Green Charging

Optimal charging in the Netherlands

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Minor Sustainable Design: IO3832 Explore Lab 1

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1.) Introduction

One of the subjects currently given in the minor sustainable design of the faculty industrial design engineering is the explore lab. In this explore lab 10 TU Delft students from multiple faculties have to design a charging system for electrical vehicles. These students were evenly divided into two groups of five people of which one group was assigned to develop the fast charging points and the other assigned to develop the optimal charging points.

In the following, JUiCE! will explain how it will develop the optimal charging spots. This concerns all the facets which are needed to implement such an electric vehicle charging system in the normal life of car users and other people.

2.) JUiCE!

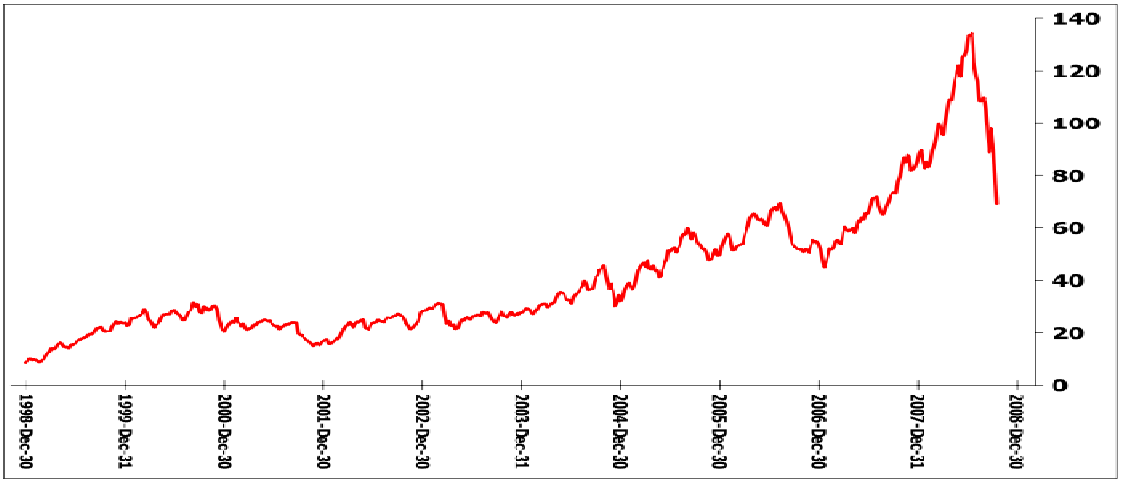
2.1 Vision

Since recently batteries and electricity form a better way of fueling your car, the problem is there are not enough infrastructure to charge your battery and batteries create high initial cost. Technological, economical and political developments make it even more attractive in the future. We believe that by supplying a charging service for electric vehicles (EV) on most of the parking spots, and taking away the high initial cost for consumers, electric driving will be the dominant way of transport by 2020.

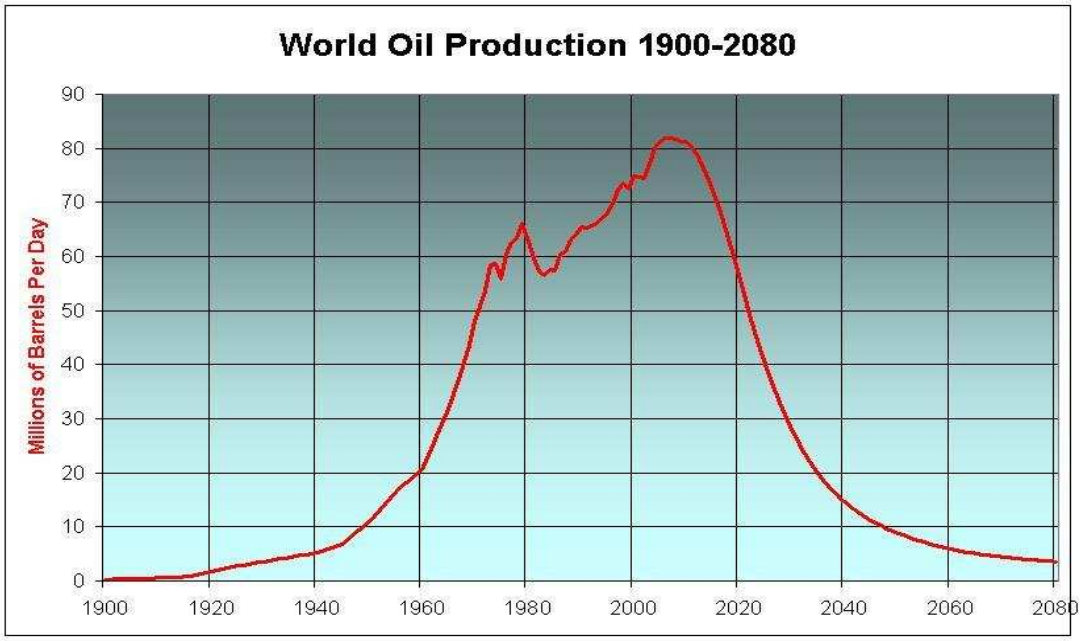
2.2 Opportunity

A new company like JUiCE! is starting up as the founders are seeing new opportunities in the world around them. Oil reserves are decreasing while the oil prices are rising. At the same time batteries are getting better and the battery prices are decreasing. People around the world are starting to worry about the environmental changes which have been showing up in resent years, although governments are not yet as worried as their inhabitants.

The price of oil rose from around 10 dollar a barrel in the nineties until just below 140 dollar a barrel in the middle of 2008. Due to the resent economic problems it decreases again and today it's around 70 dollar a barrel, still seven times as much as 10 years ago.

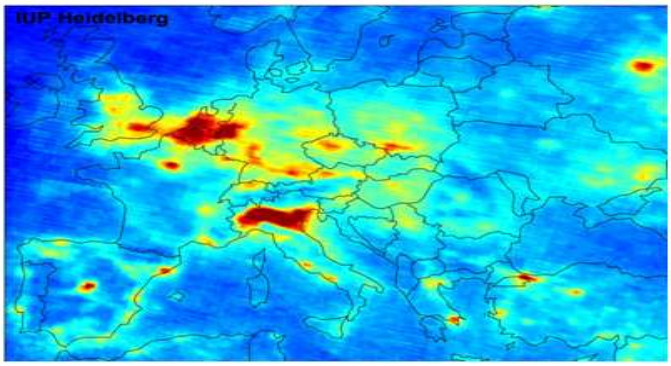


This increase in oil price has several causes, the most important being that the demand cannot reach the increased amount people and companies need. This is caused by the fact that oil wells are depleting and so are losing pressure which makes it difficult to get oil out of it. At the same time new convenient wells are not found. The amount of oil needed is increasing due to the economic growth especially in Asia, US and Europe. Another important reason for the price rising is that traders in the economic markets around the world are speculating on high oil prices in the future which create even higher prices at the moment of trading.

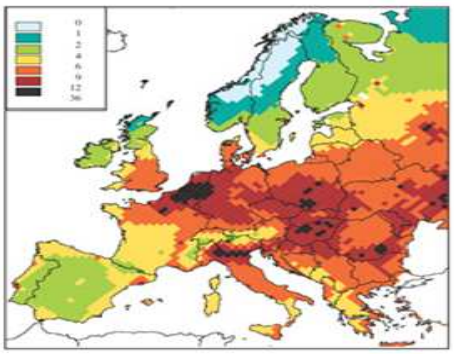


While the oil prices are sky high, battery prices are decreasing due to the higher production capacity and the competitive market. The production of lightweight batteries increased especially due to the mobile telephone industry which grew explosively last decade. The competition between the telephone brands also stimulated the development of new types and better batteries.

More and more people around the world are getting aware of the environmental problems and changes which are happening around them. The quality of the air people are breathing is going down, the quality of the sea and fresh water is decreasing, the climate is changing, these are all facts people can notice and measure.



NO2 air pollution
50% caused by traffic



Particulate air pollution
30% caused by traffic

Traffic and transport are the biggest causes of this pollution. Diesel driven vehicles are spitting out small dust particles alongside the gas emissions combustion engines produce. Petrol driven vehicles are producing lots of CO2, while electric vehicles are not causing any pollution during driving.

The electricity which is needed for an electric vehicle to drive can be produced in a lot of different ways. Burning fossil fuels is the most popular way nowadays because it is cheap and relatively easy. In fact, burning fossil fuels in power plants to produce energy to drive electric vehicles is still 50% less polluting compared to burning fossil fuels in a combustion engine. This efficiency increase is mainly due to the fact that a combustion engine produces a lot of heat which is wasted. Another way of producing energy is by using green energy. Green energy is energy produced by means which are not causing pollution, for example wind power or solar power.
For governments it would also be a nice opportunity to promote electrical vehicles to get less dependent on oil producing countries. Governments have to comply with the purchase rules of countries which produce oil, because these countries have great influence on the economic growth of oil dependent economies.

Energy producing companies are also looking at a new opportunity as electric vehicles are starting to become popular. If a lot of electric vehicles are in use for example in 2020 an enormous energy buffer is created if a lot of the electric vehicles are connected to the grid.
This buffer capacity can be used during peak hours. The peak production for power plants can be lowered by subtracting energy from the buffer. Nowadays a problem by the production of green energy is that the energy is produced when it is not needed and the other way around which makes it difficult to use. By using the electric vehicles as a buffer green energy can be used to fill the car batteries when the wind is blowing strong. In this way green energy can become more competitive compared to fossil fuel energy. The buffer can also be loaded during night hours when the power plants are still making energy. This energy is sold for bottom prices or given away for free by the energy companies; if it is put in the batteries energy companies can make money during night hours.

Another interesting fact is that car manufacturers presently are having problems to reach the new emission standards set by the EU for the year 2012 (by then car manufacturers are only allowed to build cars which are emitting less than 130gCO2/km). By using electrical vehicles car manufacturers would not have any trouble to stay beneath the limit. The problem car manufacturers are having nowadays with electrical vehicles is that there are no charging points available yet. This is why some car manufacturers are concentrating on hybrid cars. Hybrid cars have both an electrical and a combustion engine, which means that they are independent regarding charging points. A down side is that hybrids are far from optimal compared to electrical vehicles which are not carrying an combustion engine, a fuel tank, a gear box, and such which makes it a lot lighter and cheaper. This creates a big opportunity for car manufacturers to build a full electric vehicle which could in theory drive faster, cheaper and with less noise.

3.) Gathered Information

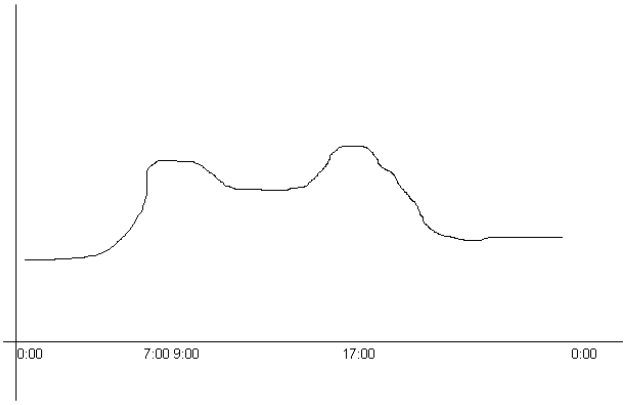
Crucial factors in designing the infrastructure
There are a variety of crucial factors which JUICE! considered important to take notice off in the developing of an infrastructure of charging points. These are as follows;

- Price of Electricity and oil: the higher the oil price, the more the tendency for the consumer to switch to electric cars
- Energy suppliers: they deliver electricity to the charging points
- Battery technology: the rate of development
- Adaptation level: the higher the better, the implementation will be facilitated
- Government: regulations regarding parking spots, taxes on Electric vehicles etc
- Car industries and their degree of involvement with EV's
- Comparison EV's with current mobility
- Marketing: macro & micro environment

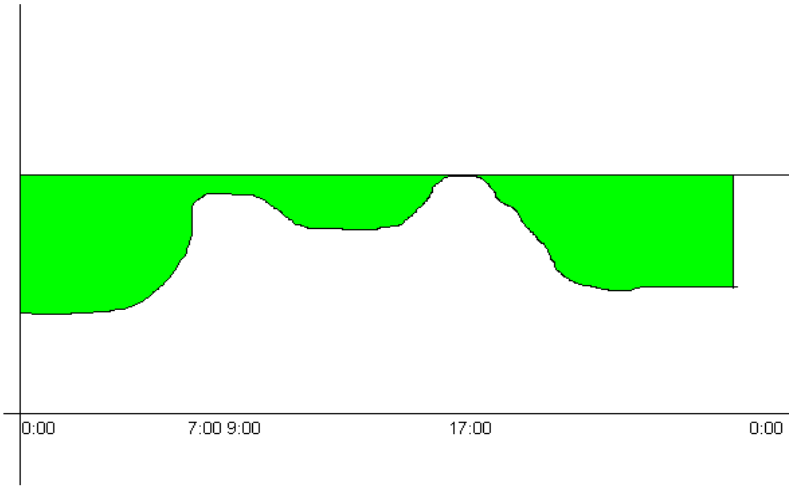
3.1 Energy suppliers

In the Netherlands energy companies are competitive in a liberated market (1998) which means that in the past the government controlled the energy market, nowadays government is only regulating the electricity grid. The way the government is regulating the market is by making a commission which is controlling the grid regulating companies, this commission is called Energiekamer. The Energiekamer controls the price for which grid regulators have to transport electricity and also the price for which grid regulators have to connect new customers on the grid. Energy companies (for example Nuon, Essent, Dong) are using this grid to transport electricity towards their customers. In the Netherlands everybody is free to choose their own energy company, this means energy companies are fighting in a highly competitive market. Customers can choose their energy company on the energy price but also on other aspects like the type of energy the company produces (nuclear, green, coal).

As shown in the graph below, the energy demand is high at peak hours, when everybody gets ready to go to work, and when they come home. The amount of power plants and the maximum grid capacity depends on the height of these peaks. Therefore a lot of power plants and electricity grid is left unused or only partly used when energy demand is lower.



This results in higher production and distribution and thus purchasing costs during these hours. This is where electric cars can help. Because electric consumer cars are standing parked 95% of the day, they can be perfectly used to even out the energy demand throughout the day when connected to a charging point. In the green area you can see the energy demand in case all petrol cars are replaced by electric ones.



During down hours, especially during the night energy companies are still producing electricity. Power plants especially nuclear and coal power plants are difficult to slow down, this means during night hours high amounts of electricity are produced and sold for lower prices. The same thing happens with green electricity. It is not always produced when there is a large demand, and therefore sometimes it is sold for very low prices or windmills are even shut off. By loading the batteries of electrical vehicles during the night, electricity companies can produce energy more efficiently.

Another interesting advantage of having a lot of electric cars connected to the grid is when electric cars can be used to supply energy to the grid. Currently this is very expensive: depreciation for the currently used batteries (LiFePO4) is roughly €0.50/kWh. Thus making this a very expensive way of supplying energy. Newly developing batteries

(LiTi) have a much lower depreciation cost (€0.10/kWh) and might become a cost effective way of delivering energy to the grid during normal. Delivering energy back to the grid is expected to be of help in case of emergencies.

Currently only 6% of Dutch electricity is produced in a green way, and when this amount rises, we expect there will be more need for storage capacity due to the mismatch between the time we need energy and the time energy will be available (when the wind blows and the sun shines intently).

Energy producers are very interested in EV's because they will be able to sell a lot more electricity in a very efficient way! Danish energy producer Dong Energy cooperates with Better Place in Denmark and is very interested in this storage capacity.

3.2 Battery Technology

JUiCE! will be primarily responsible for designing the charging points (and not the Electric Vehicles). Even though these devices will not contain high density batteries, it is favorable to be aware of the various developments in the battery sector and the specific facts of how to charge these batteries.

Electric Vehicles are of course focused on secondary (rechargeable batteries). There are several of these and these are listed below. Amongst these the most efficient batteries are Lithium ion cells and Nickel/metal Hydride cells. Lithium ion cells, however, unlike NiMH cells, do not have the memory effect and are considerably cheaper.

	Battery Type	Anode	Cathode	Electrolyte	Advantages	Disadvantages
Secondary (rechargeable) Batteries	Iron Nickel Cell	Fe	$Ni(OH)_2$	KOH	Long life under a variety of conditions, excellent back-up battery	Low rate-performance, slow recharge rate
	Lead/Acid Cell	Pb	PbO_2	dilute H_2SO_4 (aq)	Low cost, long life cycle, operates well under a variety of conditions. Common car batteries	Minor risk of leakage
	Lithium Ion Cell	C, carbon compounds	Li_2O, intercalated into graphite	$LiPF_6$, $LiBF_4$, related compounds	Relatively cheap, high energy density, long shelf life, long operational life, long cycle life	Minor risk of leakage
	Nickel/Cadmium Cell	Cd	$Ni(OH)_2$	KOH	Good performance under heavy discharge and/or low temperature	High cost, can temporary loose cell capacity if not fully discharged before recharging (memory effect)
	Nickel/Metal Hydride (NiMH) Cell	Lanthanide or Ni alloys	$Ni(OH)_2$	KOH	High capacity and power density	High cost, some memory effect
	Nickel/Zinc Cell	Zn	NiO	KOH	Low cost, low toxicity, good for high discharge rates	Zinc on the electrolyte tends to redeposit unevenly on anode, severely reducing efficiency
	Sodium/Sulfur Cell	Molten Na	Molten S	Al_2O_3	Inexpensive materials, long cycle life, high energy and power	High operational temperature lower efficiency, some danger of explosion upon degradation

At this point JUiCE! decided to council a battery expert, Jean Verniolle (see appendix 8.1.1 for the questions asked and the responses). Significant was that lithium ion batteries besides leakage have no overcharge mechanisms to compensate the capacity dispersion between cells. In order to solve this problem, the battery pack has to include software or hardware control of small resistors across the cells to discharge the one that are fully charged compared to the other ones. Nevertheless, lithium ion batteries still have the best energy density and are continuously being improved.

Amongst the various Lithium ion battery technologies (lithium ion and lithium ion polymer) there are 4 that are exceptional, particularly for the use in Electric Vehicles. These are $LiCoO_2$, $LiFePO_4$, $LiMn_2O_4$ and LiTi. Below is a performance comparison between the first 3 Li-ion batteries. One can observe that Lithium iron phosphate cells have advantages in virtually every performance factor.

	$LiFePO_4$	$LiCoO_2$	$LiMn_2O_4$
Theoretic capacity per gram (mAH/g)	170	145	148
Discharge plateau (V)	3.2~3.3	3.6~3.7	3.6~3.7
Cycle life	>1000 cycle	>500 cycle	>300 cycle
High-temp performance (C°)	>75	0~45	0~45
Safety	superior	normal	better
High-current discharge	10C>5min Instant>20C	10C>5min Instant>25C	Worse

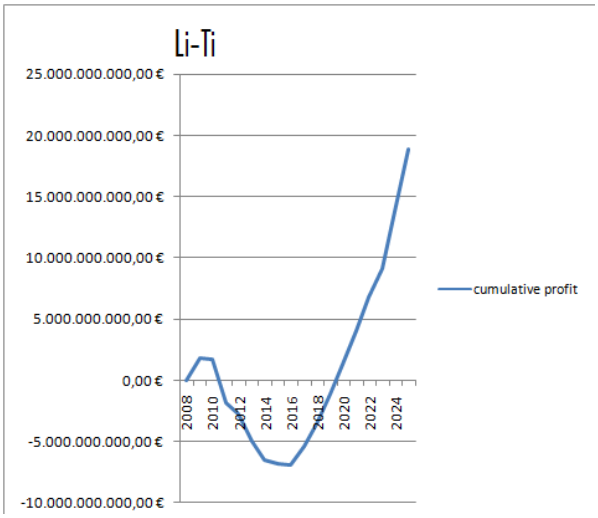
Which Li-ion battery has the greatest potential for EV's?
When considering battery types for EV's, Li-ion batteries are a lot better than alternatives, but which one has the greatest potential in the mobility sector?
The battery type used in mobile phones, LiCoO2 is not suitable for electric car use because it has a very low cycle life and is unsafe. LiMnO2 is still not completely safe, and battery packs deteriorate very rapidly when cell temperature exceeds 35 degrees Celsius. Big candidates are LiTi and LiFePO4.

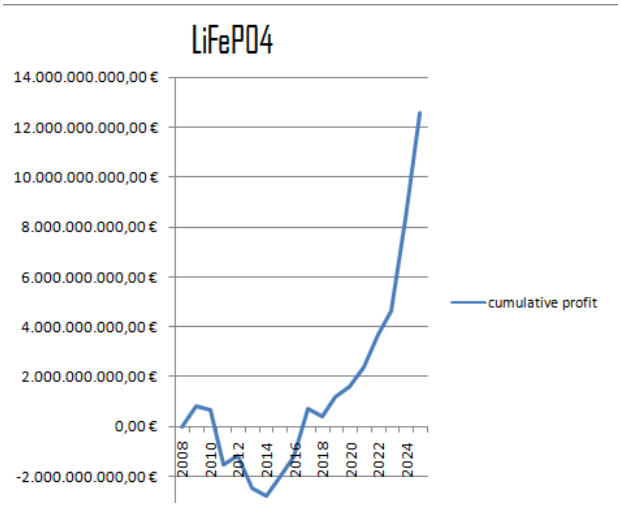
A comparison: LiTi or LiFePO4

Experts say LiFePO4 batteries will be used mainstream, which has a 50% higher energy density than LiTi. Battery producers are selling battery packs for these prices:

LiTi : 27k € for a 20 kWh battery pack[1]
LiFePO4: 18k€ for a 20 kWh battery pack.

In the graphs below the costs of Li-Ti battery packs versus LiFePO4 battery packs is shown. [2]

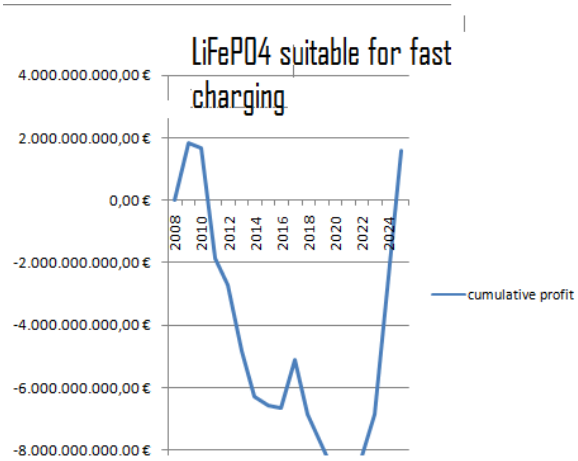




JUiCE! Conclusion

Experts, car manufacturers and JUiCE! all agree LiFePO4 battery packs, are the way to go![3]

In the graph on the right the extra costs of LiFePO4 batteries suitable for fast charging are shown.



[1] Producers claim LiTi has a longer lifetime; as a result 2010 battery packs don't have to be replaced in 2018 even if the car has travelled more than 30 thousand km yearly.
[2] The extra cost for creating a standard for battery swopping (estimated €1 billion) and €4 million/swapping station are already included.
[3] Using the battery swapping stations for urgent energy needs.

3.3 Adaptation level/Consumer Psychology

As aforementioned, the higher the adaptation level of the consumers the easier it is for JUICE! to implement and expand the infrastructure of charging points. This level of adaptation depends on various factors, such as culture (What is the Dutch stance towards electric driving or to environmental issues?) and the level of fed information towards the consumer group (for instance advertisements, commercials about EV's or environmental issues, gatherings, forums, etc).

According to Essent, 10 % of the 1000 Dutch citizens subjected to a survey about EV's, believe that all cars will be driving on electricity by the year 2018. Of these 1000 subjects, 38% believe that electric driving will be possible by 2018 on a great scale; however they don't believe that by then all cars will be able to charge them. Only about 3% believe that electric driving will never be able to be implemented on a great scale.

Another Essent survey showed the factors that Dutch citizens are most concerned about (see the list below).

- Price of gas and diesel – 80%
- The Environment – 72%
- Gas emissions and particulates – 67%
- Global warming – 65%
- Dependence on foreign oil – 65%
- Traffic jams – 58%
- Accessibility of the Randstad – 42%

One can observe that electric driving will solve the most concerns. Nevertheless, charging points may create new problems. The infrastructure will change the appearance of cities (the public parking lots). The extent to which the general public will accept (and thus not only the electric drivers) the infrastructure is important as well. This acceptance might be enhanced with promotion of the infrastructure and informing the public through city councils and such means.

Petrol tanking
Currently the average consumers tank for a couple of minutes once every 10 days. You have to stop along the road in a mostly noisy, smelly petrol station where you have to open your petrol tank handle, unscrew a plug, take out a relatively big tanking pistol, exert a force on a tanking plug for 5-10 minutes, screw the plug, close the tank and then go to a cashier. Then you have to enter the traffic again. There are also some petrol stations which offer a PIN at the pump payment method. Today one petrol station is offering a totally automated tanking robot where you can keep sitting in the car and the robot does everything for you.

Petrol driving
When you buy a car now, you buy something which you can use to drive wherever you want to go; most of your stops are at your destination and your arrival rather than the fuelling station. When you park your car, you don't need to find a special empty parking spot only suitable for petrol cars. You buy a roaring engine which a lot of people like to hear when driving it, but this does irritate the people living along a road.

EV's
Here the electric car is the competition. In order to compete with this, electric driving needs to be perceived as more attractive. A lot of the factors that make EV's attractive are out of our control; electric engines accelerate faster, are very silent and well to wheel efficiencies of electric cars are a lot higher than for petrol cars.
Consumer cars are standing still 95% of the time, this allows for optimal charging during the times they don't move. Now imagine you are trying to drive around a city to find a parking spot. In order to be competitive with petrol driving, it would be incredibly inconvenient to drive around the city for a long time trying to find a parking spot with a charging point. The drivers noticing there is a charging point everywhere they want to go will realize finding a parking spot with a charging point will not be an inconvenience.

3.4 Government & Regulations

In the Netherlands BPM (taxes for purchasing cars and motorcycles) and MRB (taxes for motor driven vehicles) will run-down slightly by 2016. Because then the "Kilometerprijs" will be introduced for all road users. "Kilometerprijs" is a system whereby drivers do not have to pay taxes for the possession of their cars, but the use of the cars. How much you have to pay, depends on the factors: how environmentally friendly is your car, where and when you drive. Electric cars are very environmentally friendly; the taxes on the first aspect will be very low. In this way the cost you have to pay is only for when and where you drive. The purpose of implementing of this system is to unburden the roads and the environment. The government helps JUiCE! to implement the infrastructure of charging points with this system. People adapt the electric vehicles earlier because the taxes on the environmental factor are very low.

Furthermore, the regulations regarding parking spots are also important for implementing the charging points. Parking spots on the street belong to the city council. There are permits needed from the government/city council to place the charging points in the parking spots. Some parking areas are owned by companies; in this case, JUiCE! needs an agreement with these companies. Parking areas which are hired by companies are more complicated. Allowances from both the city council/government and the companies are needed.

3.5 Car industries involved with Electric vehicles

Most car companies are working on electric driving one way or another, but there are a number who stand out. These are the Volkswagen Group, Daimler, a Renault Nissan partnership (working on EV's for Shai Agassi's better place), TATA and GM (the producers of the relatively, before it was pulled from the market for doubtful reasons, successful EV1). In the total landscape of car manufacturers these are reasonable large players.

3.6 Comparison Electric vehicles with current mobility

First of all we must establish what other means of power for personal there are next to the EV. First of all I will exclude all forms of public transport, such as trains and busses because they are no real competitor of a personal mobility device as they have a limited freedom and a restriction of travelling time, even though they can be a very green and relatively cheap option. I will focus on different means of powering a car like vehicle. These methods are:

- Traditional fossil fuels
- Bio fuels
- Hydrogen
- Air
- Electricity

Traditional fossil fuels: these fuels are the sole way of powering your personal mobility today. But why not tomorrow? First of all because oil is a finite resource, this means that in the future there will be less and less oil to go round. So continuing on the track of consuming oil for mobility has no long term future bearing in mind the supply demand conundrum in which if supply goes down the price goes up and there goes our cheap oil for everyday use. Next to this there are a number of other problems related to fossil fuels. First of all there is the location where they are found. The regions in which oil is found are the more political instable regions of this earth. This means oil prices can be increased or decreased with a political agenda in mind. Next to this the burning of oil brings a number of health related issues. To begin with particulate and nitrous gases which both are extremely unhealthy for all kinds of life forms. Next to this noise pollution makes a huge impact on our everyday life. People do not want to live next to roads because of the noise it brings day and night.

If you compare driving on fossil fuels there are a number of interesting points. First of course there is the total lack of harmful emissions at the tailpipe and the noise is greatly reduced. Next to this electricity prices do not tend to fluctuate as heavily as oil prices, giving electric driving a more stable base of expenditure than driving fossil fuel. And off course electricity can be generated in so many ways it will never run out. The only real

downside of driving electric is high initial battery costs (even though running costs are lower) and a limited range. However both these factors are the main focus of battery research and will be of less importance in the future. If you put this against a rising oil price driving electrically will be very interesting indeed.

Bio fuels: Bio fuels are not so much a solution as a temporary method to make people feel better. The big advantages are that there is no real need for a lot of technological innovation to power a conventional diesel engine on most types of bio fuels. This makes it an easy step to take. The other advantage is that you burn carbon from the short carbon cycle (the cycle of the burning of plants which have grown in this day and age) instead of carbon from the long carbon cycle (the carbon which was captured by plants in a long forgotten time some millions of years ago). The main disadvantages are the fact that there is still a CO2 output, as well as particulate and in some cases even more nitrous gasses than conventional fuel. Another big disadvantage is that for most bio fuel related crops you will need land to grow them on. And that is where the main problem is caused. In some cases rainforest is cleared to make way for palm oil plantations or corn is used to make fuel instead of feeding people. Here is a future for algae which uses up hardly any land area at all and yields an enormous amount of diesel like oil (up to 70% of their mass).

If you compare it to electric driving the main disadvantages are that there is still a tailpipe emission which causes trouble and that it encroaches on farmland or natural habitats to be grown. Another disadvantage is that a combustion engine is not as efficient as an electrical engine. The biggest advantage is that the car has the range of a conventional car and that there is no new technology needed to use it.

Hydrogen: a couple of years ago hydrogen was hailed as the big savior for the earth. And indeed it looks like a good alternative to fossil fuels. The only tailpipe emission is water, and all you need to make hydrogen is water and electricity. What they, however, forget to mention is that hydrogen is a highly flammable gas which is notoriously hard to store (it can seep through metals) and can only be transported under enormous pressure. Next to these logistical problems the conversion from electricity to hydrogen has a very low efficiency and the other (more efficient way) to generate hydrogen uses natural gas, in which case the hydrogen source is not very green or sustainable.

Compared tot electricity hydrogen is a good option because it can extend the range of a battery powered car to make it even up with a conventional model. But the conversion from electricity to hydrogen and back is a very inefficient one. It makes much more sense to put the electricity directly in the car. Next to this most current day hydrogen cars use hydrogen in a conventional way, by injecting it into a combustion engine. This does not only mean that most of it goes up in heat, it also means that because of a hotter flame the engine does not last as long (as with current LPG burning petrol engines). For a far and distant energy abundant future, hydrogen may still have a place somewhere but in the short term it does not make much sense.

Air: Air could turn out to be a worthy competitor for electricity. But there is not as much research done in the field of powering cars on air as there is on electric cars. The main advantages are that an air tank can be filled in a minute and that compressed air is not flammable or toxic. It is readily available and easy to produce yourself. On the downside your car still is a noisy machine (this could turn out to be a good thing considering road safety).

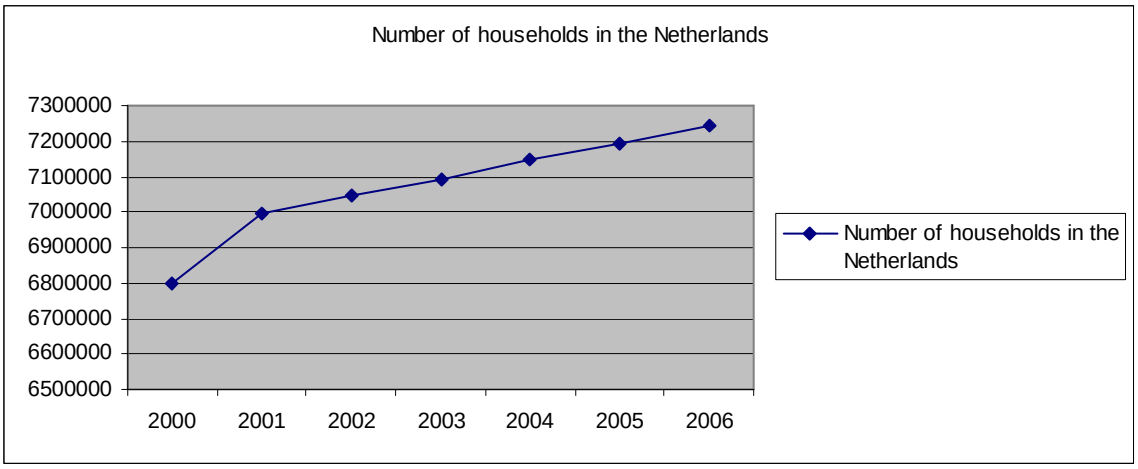
Air has some great advantages over electricity because it is faster in the recharge and easier to get. The only real limit to the success of air is that the limit of range is the amount of air that can be stored in a certain volume and this amount is a fixed amount that will not change in the future as batteries will. The real downfall in driving an air powered car is that the loss that occurs in compressing the air with electricity is that that step greatly harms the efficiency. This makes it more sensible to put electricity straight into your car instead of converting it to compressed air.

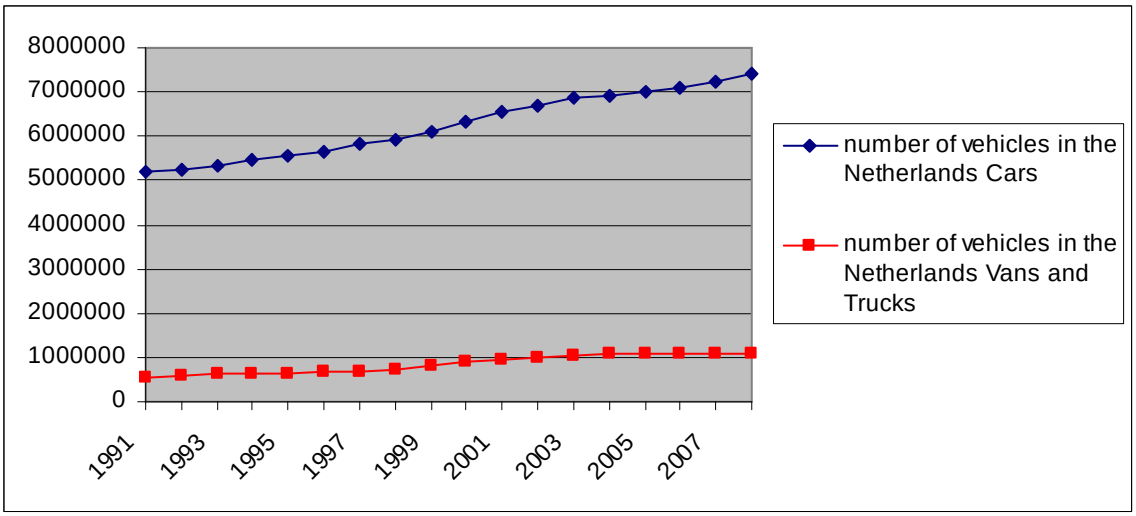
Electricity: this is in our opinion the best way to power a car. As it is versatile in the way it is produced and the storage medium still is in the height of its technological development. As well as the fact that there are no tailpipe emissions and a greatly reduced sound pollution. Next to these facts, electric engines are very efficient (nearly two times as efficient as the best combustion engines) and small. These factors, in short, are why we believe electricity will be the future of personal mobility

3.7 Marketing environment

3.7.1 Demographic environment

More people are getting rich and able to afford a car. Even though the Dutch population is getting older, the number of inhabitants rise as do the number of cars on the road (from just above five million in 1991 to over seven million in 2008). This in turn increases the demand for parking spots as there is nearly one car per household. And you do not only park your car at home. You expect parking spots near your workplace and near the shopping and city centers as well.





According to the Central Bureau for Statistics (CBS), 50% of the employed people use a car to go to work, this is almost 3 million people (see table below). JUiCE! will be focusing on a great section of these people.

Also significant, is that in the Netherlands there are approximately 16 million parking areas. This means that there are about 3 parking places available for every car in the Netherlands.

	Subjects	Unit	Total (all kinds of transport)	Car total
The Netherlands (last alteration in 2007)	Woon-werkreizigers	x 1000	5 184	2 791
	Woon-werkafstand	km	17,6	21,9
	Woon-werkreisduur	minutes	27	28

3.7.2 Economic Environment

Major Car manufactures are all planning the release of Plug-in hybrids in 2010. The plug-in hybrid is a car that runs the first 100km on battery power and when the battery is depleted it turns to a small fuel (bio or fossil) engine to recharge the power pack and provide propulsion. The Paris motor show of October 2008 revealed many electric or semi electric vehicles. With manufacturers such as VW, Nissan, GM, PSA and Mitsubishi in on the trend analyst Wolfgang Bernhart of the international consultancy Roland Berger predicts that this time round the efforts are genuine. Renault deputy CEO Matthieu Tenenbaum expects that by 2015 15% of all cars in the EU are electric and the industry goal is 1 in 4 EU cars by 2018. This means enormous research funds have become available to create competitive Electric cars.
What is also interesting here is that oil prices in that point in time are estimated to be at their peak (see chapter opportunity) thus creating a good opportunity for JUiCE! to implement the charging points at that point in time to provide for the electric vehicles that the above car industries will have sold by 2020.

3.7.3 Sociocultural Environment

Sustainability has currently become a significant aspect to which people and city councils are beginning to pay attention to. People are now increasingly aware about our environment as evidence for all kind of environmental problems mount up. This has already resulted to various environmentally friendly designs and services. One specific example is the use of the Cradle to Cradle theory by designers which states that *waste is food*. IT is clear to many that sustainable products will have the lead in the future market, this will only grow more if this sustainable trend keeps increasing.

3.8 Threats and bargaining power

3.8.1 Rivalry among competitors

Combustion fuel industries like Shell, Bp and Total are our strongest competitors because people are used to using petrol to boost their cars. Many of these industries are in fact involved in environmental related issues, usually to promote their image, like Bp and Shell. In the Netherlands there are not many charging points for cars. In fact, JUiCE! will be the first to create an entire infrastructure for charging points in the Netherlands. Epyon may be our competitors, but they focus especially on fast charging. Our charging points are intended for parked cars.

3.8.2 Threat of new entrants

Many companies, like Essent, will introduce complementary products on the market in the near future, we wish to cooperate with them. An example is the Mobile smart grid. There are also companies, like Awesome Mobility, that are coming up with fast charging stations. This system will be more expensive than our product, but the charging time will be significantly shorter than ours. It might seem that this benefit might pose a threat for our product. Although the locations of these products will be placed differ from JUiCE!'s charging points, the targeted group is similar, if not identical, to ours. Nevertheless, fast charging stations need not be considered as a threat. In fact they are also beneficial to our infrastructure as they complement it by closing the gaps between the cities. In this way a consumer will have less fear of running out of electricity on a highway for instance.

3.8.3 Bargaining power of suppliers

The suppliers JUiCE! needs to cooperate with are the energy suppliers, car companies, charging points' producers, the government/city councils and charging points' constructors, people who manage the parking areas, battery producers, electricity producers and grid controllers.

There are number of major *energy suppliers* in the Netherlands such as Essent, Eneco and Nuon. JUiCE!'s products are totally dependent on electricity, thus these suppliers are very important. The probability that they sell its electricity according to their

advantage is not low. However, JUiCE! will buy a lot of electricity at once so there may be a particular agreement made for JUiCE! such as a discount.

Car companies are also important to us, because without electric vehicles we will not have any consumers. On their side they can't sell their electric vehicles either without a proper charging system for it. So JUiCE! has to cooperate with them, for example by advertising together.

People who *produce* and *construct* the charging points have less bargaining power than the energy suppliers and car companies. Because there are plenty that could replace the one manufacturer for another, to produce and place the charging points.

The *government or city councils* have a lot of bargaining power, because we need to have licenses and permission to attain our goal. Managers of the parking areas are also influential, because they have to allow JUiCE! to place charging systems in their parking lots.

3.8.4 The bargaining power of buyers

There are a variety of cars that customers can choose from; hybrid cars which where very popular last year, petrol cars, electric cars and more. The dominant cars in the Netherlands are currently still the petrol cars. When customers have lots of choice, it is hard for them to choose. Luckily the government supports JUiCE!'s products by letting customers pay fewer taxes for environmentally friendlier cars. Electric cars are still fairly new for consumers and thus they won't accept to switch over immediately.
Fortunately people are dependent on vehicles, thus decreasing their bargaining power. Also, regarding the increase of oil price, people are more willing to buy a car that uses less or no petrol. They will also realize that filling up in a gas station is less comfortable. Finally, the fact that currently there are only very few companies that provide charging points make the bargaining power of buyers decline even more.

3.8.5 Threat of substitute products

The substitute products are related to the kinds of cars. The main substitute products are the petrol cars, in other words, the gas stations. But because of the increase of oil price, this won't be an important threat in the future. Other substitutes might be bio fuels or any other potential sustainable fuels of the future.

4.) Analysis (calculations)[4]

Assumption: During the first part of the analysis full EV's only are taken into account, which can be sold for 80% of the price of competitive petrol cars. In case of initial upward swings in cumulative profit graphs this is due to loans.

4.1 Comparison to alternative ways of range extending[5]

Creating ample infrastructure (like Shai Agassi):
Total costs of creating swopping stations throughout the entire Netherlands:
2000 petrol stations with each using one € 4 million swopping station = € 8 billion
16 million parking spaces * € 1000 per two parking spots = € 16 billion
Total 24 billion/ 8 million cars = € 3 000 per car

Extra large battery packs (Large battery packs like Tesla, and Ece cars do):
€30 000 more batteries

Plug in hybrids:
€10 000 for an extra engine

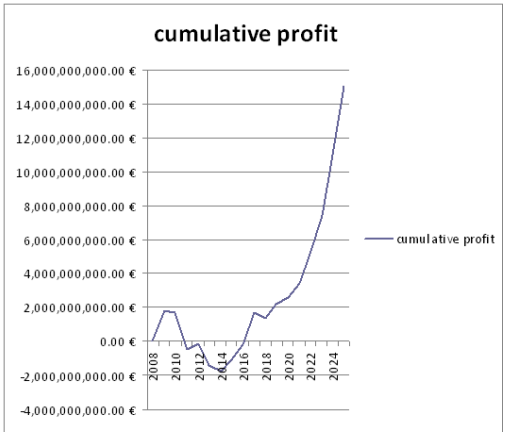
Another disadvantage for plug in hybrids and extra large battery packs is the extra weight and volume for the car.

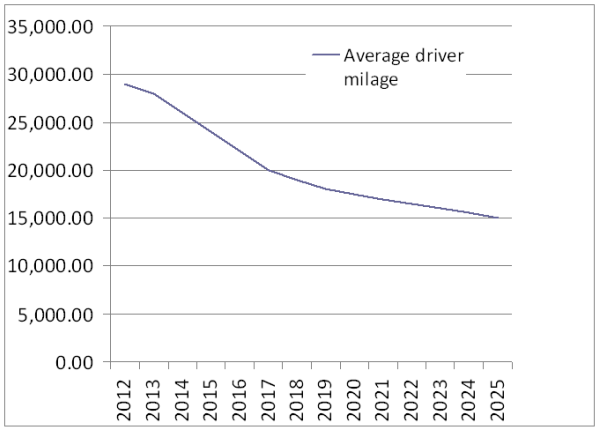
Until there will be an ample infrastructure for full EV's, plug in hybrids will be the main source of income.

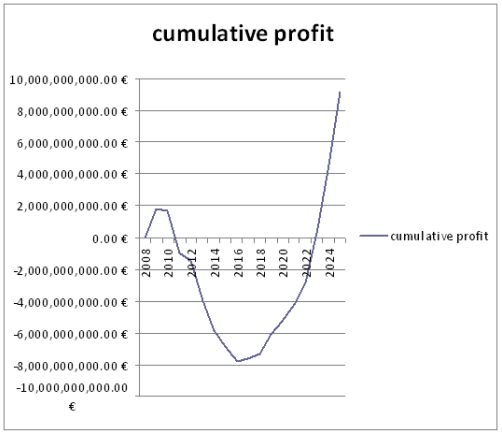
4.1.1 Cost picture for different target groups (assuming a 20 kWh battery pack)

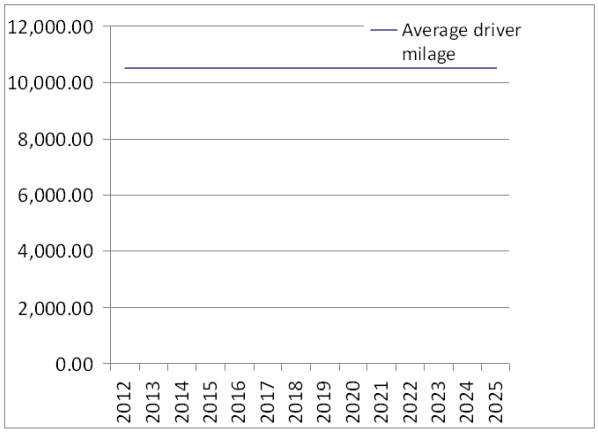
Graphs below show how total cumulative profit depends on the average driver target group. The cost difference comes from the time it takes to see return on investment on your battery. This in turn depends on the product of cost difference between electricity and petrol and amount of km driven.

[4] See appendix 8.3 for the excel sheets
[5] As a quick rule of thumb, we assume the price of battery packs and electricity is the same as refined oil



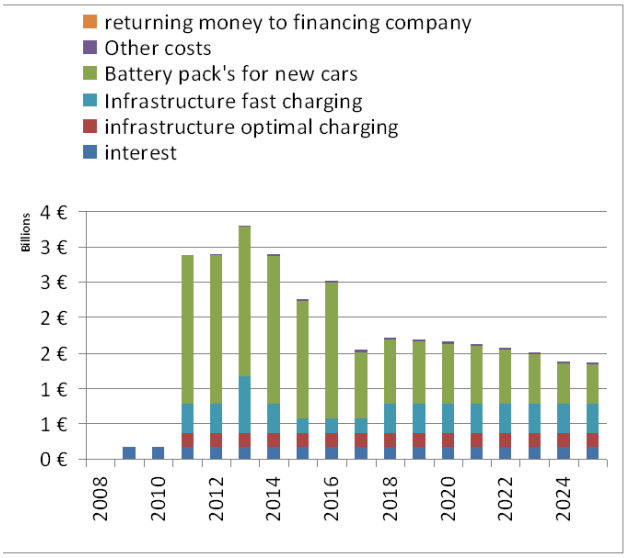






The reason for this difference is the time it takes to break even after having invested in battery packs. When offering smaller battery packs to people who drive a lot, fastest return on investment will be made. We can encourage this through offering more attractive arrangements financially to people who drive a lot with a plug in hybrid or full EV.

4.1.2 Most important costs are battery packs

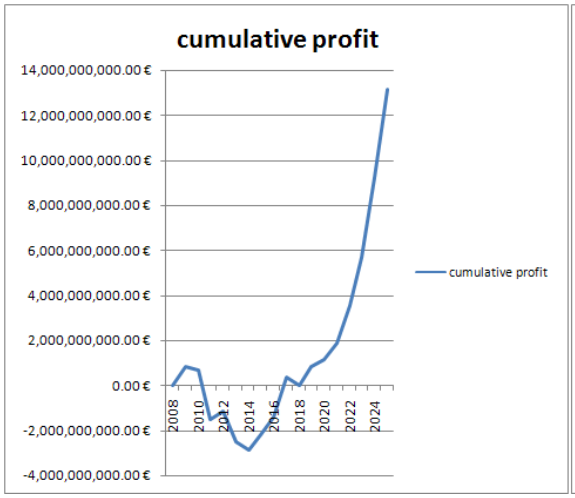


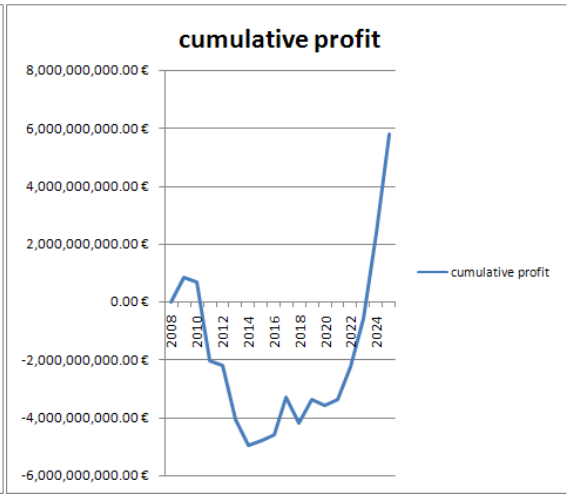
From one of the scenario's you can see total costs and the division of those costs in the graph below. Most important to note are the majority of costs being battery packs.

In the part on battery selection we have shown what kind of batteries we want to lease, in case customers want to pay for expensive battery packs themselves, we still offer electricity on our charging points.

4.1.3 Cost infrastructure optimal charging

It is important to consider the cost of different optimal charging point systems, currently there are two dominant concepts, one concealed in the ground which automatically connects to your car once you park it, and another which is more of a manual charging point. Cost Estimation for a manual charging point is €750 and the cost of an automatic charging point €1000 including everything. One manual charging point will probably be able to cover 1-4 parking spots, for now assuming 2. Another option is to make both, the super convenient ones at EV-exclusive parking spots and the manual Charging Points at regular parking spots.





5.) Conclusions Analysis

5.1 Target segments

The following description of the two different target groups JUiCE! will try to reach with its different types of contracts, the EV and the plug in hybrid.

The EV target group:
The first group that will be targeted for the fully electric vehicle will be the persons without a drive way. This means they will be city dwellers of an average or slightly lower income. They will live relatively close to their relatives and work (40km) because the first car will have a slight range limitation. Their age will be between 25 and 70 and they will be the people who at the moment are buying small cars. Furthermore they will not own a caravan unless they have a second car.

The Plug in hybrid target group:
These people are city to city commuters with big mileages. They feel the oil price in their wallet the hardest. They are freedom loving and do not want the hazard of running out of juice in the middle of a journey. They are aged between 30 and 50 and have an average income. The cars they buy at the moment are big coupes like Volkswagen Passats and Ford Mondeos or station wagons.

5.2 Roadmap

Key focus points:

- Introduction of a car buy / lease scheme
- Implementation of diverse optimal charging points
- Campaign to promote electric driving as the ride to the future

“Electric driving, the ride to the future”

How will JUiCE! achieve these focus points?
The introduction of the buy/lease scheme:
The part of the company which will generate a profit will be the car ‘sales’ part. The scheme works as a mobile phone contract would. You buy a car with a contract which allows you a certain amount of electricity for a price which is guaranteed lower than the running cost of a combustion engine. For every watt you go over you pay a premium on top of your monthly fee. We give you a fixed amount of discount on the car (symbolically the price of the battery) so your car is competitive with other non electric models on the market. Because you do not pay for ‘the battery’ it is not your property and it is the company’s responsibility to replace it free from charge if it breaks down. Furthermore, you have to hand in your car when you sell it (the company buys the car

back and sells it on for recycling) which minimizes our loss on giving the car for a discount. If you are still not convinced about driving fully electric we will also have plug in hybrids available which are off course slightly more expensive, but provide a good halfway solution.

Implementation of diverse optimal charging points:
The next great pillar of our success is the rapid implementation of charging points throughout the Netherlands allowing for a charging point wherever you are, thus enabling consumers to feel assured that they will never run out of electricity no matter where they go. The charging points we need have to be a small range of products which enables them to blend into different environments such as an industrial estates or historical inner city center. The first step will be to supply those people who cannot park their cars on their own driveway o charge them from their own sockets. This means the first charging points will appear in areas with a lot of high rise residential flats. The other starting locations will be large parking spaces just outside city centers near for instance industrial estates or shopping malls.

Campaign to promote electric driving as the ride to the future:
A promotion campaign on a grand scale must be implemented to convince the consumer, with demonstrations and free test drives that electric driving is a better way to drive than the old petrol powered cars. This can be done by a number of demonstration teams which travel the country to introduce the 'new' sensation that is driving electrically. Next to this the campaign needs to highlight the cost difference, and the difference it makes if you can calculate your fuel expenditure further into the future. An electric car with a contract can also be used as a prize for all kinds of competitions and lotteries, thereby making more people aware of the great advantages.

5.3 Marketing strategy

5.3.1 Promotion

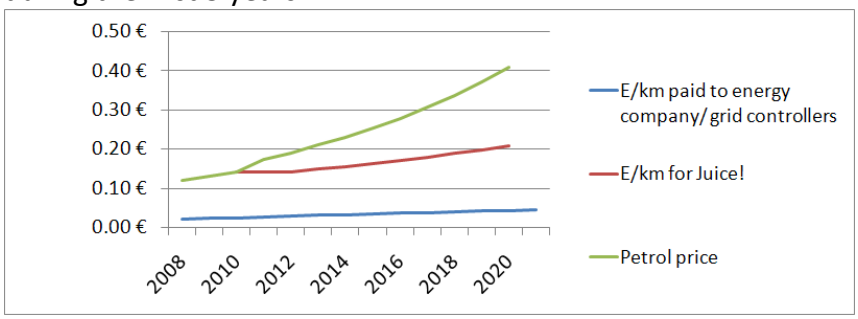
JUiCE! will be cooperating with the car companies that are selling electric cars. Hence, the product can be promoted by placing advertisements in these car companies and lease companies. Part of the costs of the advertisements can be paid by those companies.
Unfortunately, people are still unaware of the charging points, so JUiCE! is going to plan a high budget for its promotion. Cooperated with some car companies, JUiCE! would like to convince people with their promotions that electric vehicles are economical, safe, convenient and odorless to use. But when there is no infrastructure of charging points for it, no one is going to buy an electric car. JUiCE! lets them know that they are making this infrastructure for those who want to drive an electric car. This gives a good impression of the company.

JUiCE! is also counting on the government and city councils to support the promotion process in their attempt to help reduce the burden on our environment. They can also arrange for particular benefits or bonus for companies or shops that are helping in the promotion process of the product.

5.3.2 Price/ Product

We offer JUiCE! which is a better way to fuel your car then petrol. JUiCE! consists of battery packs and electricity which can be used in electric cars. To do so we create a charging infrastructure and cooperate with car manufacturers. The Price for JUiCE! will be lower then petrol and you don't have to pay a large price upfront for your battery pack. Initially JUiCE! will be sold to plug in hybrids, and full EV's will follow shortly.

In the graph below you can see an indication of our expected increase in oil and electricity price (10% yearly) and also the amount of money we want to charge for JUiCE! Because a lot of consumers worry about increasing oil prices, JUiCE! price won't increase during the first 3 years.



5.3.3 Competition

Competition is good!

The more parking spots and petrol stations have charging points, the easier consumers will switch to electric driving thus increasing the total amount of people using our and other charging points.

Customer commitment:
By offering a good service and committing customers through JUiCE! customers will not be inclined to use other charging methods.
Our charging system has to be designed in a way to meet consumer needs in an optimal way. The first mover advantage will cause competition to be delayed, and therefore JUiCE! charging points are expected to have a large market share. If competition is starting to build charging points on a large scale at the same time, this will result in a market division. In this scenario JUiCE! wants to cooperate with these parties to make

sure we don't place multiple charging points at one parking spot. The market is very large and developing will easily allow for multiple competitors.

In an alternative scenario where JUiCE! will be the dominant actor in the market, JUiCE! is still inviting other parties to build charging points. One issue arises then: how do we make the payment system convenient for customers when there are a lot of different payment systems? An automatic payment system which sends you one bill at the end of the month is preferred over having to go through a payment procedure every time you park your car. A lot of small scale parties are more prone to this problem.

Other battery financing companies:
JUiCE! wants to invite battery financing companies to lease batteries. This scenario would allow for lower investment costs while we can still show a profit from selling electricity.

Fast charging companies:
Fast charging works with expensive batteries which are not expected to be used on a large scale in the near future. In case the consumer wants to pay the extra price for these batteries they we will still give them a relatively small discount, provided car companies will build cars with these batteries.

Battery swapping companies:
As shown in the battery sections, looking at total costs and customer convenience this is the kind of 'fast charging' which is clearly favorable. Swapping can be done 20 times faster than fast charging and without the need of attaching a big industrial cable to your car. For battery swapping stations the challenge is to get different car companies to agree on creating one standard. JUiCE! Wants to encourage companies to create these companies, to accelerate the adoption of the electric vehicle.

5.3.4 Pioneer Advantages

JUiCE! is a pioneer in this market in the Netherlands, because there is no place in the Netherlands where there is an infrastructure of charging points. There are some specific locations like ESA (European space agency) or camping places which are provided with a few charging points for electric equipments. But JUiCE! is the first one to come up with the idea of a charging point infrastructure to stimulate people to drive electric vehicles in the Netherlands. As a pioneer, JUiCE! can set standards to the product quality, price, distribution, warranties and promotional appeals. Subsequent competitors must meet or beat these variables. When the standards are high enough, it can raise the costs of entry and perhaps pre-empt some potential competitors.
Besides this advantage, JUiCE! has lots of choices of, for example, distribution and designs. JUiCE! will also maintain a commanding share of the total market for the new product. Hereby, it is possible to make more profit from the mass production.

Although being a pioneer has lots of advantages, there are still risks. Especially the risk that the followers copy the product is big, because in the first step we only focus on the Randstad. Followers can locate familiar products which are improved from JUiCE!'s products, in the places outside the Randstad.
The developments of the charging points and requests for licenses from government and companies will take lots of time. In this period, JUiCE! has to do some measures to prevent the followers or competitors.
In any case, being a pioneer is not easy, but JUiCE! goes for it and will perform very well.

5.3.5 Advantages JUiCE! charging point

A JUiCE! Charging point as we envisage it is a terminal which services one or more actual charging spots. The biggest advantage is that you can use a prepaid or contract system to pay at our terminals so there is no direct cost for charging your car. The JUiCE! Charging point will also be the most widespread of charging points in the Netherlands giving you a nearly unlimited access to a charging spot wherever you are. This unified system is the main advantage. We also expect that within a number of years different companies will use our charging points meaning that the JUiCE! Charging point will become standard.

6.) Design brief JUiCE! Charging Point

Company profile
JUICE! is specialized in the design and implementation of charging points of electric vehicles and the exploitation of these vehicles.

Corporate personality
Image we wish our product should radiate;
It should radiate reliability, high efficiency and quality. The design should not be a taboo, people should be able to adapt to the image and use easily. It should indirectly promote or encourage people to be green (or more environmentally friendly).

Challenge
To rid the community of its current addiction to combustion fuels by encouraging the general public to use electric vehicles through implementation of a charging point infrastructure. .

Aims/Objectives for the consumers
To create a better fueling experience for consumers, provide a system affordable for everybody and at the same time reducing the burden placed on the environment and creating an oil independent, sustainable future.

Aims/ Objectives for the JUiCE! business
Our primary goal is to achieve sustainable mobility by providing electric vehicles with an infrastructure of charging points. These charging points will be positioned at parking lots (both private and public) at which the electric vehicles will charge optimally. Our secondary goal is to encourage electric driving with this infrastructure and promote it to the general public.

Initial Target audience

I. The general public;
These are all people that encounter the charging point in their daily activities.
Age: 18+
Sex: both genders
Income: just under average to just above average
Location: initially the Randstad, concentrating on domestic high rise areas and industrial estates and then expanding to the rest of the Netherlands.

Care should be taken to include the interests of non users who encounter the charging point.

II. City councils and governments;

Because permits are necessary to position charging points at public parking lots.

Budget and Time scale

Budget
€500-1250 per charging point (including material, production and installation costs & maintenance)

Deadline
To provide most parking lots in the Netherlands with charging points for electric vehicles by 2020.

Design criteria

Exterior/image of the charging point

Preferences
- Modern/ elegant

Requirements
- radiate reliability and quality
- Non conspicuous but also not dull

Technical and functional aspects

Preferences
- As little connecting effort as possible
- Automatic or very easy payment system
- Vandalism proof
- "EV-only" parking spot CP, public parking spot CP.
- Low maintenance
- Design with cradle to cradle in mind
- Possible to redeliver to grid

Requirements

- Standardized authorization and connection
- Power easily switched off/on to protect from stealing
- Suitable for quick mass production and installation
- Most convenient for large users
- Allow for easy use of green energy

7.) List of sources

7.1 Internet sources

http://www.azom.com/details.asp?ArticleID=2774#_Common_Types_of
http://www.essentelektrischrijden.nl/uitonderzoek
www.vrom.nl
http://www.time.com/time/business/article/0,8599,1847544,00.html
http://www.ad.nl/autowereld/2376195/Elektrische_auto_in_stroomversnelling.html
www.cbs.nl
www.spinnovation.com/sn
www.treehugger.com
http://www.oplaadpunten.eu/index.php?view=article&id=16%3Amapauto&option=com_content&Itemid=29
http://www.mistergreen.nl/nieuws.php
http://www.betterplace.com/
http://en.wikipedia.org/wiki/Shai_Agassi
www.cmmn.org
www.paulchefurka.ca/Population.html
www.dongenergy.com
www.tennet.org
www.energieleveranciers.nl
www.pgn.nl

7.2 Experts

Jean Verniolle, European Space Agency battery expert
Dong Energy
Spinnovation

8.) Appendix

8.1 Experts

8.1.1 Jean Verniolle, ESA battery expert

1.) What is done when a satellite battery is overheated or stops working? Do they get replaced?

The battery is controlled in temperature (i.e is temperature is maintained in a given temperature range considering the maximum dissipation of the battery and even with some failure which gives some local higher dissipation). If a battery is overheated, it is due to a major failure either on the battery or on the battery charge management (which shall guarantee that the battery is not overcharged or has some protection to avoid over discharge (by disconnecting some equipment from the satellite power bus).

A battery on a satellite cannot be changed in orbit (un-manned). Some satellites have multi-batteries and are sized to be able to lose 1 battery. Now there is a tendency of having a single battery on board but configured in series-parallel battery cells connection which in case of failure limit the battery capacity degradation.

2.) Is there a particular software that manages the output of the battery's energy for higher efficiency? Are there particular sensors installed on the batteries that detect any malfunctions?

Software is used on some battery for controlling the charge of the battery By injecting more or less charge current or by limiting the current when the battery has reached its end of charge voltage.

The sensors used are mainly thermistors for temperature monitoring and Pressure gauges (some type of batteries are generating gas on charge or on overcharge) can also be used.

3.) Besides a small probability of leakage in Lithium-ion batteries what other disadvantages are important to take notice of? (i.e. toxicity, wearing down rate, operational temperature range)

The difficulty with lithium-ion batteries is to balance all the cells that are in series to avoid that some can be overcharged because they have no

overcharge mechanisms to compensate the capacity dispersion between cells. This requires including software or hardware control of small resistors across the cells to discharge the one that are fully charged compared to the other ones.

4.) Lithium ion batteries (including lithium ion polymer batteries) are currently the most efficient (and cheapest) batteries. Are there any other emerging developments that are important to take notice off that could be revolutionary to the battery industry? (Such as nanowire lithium ion batteries?)

So far the lithium-ion battery technology has made a real breakthrough in the battery market and has the best energy density and there is research to improve the performance of the Li-ion.
Other system being developed for electric car for instance is the FUEL CELL (with H2 and air). This system has very high energy density 1000 Wh/kg (depending on the amount of H2 can be stored) but has still safety problem of using Hydrogen (explosive).

5.) What is the highest achievable energy density [Wh/kg] for lithium ion batteries?

Today it is 200 Wh/Kg with an objective to 250 Wh/Kg

8.1.2 Dong Energy

1.) What is exactly the DONG Energy task in this project, since Better Place develops and builds the charging spots and changing stations?

DONG Energy's task is to supply energy and we have local knowledge about how our system w.r.t. electricity, tax a.s.o. works in Denmark. We will also own parts in Better Place Denmark

2.) Is DONG's Energy main benefit the possibility to make money during night hours (when energy is produced which is sold for a relatively low price related to energy produced during day time)?

Our main benefit is that we can integrate more Renewable Energy into the system and since we are looking at wind energy it is when the wind is blowing and it is of course also beneficial to move some of the consumption to night instead of peak hours.

3.) Is it possible to use to the electricity grid connected vehicles as an energy buffer, and if so, would a company like DONG Energy be interested in this buffer?

Yes

8.2 Battery information

Comparison of characteristics

	Cost/cycle	Weight	Other noteworthy things
NiMh	€15	300 kg	
Zebra	€8	190kg	Not enough power
LiFePO4	€10	215 kg	
Lead-Acid	€13	600 kg	
LiTi	€2.7*	270 kg	Suitable for charging in less than 20 minutes *In practice the battery pack is 50% more expensive then LiFePO4 during the first 200 000 km of use.

A list of suppliers for 20 kWh battery packs:

Supplier		Battery type	Weight	Max power	Cycle life	charging time	Price
Cobasys	US	NiMH	300kg	60-100kW	500-1500	1-2h	€ 15k
MES-DEA	CH	Zebra	190kg	30kW	1000-1500	1-2h	€ 10k
Amberjac*	UK	LiFePO4	180kg	100kW	1500-2000	1-2h	€ 18k
Axeon*	UK	LiFePO4	220kg	100kW	1200-1700	1-2h	<€ 15k
JCS	FR/US	Ni-Co	240kg	100kW	>2000	1-2h	€ 21k
Nilar	US/SE	NiMh	290kg	60-100kW	500-1500	1-2h	€ 15k
Enerdel	US	Li-Ti	270kg	>100kW	>3000	<30mins	N/A
Altair	US	Li-Ti	270kg	>100kW	>10000	<30mins	€ 27k
Valence	US	LiFePO4	220kg	100kW	1500-2000	1-2h	€ 18k
A123	US	LiFePO4	215kg	>100kW	1500-2000	1-2h	€ 25k
Kokam	SK	LiCo (pol)	170kg	100kW	±1000	1-2h	€ 25k
Thundersky	CN	LiFePO4	220kg	100kW	1200-1700	1-2h	<€ 15k
Firefly	US	Lead-acid	550kg	>100kW	500	3-4h	N/A
NEC/Lamilion	JP	LiFePO4	200kg	>100kW	400	1-2h	N/A
GAIA/LTC	FRG/US	LiFePO4	200kg	>100kW	1500-2000	1-2h	€ 21k
ElectroVaya	US	LiFePO4	230kg	>100kW	1500-2000	1-2h	N/A
Trojan	US	Lead-Acid	600kg	>100kW	300	3-4h	€ 4k
SEC	US	Lead-Acid	600kg	>100kW	300	3-4h	€ 4k

8.3 Excel sheets of financial analysis