that also facilitates EVs’ penetration into the Swedish market in the following years.

The first customers will be bigger companies and municipalities where the environment care is important. That is why Renault takes part in EV tenders like the Stockholm City EV initiation. Companies buy a bigger amount of fleet that gives an opportunity to Renault to cut down the prices (and gain market advantage again).

In which countries will you put into the market the electric car in the first step, and then what are the following ones? What is your strategy in the Nordic countries to expand the market?

Renault focuses firstly on countries where there are subsidiaries or tax reductions given by the government for buying an EV (Israel, Denmark, France and Spain). The market entry for Sweden is estimated for 2012. That strategy is reasonable, the initial high cost of EVs are more affordable for customers when they get a subsidiary. But it concerns to all EV manufacturer, thus it is an overall competitive advantage of electric cars against conventional ones. Those steps are important in the fluid phase to increase the competitiveness of electric cars. In order to expand in the Nordic countries, marketing campaigns and the preparations of retailers were emphasized. Again, it is crucial to reach the potential customers and show them the advantages of electric cars.
What is your strategy for the infrastructure? Do you have some interested potential investors in the infrastructure in the Nordic countries?

Better Place will establish a pilot charging and changing system in Denmark. But in general Renault works together with local energy companies that can establish the necessary infrastructure (the charging spots). Also, some supermarket chains (ICA or McDonalds) have already installed some charging points in their parking area. The infrastructure is also a crucial factor for electric cars. The fact that the infrastructure is established by other actors than the EV manufacturers helps the EV market expansion (manufacturers do not have to invest in the infrastructure).

Do you have already some agreements in the Nordic countries governments, or municipalities? What is your expectation from the government (grants, subsidiaries, tax rebate) especially in the Nordic countries?

There is no direct agreement with governments, but as it was already mentioned many countries give tax rebate for newly bought EVs (in Denmark it is 100% price reduction). The Swedish government promised to give a subsidiary for buying an EV, but it is not accepted yet. Also in Sweden it would be important to have some reserved parking places for electric cars with charging spots in cities. Municipalities can help in the establishment as well. In time, when the competitiveness of EV is enough increased compared to conventional cars, these subsidiaries can be reduced or diminished. As it was already mentioned these factors contribute to the overall EV market expansion. It can accelerate the fluid phase in order to step into the transitional phase where the new dominant design of the vehicle market can be the electric car.

7.3.2 Electric car tender survey

What is the main purpose of this tender?

The main purpose is to increase the expansion of EVs in the Swedish market. During that period, local authorities and companies will have the chance to show society their responsibility for the environment. As analyzed in the Renault survey, the main target group of customers in the beginning is the municipalities and companies. Their increased interest will facilitate the expansion of EVs. As the tender helps this expansion, we can say that it can accelerate the transition from the fluid phase to the transitional phase in the dominant design theory.
Who are the initiators of the tender, and how can they contribute to it?

The initiators of the tender are Stockholm City, Vattenfall AB and SKL Kommentus AB. The tender is aimed to choose among applicant manufacturers that will satisfy the needs of the participating organizations who are the potential EV buyers. First application phase is closed for the tender.

Who can participate in the tender, and who are the actual participants?

Only organizations are accepted to participate in the tender and they signed a framework agreement which bounds them to purchase EVs from the manufacturers chosen in this tender. The group of actual participants is the manufacturers target market. Selecting one company among many EV producers gives a bigger market share to the EV manufacturer and a better opportunity to become the market leader. In the future it can facilitate the standardization process that is usually related to the market leader already in the transitional phase of the dominant design.

What are the advantages for companies, municipalities to participate in the tender?

Usually tendering is a long and expensive process. In that case, the tender organizer does all the tendering processes instead of each municipality and company. It is indicated that EV prices are high since the technology is only in the fluid phase. Decreasing the overall cost of buying an EV will definitely make electric cars more attractive for potential customers.

How big is the support from the Swedish Energy Agency?

The SEA will give subsidiaries for the first 1000 bought EVs, which is a maximum 25% of the extra cost for an EV. As mentioned before, high prices are one of the challenges a new technology should overcome in the fluid phase to be able to proceed into the transitional phase. Hence, subsidiaries from Energy Agency increase the competitiveness of EVs and their expansion.

What are your expectations for the future regarding EV expansion?

Although officially it is not declared yet, the government promised to give 40 000 SEK for private persons buying new EVs from January 2012. Government support is needed as indicated by Renault survey. With the support of authorities, the expansion will be easier
among private customers, since the initial cost of buying an EV is considerably high compared to a regular one.

*Why do you think, electric car is the future alternative solution in the vehicle market?*

EV is just one solution among many others. This is another property of fluid phase when different technologies compete with each other. Although they are not currently in real competition, it is expected to happen in the long term. Stockholm City already experienced in EVs in the 90s, but due to some technological problems, they could not become really attractive. However in their point of view, it is hard for EVs to become a dominant design with their current situation.

*What do you think, what are the main disadvantages and advantages of electric cars nowadays?*

A major advantage is that EVs have much less pollution impact. An economic advantage is the low maintenance cost since electric engines do not contain moving parts. It is important to analyze the origin of the electricity used in electric vehicles. When the electricity does not come from renewable sources, using an EV produces pollution indirectly as well. The disadvantages of EVs are clearly their prices and their limited range. As already explained in Renault Survey analysis, the major threat still comes from the old technology. The conventional cars are still in the specific phase regarding the dominant design theory with low prices and high technological developments, hence they can be considered as the greatest rivals of EVs.

*What do you think in which area EVs have to develop the most, and do you think they can achieve it?*

Major drawbacks of the EVs are obviously the range and price. These can be solved through technological improvements but there is no clear solution how to achieve this development. That is also a specialty for fluid phase in the dominant design theory. On the other hand, the range of EVs is not as negative as it is usually seen, considering the average daily driving habits. It is already enough for inner cities and for suburbs. However, an educative marketing campaign can teach some facts to the customers like the fact that they do not need a very long range to use a car in the city.
What do you think how can municipalities, companies or the government contribute to EV development here in Sweden?

Mostly the market actors will build up the charging poles. However, municipalities can help with the planning and building of charging infrastructure in parking areas and in newly built houses. Reserved parking places for EVs gives also more advantages for EV customers. In addition municipalities or the government can play an important role in the standardization process of the charging spots. As we have already written, it is a necessary element towards to the transitional phase.

Do you think customers are open for electric cars here in Sweden?

The answer to this question is in accordance with Renault survey analysis. Basically Swedes are really interested in new technologies and they are relatively environment friendly. Previous survey’s results point out that customers consider the home charging as an advantage compared to conventional fueling at oil stations. Charging at home gives them more independence. These positive results show a customer behavior changing that is necessary for the acceptance of EVs from the customer point of view.

What do you think, what kind of customers will buy EV’s in the near future, and what kind in long term?

In short term, public authorities and companies will buy EVs. It is expected that EVs will be more accessible among private users after being available in the second hand market. That will increase the number of potential customers, and accelerates the penetration of EVs.

What do you think, how will the charging infrastructure and technology improve in the future?

Most important thing that should happen is the standardization of charging spots. In Stockholm, there are different types of charging points. Some of them are locked by key, and others can be opened by sending an SMS. It would be also a big advantage for EV technology to be able to use the same charging spots for all types of electric vehicles. In long term a smart grid electric system can help the infrastructure when many EVs are charged in the same time, mostly during the night. Without standardization of the charging infrastructure, the transfer to the transitional phase from the fluid phase is really difficult. Also, it is important to realize some planning regarding the electricity infrastructure towards a smart grid system where the
electricity can be stored for a time period where more electricity is used. That can happen in the specific phase with a well established infrastructure in the industry.

In your opinion, when can electric cars become competitive against conventional ones?
The answer is related to the biggest disadvantages of EVs, the price. If it goes down, EVs will be more attractive. As we already know, the battery is one of the most costly part of an EV. Improving the battery technology can cut down the prices. Also, EVs have a great competitive advantage already; that is the low fueling cost. With increasing petrol prices, the competitiveness of EVs increases as well. Also, as mentioned before, if Renault’s battery renting strategy is a viable business it can really reduce the actual price of EVs. When EVs are more competitive than conventional cars they can become the new dominant design.

8. Conclusion
The research analysis gives us the necessary information to provide a relevant conclusion. The aim of our thesis is to give suggestions and advices to electric car manufacturers what to focus on and what to develop regarding EV technology to make electric cars more competitive and increase their opportunity to become the dominant design. The question is not whether EVs have the opportunity to become the dominant design, because the answer is obviously yes. As we can see in our analysis, there are many factors that contribute to the competitiveness of EVs. To mention some of them, they are the increasing oil prices, the more and more strict regulations and policies, the government subsidiaries, the customer behavior changing towards a more environment friendly thinking and the spreading infrastructure. The EV technology reached a level where it can enter to the market, and start its expansion. On the other hand as we can see in our research, there are still many disadvantages and problems with electric cars. These are the usually criticized range, the high price and the missing infrastructure. However these facts cannot be solved in short term, an educative, driving behavior focused marketing campaign can make understand people that the range and the infrastructure is not a huge disadvantage. It is the habit of driving that should be changed, while the prices with the introduction of mass production can decreases as well.
Thus, it is really important how to move on in the development of electric car technology in order to increase EVs competitiveness.
As we have already mentioned an educative advertising, marketing is really important in order to establish a new driving habit. Electric cars are already useful for average customers
regarding the range and the home established charging infrastructure. For many companies who use their cars in the inner cities or for customers who use their cars mostly to going to work and to supermarkets electric car can be already a convenient solution. It is important to reduce this education process with a new driving habit focused marketing strategy.

Secondly, it is obvious that the battery technology should improve as well. Reaching 400-500km with one charge and 12-15 years lifetime would be really competitive level. However it can not be acquired in the near future. Focusing on the energy consumption optimization and on the battery capacity incensement can push the technology towards that goal. The battery price is also a crucial factor. One solution for that is the increased mass production, but it requires increasing EV market share. The other one is the previously mentioned capacity development (same range for less price). Or Renault’s solution; renting out the batteries. Hence, customers do not have to pay the huge battery cost and the overall renting and fueling cost is similar to the fueling of a conventional car. We think that it can be a crucial market advantage for Renault, and that solution can increase EVs’ competitiveness considering other actual opportunities. However, in long term we think that there is a really big risk in this business idea. As we have already mentioned in our research, Renault has to finance all new batteries, while the rental cost will cover the investments in 8-10 years. This initial cost will only grow when there will be more and more electric cars, that means a continuously growing risk factor.

There should be a standardization process regarding EV technologies. It concerns on a standardized battery charging and changing system, standardized battery solutions, standardized design patterns. It is really important to have an established, accepted standard system around EV technology to be able to use all kind of electric cars in the same way as we use nowadays conventional cars. Think about the fueling system or the maintenance system that is already well established for gasoline cars. Regarding the dominant design theory, the market leaders, who have bigger advantages, can usually form the future standards. Thus, Renault has an important role in this area as well.

The fourth factor that needs high focus is the lobby activities among local authorities, municipalities, governments and electricity suppliers in order to gain more help and advantages for electric cars. These are the received subsidiaries, tax rebates for newly bought EVs, future research investments into the technology, free parking places, spreading charging infrastructure or EV tenders. That part has already started with the environment regulations, EV tenders and with several tax rebates examples. However it is important to broaden these opportunities in other to increase EVs’ competitiveness.
We think that three of the above actions (educative marketing, standardization and lobby activities) are feasible in the close future, but the battery technology probably still needs several decades. However if Renault’s renting strategy is a viable business, the negative battery fact can be hugely decreased as well. Also, an entire infrastructure system like charging spots, upgraded electricity network, maintenance services should be established around EV technology in order to become the dominant design, but due to time restrictions these topics are not focused in our thesis. Probably several technologies will leave together in the future, but in time one of them will finally take the dominant role. Although we can hear nowadays more and more about electric cars, we saw in the past several times how this technology failed. Today, EV technology is much better that it was ever, however the competitiveness is still far from the dominant design role. The future market and the future dominant design mostly depends on the manufacturers, how and what will they develop on electric car technology in the future to reduce the competitive advantages of today’s dominant design gasoline cars.
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Appendices

Research questions for Renault as EV manufacturer

We had an interview with Josephine Adorelle, Renault Product Manager of Electric Cars in the Nordic Countries. Renault will put two electric cars into the market in this year, and two more in the upcoming year. Renault has a long term strategic plan regarding EV technology and market, and tends to be the market leader in the future.

*What are the most important reasons of Renault electric car investment?*

The most important reason is the environmental responsibility. Renault, as a car manufacturer has a large influence in our environment in the areas of CO₂ emission and global warming. According to Renault statistic, 79% of the travels all around the world is conducted by vehicles and it causes a huge impact in our environment mostly by the CO₂ emission. Renault has a target to decrease its cars emission to an average of 100g/km CO₂. According to the project manager it can not be reachable by only improving the combustion engines, but a high percentage of the manufactured cars need to be fully electrical.

*Why does Renault invest in electric cars and not in other alternatives (like Plug-in hybrid or Fuel Cell Vehicles)?*

EVs could have a bigger positive impact in the environment. According to Renault the PHEV is not a full solution but a transition vehicle since it still contains combustion engine. Also it is a strategic decision for Renault, because the EV market is a quite new market and Renault ZE series has a strong position since it includes cars for various segments. Thus, Renault has a much bigger chance to become the market leader compared to the PHEV market that is already more established around other leaders. Renault’s target for EVs is to reach 10% of sales of all Renault vehicles by 2020. It means approximately 260 000 manufactured EVs per year. The planned maximum capacity of battery factories for Renault is 500 000 batteries per year, that gives the opportunity to increase the produced EVs number as well.

*What do you think, what are the most important reasons for customers to buy an electric car?*

The two main reasons are the environmental thinking, and a new way of driving experience. People started to take care of environment – we can think about the selective garbage
gathering, the increased use of bicycles or the spread of environmental friendly products. In Sweden this thinking is stronger than in other countries. Swedes consider low emission with high importance when it comes to buying a new car. On the other hand, the driving of an EV is different from a conventional one. It is silent, giving the possibility to really enjoy music. It gives a high technology feeling, a new way of driving that is fun for a lot of people. This feeling can be defined as giving the people the chance to “feel like a pilot”. Another advantage is removing peoples’ dependence on oil stations and giving users a feeling of a new sense of freedom. In addition, Renault is planning new add-ons for cars and trying to agree on new solutions related with Biotherm and other health care companies.

What are the main disadvantages of electric cars nowadays compared to conventional ones?
Obviously the main disadvantage is the range, especially in the winter. A fully fueled conventional car can run 600-700km compared to the 100-200km range of an EV. According to Renault their cars could run 160km when the battery is fully charged. But the capacity of the batteries could be reduced by 50% during cold days.

The other negative point is that electric cars are really silent. It can be dangerous regarding the pedestrians. Also some people can think that an EV contains too much technology. For example they are afraid of the high voltage and believe high technology requires special care.
An interesting thing that Renault concluded is about the charging method. People who have electric cars think that charging their vehicle at home whenever they want is a really positive fact. Even if the charging takes 7-8 hours, the fact that they do not have to go to any petrol station gives them more freedom. In addition, a group of customers indicated that not hearing the sound of the car engine as a disadvantage.

What do you want to improve in the future among these disadvantages to make electric cars more competitive?
It is crucial to improve the range of EVs. That can be done by developing better batteries and by using the energy in a better way. The latter one can be achieved by energy consumption optimization and charging optimization.

The other important step is to educate people about driving behaviors. According to Renault, 80% of people who has a car drive less than 60km per day. That means they could use EVs without any range problem. Also it is important to teach people how to use their vehicle more economically, with less “sportive” driving. If we understood these factors, EVs would be more attractive.
How do you want to improve them, do you have a strategy?

Renault wants to put in action the previously mentioned facts in two steps. In the first one they will concentrate on the electric vehicle (optimizing the energy consumption). In the second phase they will work on battery improvement and charging optimization. Although, Lithium reserves are not renewable, Renault considers that there are enough resources for the future for battery production. But it also means that in the far future another way of storing energy may be needed. In addition the recycling and resale of batteries should be considered. As used batteries can be sold, it will reduce the overall price of the battery as well.

Who are Renault’s biggest rivals?

In the near future almost all big car manufacturers put one or two EVs on the market. But Renault will have 4 different lines of EVs that can make it stronger competitor in the market. For example Mitsubishi, Peugeot, Citroen will have one common electric car. Volvo and Mercedes will come out with an EV soon. There is a quite big Chinese company, Build Your Dream (BYD) that produces PHEV and EVs as well in a larger scale, but it is a young company with less experience and their EVs are not tested in Europe yet. They started with just producing batteries but their expansion should be evaluated.

What is your calculation, how bigger is the price of an electric car compared to a conventional one from the same category?

EVs without battery cost 5000-6000 Euros more than a conventional car, but in some countries there are subventions from the government for buying EVs (in Spain and in France it is 5000 Euros, in Denmark the tax paid for new cars – that is around 100% - is deducted). If we compare EVs with batteries, the price is sometimes more than the double of conventional ones from the same category. Renault’s customers will rent the batteries for a price around 80 Euros per month. According to Renault the cost to fully charge its battery is around 22 SEK (2.2 Euro) here in Sweden. Calculating with the actual petrol prices, the fueling cost of an EV including the battery rental is cheaper compared to a conventional one if the EV is used more than 12 000 km yearly.

Do you think customers are open for electric cars here in Sweden?

Swedes are very open-minded. Lots of products are tested first here in Sweden because Swedes are culturally willing to switch to test and use new products. Also people in Sweden
are very eco friendly. They prefer to by a green car rather than one with a huge consumption and emission. Also, the country has a well established warming box infrastructure that can be used for the charging points for EVs. People are already using this infrastructure and familiar with the behavior of using plug-in technologies. The only bad factor in Sweden is the weather. As it was already mentioned before, the range of EVs reduce drastically during cold weather.

On what kind of customers will you focus in the near future, and on what kind in long term?
In the beginning Renault’s main customers will be bigger companies and municipalities who buy fleet quantities since it is easier for Renault to enter the market with a wholesaling method. In long term they will focus on the private sector as well. Probably the first individual customers will come from the suburbs around bigger cities, because it is easier to build charging points (or to modify the heater boxes) in suburbs than in the inner cities (where the heater boxes are not so spread). Families with more than one car are another target group.

In which countries will you put into the market the electric car in the first step, and then what are the following ones?
Renault will focus mostly on countries where the government supports the EVs (gives subsidiaries or tax reduction for new EVs). The first Renault EV models will be available on the market in Denmark and Israel from autumn 2011 and after, almost every week EVs will penetrate in other countries like France, Germany, Italy and England. The estimated market entry in Sweden is January 2012

What is your strategy in the Nordic countries to expand the market?
One of the most important steps is the information spreading about EVs. It can be done by seminars or presentations in related forums. Of course Renault has a marketing campaign for EVs as well. And it is also important to prepare the retailers about EVs. In Sweden the need for EVs is quite high, so it is crucial to deal well with these potential customers. However, Renault indicates that the demand for EV’s is so high that they don’t need to be so proactive in this part.

What is your strategy for the infrastructure? Do you have some interested potential investors in the infrastructure in the Nordic countries?
There is a pilot charging system in Denmark that will be established by Better Place. They will introduce the first time a battery changing and changing technology. In other countries Renault works together usually with local energy provider companies. They will provide the service for the charging facilities (they will sell the charging boxes, and they will build in as well), because they have the necessary knowledge. But in many cases supermarket chains or municipalities build up charging points as well (ICA and McDonalds have already their own charging points).

In Sweden the infrastructure is really well established because the already existing heater spots can be used as charging spots as well.

**Do you have already some agreements in the Nordic countries governments, or municipalities?**

In Sweden some municipalities signed up a letter of intense where they declared their willingness to buy EVs. Renault participates in several tenders like the Stockholm City EV initiation. In Denmark the tax is totally deducted from the price of newly bought EVs that more than 100% reduction. However, Stockholm City still does not give reserved parking places for EVs due to their regulations.

**What is your expectation from the government (grants, subsidiaries, tax rebate) especially in the Nordic countries?**

One of the expectations from the governments is to give some incentives (subsidiaries, tax reduction) for EVs to facilitate their penetration. In long term the EV cost will be reduced and these incentives can be decreased as well. And it is important to have these incentives for the public and private sector as well.

The Swedish government promised that they will give some subsidiaries for private persons who buy EVs from 2012, but it is not accepted yet. In addition to subsidiaries, some reserved parking places and installment of charging stations can hasten the expansion of electric vehicles.

**Research questions about EV tender in Sweden**

We had an interview with Eva Sunnerstedt, Project Manager of an ongoing electric car tender in Sweden. Companies and organizations can apply for the tender, they can declare how much
EVs they would like to buy. Then, EV manufacturers can apply for the tender, and the most suitable one can deliver EVs for the Swedish market.

What is the main purpose of this tender?
The main goal is to put EVs on the Swedish market. Actually, even though Sweden does not have a large population, it is calculated that the demand for EVs in Sweden is bigger than the near future production. That means Sweden is really open for EVs. Also, the tender wants to show for EV manufacturers that it is worthy to penetrate into the Swedish market due to several reasons. 47% of the electricity production is hydro energy, and 42% is from nuclear power plants. In that sense Sweden has really green electricity production. The other important factor is the already existing infrastructure for the charging system. 65% of houses in Sweden have access to heater boxes. Also, Swedes are environmental open minded and they are willing to try out new products, technologies. With these facts, the tender wants to show the EV market potential here in Sweden. It is calculated that the tender can contribute to the cost reduction of EVs by aggregating the potential customer needs. A larger EV production can cut down the prices. The selected manufacturers should build up the maintenance system that contains the repairing and the recycling of EVs and their batteries as well. In addition, local authorities know that they are responsible for the environment and want to show their awareness and help expansion of these vehicles.

Who are the initiators of the tender, and how can they contribute to it?
Stockholm City, Vattenfall AB and SKL Kommentus AB. Vattenfall AB is the Swedish state-owned energy company, SKL Kommentus AB is specialized in national procurement processes for municipalities, county councils and regions. The tender is a three year process. Different organizations can sign up to show their interests for buying electric cars and over 300 organizations have already applied. The tender responsibility is to qualify the EV manufacturers. 20 car companies were interested in this tender, and they all received the specifications that are necessary to meet the actual regulations. After each EV manufacturer can apply to be part of the tender as manufacturer. Actually, the application process took place when we had the interview. The tender will choose the most suitable company who meets all the requirements, and can deliver the sufficient number of EVs. Also this is the end of the first phase of tender and other applications will be accepted in the near future for more vehicles.
Who can participate in the tender, and who are the actual participants?
Only organizations could participate in the tender. 303 organizations signed up for the tender in which 246 were public companies. They declared how many EVs they are willing to buy, but it is not a must. They can decide later about the quantity because the conditions (prices, maintenance services) are not known yet. The only obligation is that they have to sign a framework agreement and purchase EVs through the chosen manufacturers via this tender. Altogether they requested 4500 EVs. Regarding the fact that Swedish public organizations own only 44 000 cars, and there are around 4,4 millions on the roads in Sweden, we can conclude that most of the interest is coming from the public sector.

What are the advantages for companies, municipalities to participate in the tender?
The main advantage for participant organizations is that they do not have to do a tender. In Sweden, if public companies want to invest more than 287 000 SEK, they have to do a tender. Tendering is a long and complicated process in Sweden and they save a lot of work by only participating in this single tender. Also when a company tries to buy small amount of EVs, many manufacturers will not be interested. By participating in this tender, they can use the advantage of the bigger quantity that reduces the price as well. Most of the interests are coming from bigger cities like Malmo, Stockholm and Goteborg. For EV manufacturer it is also easier to concentrate on bigger cities initially, because it worth to build up a new service centers in more frequent places.

How big is the support from the Swedish Energy Agency?
The SEA will give subsidiaries for the first 1000 bought EVs. It can be maximum 25% of the extra cost for an EV. The extra cost is the difference of the EV price compared to a conventional one in the same category. This amount is around 50 000 SEK. A Peugeot EV cost 200 000 SEK more than its conventional type. It is because of the high cost of the batteries. It is only Renault how will lease the batteries giving a much lower price for the initial cost of their EVs.

What are your expectations for the future regarding EV expansion?
The goal is to have 8 manufacturers applied for this tender. The application process was not yet finished during our interview, but 20 companies showed interest in the tender as we have already mentioned. This tender will last for 4 years. After, there should be a deep evaluation to be able to decide the future steps.
In the future it should be necessary to include the EV procurement in regular procurement processes. Also there is an opportunity to open EV market in other areas like small, slow and silent EVs for parks, cemeteries. And it would be important to receive subsidiaries for newly bought EVs. The government promised to give 40 000 SEK for private persons buying new EVs from January 2012, but officially it is not yet decided.

Why do you think, electric car is the future alternative solution in the vehicle market? EV is just one solution among many others. In the 90s there were several problems with EVs especially the lifetime of their batteries and the maintenance since they frequently broke down. Today’s expectation is that they will be more reliable than the previous generation due to technological improvements. PHEV is another alternative and it is more popular for private sector because of their longer range compared to EVs. Also a PHEV could be more environmental friendly by using ethanol instead of petrol. Probably different alternatives will live together because different technologies are suitable for different kind of vehicle transportation.

What do you think, what are the main disadvantages and advantages of electric cars nowadays? EVs pollute less and they do not emit CO₂ and other pollutant substances. They are also silent that decrease the noise pollution. The maintenance cost is lower, because the electric engine does not contain moving parts. Electricity costs less than petrol and it can be gained from renewable energy. However in Eastern Europe since the produced electricity is not so green, the life cycle analysis for EVs is not showing great results. In addition, generally it is really positive feeling to drive an electric car. If customers start using EVs they also have to change their driving behavior.

The main disadvantages of EVs are obviously the price and the limited range. Also, the charging infrastructure is not well established yet. The facts that EVs cost much more than conventional cars and that the maintenance and fueling cost much less can result with an increased use of cars among EV customers. It is reasonable to save money during the usage if the initial cost was really high.

What do you think, what are the most important reasons for customers to buy an electric car? Obviously it is the environmental friendly mentality. In Stockholm the main source of pollution is from the traffic. It pollutes the air, the water and the soil as well. EVs can
contribute to the decrease of this pollution. Private companies are interested in EVs mostly when they have an environmental friendly profile and they want to emphasize it more to increase their profits. Also local authorities are responsible for the environment and they try to show that they care about the environment by using green vehicles.

What do you think in which area EVs have to develop the most, and do you think they can achieve it?

EVs have to improve in their most negative factors, the price and the range. The prices can be cut down with higher production. But EVs can be more attractive when the petrol price goes up. EVs’ range cannot be sufficient especially if we want to use our car for longer distances. But there are several factors showing that it is not usually a huge problem. Swedes drive 40km per day in average and 50% of the population lives less than 5km from his or her workplace while it is only 5% that live more far than an EV can drive. The most important thing is to teach this fact to customers and show them that they don’t really need such a long range as they have it for conventional cars.

What do you think how can municipalities, companies or the government contribute to EV development here in Sweden?

Basically the market actors will build up the charging poles. But municipalities can help with the planning of where to build these spots. Also municipalities can order to build charging infrastructure in newly built houses. They can also recommend reserved parking places for EVs and they have a role to inform the public about EVs (like prices, charging points). Also, municipalities have good opportunity to influence the government for future regulations.

What is your calculation, how bigger is the price of an electric car compared to a conventional one from the same category?

EVs today cost 200 000 - 250 000 SEK more than a conventional car in the same category.

Do you think customers are open for electric cars here in Sweden?

In general Swedes are quite open for new technologies like for EVs as well. But it is important to mention that 60% of the new cars are bought by companies. So probably, in the beginning companies will buy EVs. When these EVs will appear in the second hand market the private usage of EVs will grow as well and it is expected to happen in 3-5 years. Customers are happy with getting rid of the habit of going to oil stations and it shows that
they are open for EVs. However, some interviews show that they always park near to the charging stations for the first few months and by the time they realize that they do not need daytime charging, and they get rid of this habit.

**What do you think, what kind of customers will buy EVs in the near future, and what kind in long term?**

In the near future mostly public authorities and some environmentally engaged private companies will buy EVs. It is usually a marketing message that they care about the environment. And as it was mentioned in the previous answer EVs can spread among private users faster when they appear into the second hand market.

**What do you think, how will the charging infrastructure and technology improve in the future?**

Maybe it is surprising but for the beginning it is not needed to have a widespread infrastructure. Usually the standard home charging is enough. In the 90s when some EVs appeared in the Swedish market 4 fast charging points were built in Stockholm. According to the surveys about EV drivers they were satisfied with the fast charging points, and they all knew about it. But they did not use it and 2 of them were closed down after a while. It is also a learning process to recognize what is the most suitable way of charging. On the other hand, there should be standardization about charging spots. In Stockholm, there are some that are locked by key, and others that can be opened by sending an SMS. Also, a smart grid electric system will be needed in the future when many EVs will be on the roads. When all the EVs are charged in the same time (during the night), the electricity system needs to be adjusted. Also, EV batteries that are fully charged could be used for gaining electricity.

**In your opinion, when can electric cars become competitive against conventional ones?**

They will be very competitive when their prices go down. Also, the increasing price of petrol can reduce the competitive advantage of conventional cars against electric vehicles.