

# Electric driving in the Netherlands



## Policy recommendations for Dutch national and local authorities to stimulate electric driving in the Netherlands



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## Index

Index.....	2
Summary.....	4
Nederlandse samenvatting.....	6
1 Introduction and problem setting.....	8
2 Research aim.....	9
3 Method.....	9
4 Introduction to Battery electric vehicles.....	10
4.1 Primary energy efficiencies.....	11
4.1.1 Plant to tank efficiencies.....	12
4.1.2 Tank to wheel efficiencies.....	12
4.1.3 Plant to wheel efficiencies.....	13
4.2 Emissions.....	13
4.2.1 CO <sub>2</sub> emission.....	15
4.2.2 PM10 emission.....	15
4.2.3 SO <sub>2</sub> emissions.....	16
4.2.4 NO <sub>x</sub> emission.....	16
4.2.5 Overall emissions.....	17
4.3 What about biofuels and hydrogen?.....	17
4.3.1 Biofuels.....	17
4.3.2 Hydrogen.....	19
4.4 The battery, the heart of the electric car.....	19
4.4.1 Battery costs and mass.....	20
4.4.2 Driving range.....	21
4.4.3 Recharging and/or swapping batteries.....	22
4.5 Cost comparison electric car vs. gasoline car.....	23
4.5.1 Maintenance costs.....	23
4.5.2 Fuel costs.....	23
4.5.3 Battery costs.....	24
4.5.4 Overall costs comparison.....	24
4.6 Overview of pros and cons of the electrical car.....	25
4.7 Dutch mobility patterns.....	26
4.7.1 Average Dutch mobility distances.....	26
4.7.2 Motor vehicle fleet of the Netherlands in 2008.....	26
5 Transitions Theory.....	27
5.1 Transition pathways.....	27
5.2 Taking transition steps.....	30
5.3 The role of national and local authorities in transitions.....	32
6 Policy analysis for electric mobility.....	32
6.1 Why is policy needed?.....	32
6.2 Overview of policy instruments.....	33
6.2.1 A) Command and control instruments.....	33
6.2.2 B) Economic instruments.....	33
6.2.3 C) Procurement instruments.....	34
6.2.4 D) Collaborative instruments.....	34

6.2.5	E) Communication and diffusion instruments .....	34
6.3	Experience from electric driving pilot projects.....	34
6.3.1	Evaluation.....	39
6.4	First hand experience of electrical vehicle experts .....	39
6.4.1	Evaluation.....	46
6.5	National governments going electric.....	46
6.5.1	Israel.....	47
6.5.2	Denmark.....	48
6.5.3	Transition theory on nation wide introductions .....	49
6.5.4	Evaluation.....	50
6.6	Policy demand from Dutch electric vehicle actors.....	50
6.6.1	Policy demand on national level .....	50
6.6.2	Policy demand on local level .....	51
6.6.3	Evaluation.....	52
6.7	Current policy in the Netherlands .....	52
6.7.1	Exemption from purchasing taxes.....	52
6.7.2	Exemption circulation taxes .....	53
7	Policy recommendations .....	53
7.1.1	National level .....	54
7.1.2	Local level .....	55
7.1.3	Recommendations on setting up a pilot project .....	56
8	Conclusion and Discussion .....	58
9	References .....	62

## Summary

Mobility gives individual people and society as a whole much freedom and allows for a complicated network of products and services. However mobility comes with a price. Almost all transport is currently fuelled with fossil fuel sources in Western countries like the Netherlands; this causes both dependence on fossil fuels and various negative emissions. These emissions add to global warming, are negative to the local environment and are damaging to human health. Electric driving, especially fuelled with renewable energy sources like the sun and the wind, seems to offer solutions to these negative side effects of mobility. Therefore electrical driving in the Netherlands has been chosen for this research. The focus is put on the possibilities of Dutch authorities, both national and local, to effectively stimulate electrical driving in the Netherlands.

First a literature study was conducted to determine the current pros and cons of electric driving in comparison with the current cars that use an internal combustion engine. The advantages of electric driving are the higher system efficiency, the zero tailpipe emissions, the low noise levels and the lower user & maintenance costs. The disadvantages of electric driving are the high initial costs of the battery and the lower driving range of electrical cars. A cost comparison shows that electrical cars with Li-ion batteries are cost-effective up to a driving range of 150km. Once batteries are mass produced and prices go down this driving range can increase up to 350km. However it is unlikely that electric cars will be able to reach higher driving ranges because battery costs and mass are both starting to get too high. This causes electric cars to be unable to compete with current internal combustion cars since these easily can reach a driving range of 800km per tank and are able to refuel quickly. A study of the Dutch motor vehicle fleet showed however that about 2 million vehicles or 20% of the total fleet are potential candidates for electrical driving since these vehicles have no specific need for high driving ranges. Especially city traffic and certain distribution services are interesting areas for the use of electric cars since the positive qualities of electric driving can add to a better living environment in these areas.

Next to transition theory and how this can be applied to electrical driving, several pilot projects that used electrical cars were studied. In total 500 electrical vehicles were introduced in 20 European cities in these studies. Next information from experts with first hand experience in electrical driving from Monaco, Sweden, Switzerland and the Netherlands was gathered through questionnaires. Additionally large scale planned introductions with Project Better Place have been studied in which special interest was taken in the role of the national governments of Denmark and Israel in these nation wide planned introductions. Last seven Dutch actors in the field of electrical driving were interviewed to determine the policy demand from these parties.

It is obvious that the availability of electric cars is currently the biggest barrier of electrical driving, followed by the higher prices of electrical cars and putting unfamiliarity of people with the technology on the third place. While the Dutch authorities have only limited influence in the whole area of electrical driving they can certainly stimulate electrical driving in the Netherlands. Both national and local governments should be pro-active in making policy for electric driving and various aspects involved like charging stations, safety regulations etc. This can best be done

together with actors already involved with electrical driving and once established this policy should be clearly communicated to the actor field so that the rules of the electric car game are clear and actors can more easily start working together. The current policy from the national government of zero purchasing taxes and zero road taxes makes electrical driving already economically attractive. However this policy should be transformed so that electric driving can also be stimulated in the long run as well. The policy of Israel can serve as an inspiration in this respect. The best way to stimulate electric driving for local authorities is to start or facilitate pilot projects. In this way important information about electrical driving can be gained and various actors in the field can be involved. From the information gained in these pilot projects the future of electric driving in the Netherlands can be determined more precisely.

## Nederlandse samenvatting

Mobiliteit heeft voor een grote toename in bewegingsvrijheid van individuen gezorgd en heeft ons toegang gegeven tot een uitgebreid netwerk van producenten en diensten. Maar deze mobiliteit heeft wel een prijs. Op dit moment vindt bijna al het transport in Nederland plaats met behulp van fossiele brandstoffen. Dit zorgt voor een grote afhankelijkheid van landen die grote voorraden fossiele brandstoffen bezitten en tevens komen er bij de verbranding verschillende schadelijke emissies vrij. Deze emissies versterken het broeikaseffect, zijn schadelijk voor het lokale milieu en hebben een negatief effect op de menselijke gezondheid. Elektrisch rijden, vooral als het wordt gecombineerd met duurzame elektriciteit uit onder andere de zon en de wind, lijkt oplossingen te bieden voor de negatieve bijeffecten van mobiliteit. Om deze reden is elektrisch rijden gekozen als onderwerp van deze studie. Het doel van het onderzoek is het vaststellen van de mogelijkheden van Nederlandse overheden, zowel nationaal als lokaal, om elektrisch rijden effectief te stimuleren in Nederland.

Een literatuurstudie is gedaan om inzicht te krijgen in de voor en nadelen van elektrisch rijden in vergelijking met de huidige auto's die gebruik maken van een verbrandingsmotor. De voordelen van elektrisch rijden zijn de hogere systeemefficiëntie, de afwezigheid van uitstoot op locatie, de verminderde geluidsproductie en de goedkopere gebruik- en onderhoudskosten. De nadelen van elektrisch rijden zijn de hoge aanschafkosten van de batterij en de verminderde actieradius. Een gemaakte kostenvergelijking laat zien dat een elektrische auto met Lithium-ion batterijen op dit moment kosteneffectief is tot een actieradius van 150 km. Wanneer de kosten van deze batterijen naar beneden gaan door massaproductie wordt een actieradius tot 350 km aantrekkelijk. Het is echter onwaarschijnlijk dat elektrische auto's een grotere actieradius gaan krijgen omdat boven deze afstand de prijs en het gewicht van de batterijen te hoog worden. Dit leidt ertoe dat elektrische auto's niet in staat zijn om qua actieradius te concurreren met de huidige auto's die gemakkelijk een bereik van 800 km met een volle tank hebben waarna de tank ook nog eens gemakkelijk kan worden bijgevuld. Een inventarisatie van het Nederlandse motorvoertuigenpark laat desondanks zien dat er in Nederland 2 miljoen voertuigen, 20% van het totaal, zijn die potentieel elektrisch kunnen worden omdat deze voertuigen deze langere rijafstanden niet nodig hebben. Vooral stadsvervoer, woon-werk verkeer en bepaalde vormen van distributie zijn interessant om elektrisch rijden toe te passen omdat de voordelen van elektrisch rijden hier kunnen bijdragen aan een verbeterde leefomgeving. Om te bepalen wat nationale en lokale overheden kunnen doen om elektrisch rijden zo effectief mogelijk te stimuleren zijn verschillende methoden gebruikt.

Naast het bestuderen van transitie theorie en hoe dit van toepassing is op elektrisch rijden zijn verschillende pilot-projecten met elektrisch rijden geanalyseerd. In deze experimenten zijn in totaal meer dan 500 elektrische voertuigen in meer dan 20 Europese steden ingevoerd. Daarnaast is er directe informatie verkregen over elektrisch rijden via experts uit Monaco, Nederland, Zweden en Zwitserland door middel van vragenlijsten. Ook zijn een aantal grootschalig geplande introducties van elektrisch rijden bestudeerd, die worden geïnitieerd door Project Better Place. Hierbij is vooral gekeken naar de rol en het beleid van de nationale overheden van Denemarken en Israël bij deze introducties van

elektrisch rijden op landelijke schaal. Ook zijn er interviews gehouden met zeven verschillende Nederlandse actoren die zich bezig houden met elektrisch rijden om zo de beleidsvraag vanuit het veld in kaart te brengen.

Uit deze analyse is duidelijk geworden dat een gebrek aan beschikbaarheid van elektrische auto's op dit moment het grootste probleem is. De hogere aanschafprijzen van elektrische auto's staan op de tweede plek en de onbekendheid van de technologie bij consumenten sluit de top drie af. Hoewel Nederlandse overheden slechts beperkte invloed hebben in het gehele veld van elektrisch rijden zijn er een aantal belangrijke maatregelen die ze kunnen treffen om elektrisch rijden te stimuleren. Zowel de nationale als lokale overheden moeten proactief zijn in het maken van beleid over elektrisch rijden en aanverwante zaken zoals oplaadinfrastructuur, veiligheidseisen etc. Dit kan het beste gedaan worden in samenwerking met de huidige actoren die in Nederland reeds actief zijn met deze zaken en zodra dit beleid rond is moet dit duidelijk gecommuniceerd worden. Op deze manier zijn de regels rond elektrisch rijden duidelijk en dit zorgt ervoor dat actoren gemakkelijker kunnen gaan samenwerken rond elektrische mobiliteit, iets wat van groot belang is om elektrisch rijden te ontwikkelen in Nederland. Op dit moment stimuleert de nationale overheid elektrisch rijden doordat elektrische auto's vrijgesteld zijn van BPM (Belasting van Personenauto's en Motorrijwielen) en MRB (MotorRijtuigenBelasting). Dit zorgt dat elektrische auto's economisch interessant zijn voor consumenten. Het is echter van belang dat de overheid dit beleid zo omvormt dat elektrisch rijden ook op de lange termijn gestimuleerd kan blijven. Het beleid van de overheid van Israël kan hierbij goed als inspiratie dienen. De beste manier voor lokale overheden om elektrisch rijden te stimuleren is door zelf pilot-projecten met elektrisch rijden te beginnen of deze te faciliteren waarbij zoveel mogelijk relevante actoren betrokken worden. Op deze manier kan belangrijke informatie verzameld worden over de huidige prestaties van elektrisch rijden en kan er door verschillende partijen op verschillende fronten ervaring worden opgedaan. Aan de hand van de verkregen resultaten in deze pilot-projecten kan de toekomst van elektrisch rijden in Nederland nauwkeuriger bepaald worden.

# 1 Introduction and problem setting

The increased mobility during the last century in the Netherlands shows many advantages, increased personal freedom, blooming economies and a greater exchange of ideas are but a few. However there are also downsides to the increase in mobility. Transport is responsible for a large amount of energy use and a great number of emissions since almost all transport is done with fossil fuels.

CO<sub>2</sub> emission caused by transport is an important disadvantage; CO<sub>2</sub> is responsible for global warming and the related climate change. (IPCC, 2007)<sup>1</sup> In 2006 the total energy use of the Netherlands was 3233PJ (CBS Duurzame energie 2006, 2007)<sup>2</sup> The transport sector in 2006 used 582 PJ (18%) of energy, of which road transport used 433 PJ (13%) (MNC, 2008)<sup>3</sup>.

In that same year the total CO<sub>2</sub> emission of the Netherlands was 208 billion kg (CBS magazine, 2007)<sup>4</sup> The transport sector was responsible for 39.6 billion kg (19%) CO<sub>2</sub> emissions of which road transport was responsible for 34.8 billion kg (17%) (MNC, 2008)<sup>5</sup>

Next to CO<sub>2</sub> emission, particulate matter is another important emission of the transport sector that negatively affects human health. Particle matter of very small sizes, (less than 10 micrometers [PM10] and less than 2.5 micrometer [PM2.5]) is inhaled by people where it may cause lung and heart problems. The number of people dying each year in the Netherlands due to long term exposure to PM10 and PM2.5 is estimated to be around 18.000, these victims have a reduced life span of 10 years. The acute victims of PM10 and PM2.5 are another 2900, their life span is shortened by approximately 1 year.(MNP, 2005)<sup>6</sup>

Another disadvantage is the emission of NO<sub>x</sub> and SO<sub>2</sub>, which together give rise to environmental damage in the form of acidification, damage to agricultural crops and a decline of biodiversity. The transport sector is responsible for about 66% of NO<sub>x</sub> emissions and for 20% of SO<sub>2</sub> emissions. (VROM, 2008)<sup>7</sup> Acid rain produced by these emissions can also be corrosive to limestone buildings (Gene E. Likens & F.Herbert Bormann, 1974)<sup>8</sup> and so can cause economical damage.

Next to emissions, other unwanted byproducts of transport are noise and odour nuisance. 43% of the people in the Netherlands in 2004 indicated they were partly or greatly hindered by noise nuisance. Road transport is the most important source of noise nuisance with 31%, leaving airplanes (18%) and trains (6%) on a second and third place. (MNC, 2004)<sup>9</sup>

In that same year 7% of the population indicated that traffic was the most important source of odour nuisance. Traffic takes with this 7% a 4<sup>th</sup> place after agriculture and chimney's (both 11%) and industry (9%). (MNC, 2004)<sup>10</sup>

All these negative side effects show that there is much room for improvement in the transport sector. Keeping the advantages of mobility, with a minimization or even total elimination of these negative side effects seems to be a very interesting terrain. There are currently many innovative technologies in the transport area; biofuels, fuel cells, hybrids, and electrical driving. In terms of energy efficiency and emission & noise reduction electrical driving offers the greatest advantages.

Therefore electric driving is chosen as the technology for this research. Electric driving promises higher system energy efficiencies and zero tailpipe emissions. When using renewable electricity sources like solar and wind energy overall emissions could also be greatly reduced.

Since the Netherlands is a compact country with relative small distances electric driving could be an attractive option. The promises of electric driving seem high. However the reality is that there are hardly any electric cars for sale at this moment. Also electric driving is not widely used anywhere these days. So what is myth and what is reality about the electric car. And if electric driving could indeed live up to its promises what can the Dutch government do to stimulate the introduction of electric driving in the Netherlands?

## **2 Research aim**

This research aims to determine if electric driving can be successfully implemented in the Netherlands within a 5 to 10 year timeframe. Emphasis is on the role of the national and local governments, and their possibilities to effectively stimulate electrical driving in the Netherlands. The following research questions have been formulated.

- 1) What are the current advantages and disadvantages of battery electrical driving?
- 2) How does a transition work, what are the mechanisms that cause some products/technologies to go to a transition and become a success while others never become a success?
- 3) What are currently the most important barriers of battery electrical driving and can these barriers be effectively solved to start a wider application of electric cars in the transport sector?
- 4) What can the Dutch government, on national and local level do to stimulate electric car use in the Netherlands?

## **3 Method**

Question 1 will be answered with a literature study.

Question 2 will be answered with a literature study into transitions. Different theories will be studied to give an insight into the processes of a transition.

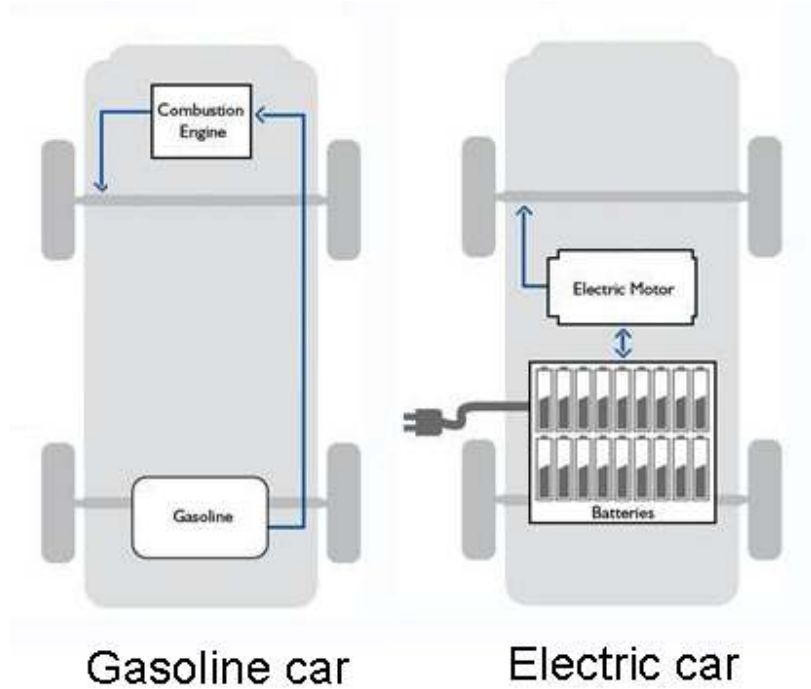
Question 3 will be answered with both a literature study and with various questionnaires. One of these questionnaires is send out to people who have first hand experience with electrical driving from pilot projects. This questionnaire is made in a quantifiable way so data is easy and quick to process. Also interviews are done with various actors in the Dutch actor field of electrical driving to determine the barriers and possible solutions for the Dutch situation.

Question 4 will be answered with a literature study of the policy of the various countries and implementation strategies both on small scale and large scale introductions of electrical driving. Also interviews are done with various actors in the Dutch actor field of electrical driving to determine their ideas about the possibilities and needs in Dutch Policy.

Feedback from one question to the others will be taken into account in this process.

An overview of best practices based on the results on these answers will be given. These results will be presented in a workshop to both local and national policy makers. This is done both to inform these actors, but also to gain feedback for this research.

## 4 Introduction to Battery electric vehicles



**Figure 1, schematic representation of a gasoline and an electric car**

The current standard of personal transport is a car propelled by an internal combustion engine (ICE) fuelled by a fossil fuel of which gasoline and diesel are most commonly used. The internal combustion engine (ICE) is an engine in which the combustion of fuel and an oxidizer (typically air) occurs in a confined space called a combustion chamber. This exothermic reaction produces gases at high temperature and pressure, which are permitted to expand. ICE's are defined by the useful work that is performed by the expanding hot gases acting directly to cause the movement of solid parts of the engine.

A battery electric car works differently. The car is propelled by an electromotor (EM) which is powered with electricity from a battery that can be recharged. Electric motors involve rotating coils of wire which are driven by the magnetic force exerted by a magnetic field around an electric current. They transform electrical energy into mechanical energy. Figure 1 shows a schematic representation of the two types of cars.

The difference between an ICE car and a battery electric car extends to the broader system. To gain insight into the advantages and disadvantages of electric driving the larger system around the propulsion is also taken into account. First the primary energy efficiencies of both systems are compared. Next emissions for the systems are compared.

### 4.1 Primary energy efficiencies

The overall system of electric driving including the generation of electricity to propel the battery is compared with the system of an internal combustion engine that is propelled with fossil fuels. An analysis can be made on various system levels as shown in figure 2.

Figure 2, system representation of a gasoline car with various comparison levels

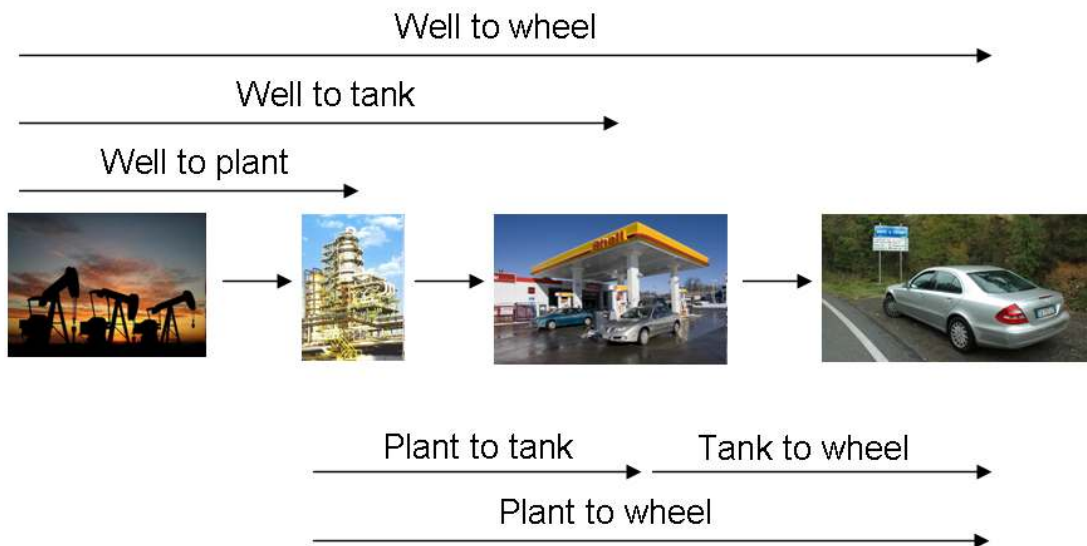


Figure 2 represents the overall system of an ICE car running on fossil fuels. Oil is produced from the soil, next the oil is transported and refined in an oil refinery, the refined oil is transported to the fuel pump where consumers fill up their tanks and the gasoline is used in an internal combustion engine to propel the car.

The electrical system works differently. In this comparison we take a system where electricity is produced from fossil fuel sources and a system where the electricity is produced from renewable energy sources like solar and wind power.

First the fossil fuel electricity system. Figure 3 illustrates the system. It starts with the harvesting of fossil fuels from, in this example, a coal mine, these fossil fuels are transported to a power plant where the fossil fuels are transformed into electricity. The produced electricity is then transported over the grid into the battery of the electric car where it is used to propel the car.

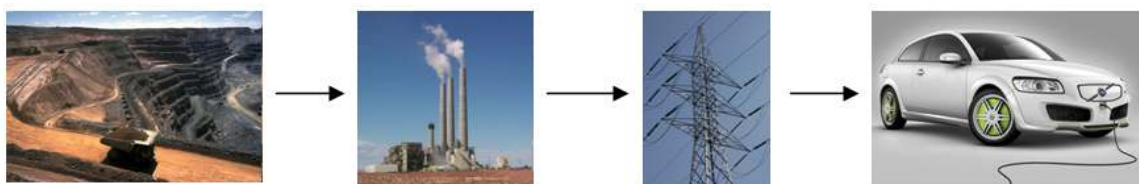
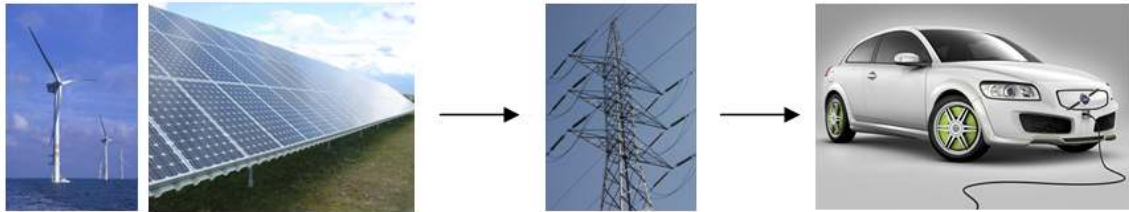


Figure 3, system representation of an electric car powered by fossil electricity

Next is the system where the electricity is produced from renewable sources. A visual representation is given in figure 4. Here electricity is produced by means of water or, as shown in the example, by wind and sun. The renewable electricity is then transported over the electricity grid into the electrical car where it is again used to propel the car.



**Figure 4, system representation of an electric car powered by renewable electricity**

In this research the comparison of the system is on the plant to wheel level. This is done because wind turbines and PV panels can be seen as renewable electricity plants.

The production of PV panels and wind turbines requires energy just like building an oil platform and an oil refinery plant require energy to be built. However to take all these extra energy requirements of the different parts of the system into account makes the comparison very complex. Therefore the plant to wheel comparison is chosen and this should give a sufficiently accurate picture of the primary energy efficiencies in comparing these three systems. The plant to wheel efficiency is built up by adding the plant to tank and tank to wheel efficiencies as shown in figure 2.

#### **4.1.1 Plant to tank efficiencies**

For the fossil fuel – ICE pathway there is an efficiency loss in the refinement and distribution of oil to the tanks. The loss is estimated on 17% (Kendall, 2008)<sup>11</sup> which results in a plant to tank efficiency of 83% for the “fossil fuel – ICE pathway”

For electricity a distinction is made between fossil electricity and renewable electricity. Electricity that is derived from fossil fuels is produced in power plants. In the Netherlands power plants had an efficiency of 40% in 2004 (ECN, 2005)<sup>12</sup>. In this step 60% of the energy value of the input in the plant is lost in the process to converse it to electricity.

PV solar panels and wind turbines produce electricity themselves and since there is only an output, one cannot speak of an efficiency loss in this case. Therefore this efficiency is set at 100%.

The next step is the transportation of the produced electricity to the battery of the electric car. These losses are assumed to be equal for both the fossil and renewable electricity system. Typical grid transmission and distribution (T&D) losses of electricity are around 8% (Kendall, 2008)<sup>13</sup> which result in a 92% transport efficiency of electricity.

#### **4.1.2 Tank to wheel efficiencies**

The tank to wheel efficiency of an internal combustion engine is currently 18% for gasoline and 23% for diesel. The tank to wheel efficiencies of an electromotor varies between 65% and 74%. (Max A° Hman, 2000)<sup>14</sup> (Kendall, 2008)<sup>15</sup> This difference is largely due to the different motor systems. An ICE that works with the ignition of fossil fuels to propel the car produces a lot of heat in the process. This heat is lost and cannot be

used to propel the car. An EM works with an electric current that drives the magnets that in turn converts the electric energy into mechanical energy on the wheels. This difference is the main reason of the significantly higher EM tank to wheel efficiency compared with that of an ICE.

### 4.1.3 Plant to wheel efficiencies

With the outcomes of 4.1.1 and 4.1.2 the plant to wheel efficiencies of these three systems can be calculated. The results are presented in table 1.

**Table 1, plant to wheel energy efficiencies of different systems**

Primary energy efficiencies		Fossil fuel internal combustion pathway	Fossil electricity electric motor pathway	Renewable electricity electric motor pathway
Plant-to-Tank efficiency	Plant efficiency	83%	40%	100%
	Transmission & Distribution		92%	92%
Tank-to-Wheel efficiency		18%-23%	65%-74%	65%-74%
Plant-to-Wheel efficiency		15%-19%	24%-27%	60%-68%

These numbers show that the “renewable electricity–electric motor” pathway has the highest plant to wheel efficiency of between 60% and 68%. The “fossil electricity–electric motor” pathway is in second place. While this path has the benefit of the high tank to wheel efficiency of electric cars, the plant to tank efficiency is low due to the conversion of fossil sources into electricity in a power plant. The overall “fossil electricity–electric motor” plant to wheel efficiency is 24% to 27%.

The currently most frequently used “fossil fuel–internal combustion engine” pathway has the lowest plant to wheel efficiency of 15% to 19%. The low tank to wheel efficiency of the ICE largely accounts for this.

This comparison of the system from plant to wheel shows that both electric driving on fossil and renewable electricity have higher system efficiencies than the current system. This higher plant to wheel system efficiency is therefore one of the advantages of electric driving.

## 4.2 Emissions

Both fossil electricity and renewable electricity are taken into account when comparing electric car emissions with the ICE car emissions. Emissions of gasoline, diesel, LPG (Liquefied Petroleum/Propane Gas), and natural gas are analyzed. The comparison is made for emissions of CO<sub>2</sub>, PM<sub>10</sub>, SO<sub>2</sub> and NO<sub>x</sub>.

In the Netherlands electricity from fossil fuel sources is derived from coal and gas fired electricity plants. About 57% of this electricity is generated in natural gas fired electricity plants and 43% comes from coal fired electricity plants. (CBS, 2007)<sup>16</sup> The average kWh from a coal fired plant produced 863 grams in CO<sub>2</sub> emission in 2004, while the average kWh from a gas fired power plant produced 580 grams in CO<sub>2</sub> emission in the same year. This includes the efficiency of these power plants around 40% in 2004. (ECN, 2005)<sup>17</sup>

The calculations in table 2 show that the average kWh produced from fossil fuels in the Netherlands results in an emission of 702 grams of CO<sub>2</sub>

**Table 2, CO<sub>2</sub> emissions per kWh of fossil electricity produced in the Netherlands in 2004**

	CO <sub>2</sub> emission (g/kWh)	Share in total fossil fuel electricity production
Coal	863	43%
Natural gas	580	57%
Average kWh	702	100%

Just like CO<sub>2</sub> emissions, PM<sub>10</sub>, NO<sub>x</sub> and SO<sub>2</sub> emissions can also be calculated for each kWh. (ECN, 2005)<sup>18</sup> It is further assumed in these calculations that an electric car uses one kWh per six kilometers (EVworld, 2008)<sup>19</sup> (SenterNovem, 2008)<sup>20</sup>. This number includes the tank to wheel efficiency of electric motors. Emission numbers for the other ways of transport are derived from “Emissions and emission profiles: Average driver”, from TNO (P.Hendriksen et al, 2003)<sup>21</sup>.

It is important to keep in mind that tank to wheel emissions for electric cars are zero. An electric car is propelled with a battery that can be recharged and therefore it has no local emission at all. The electricity that is used is either produced in a power plant or in a wind turbine, solar panel etc. this is also where the emission occurs. This is important since many emission problems, especially those that have a health impact are very much dependant on where the emission takes place. In heavily populated areas, exhaust of PM<sub>10</sub> for example is much more damaging than in thinly populated areas. Therefore, looking at tank to wheel emissions, electric cars have a great advantage.

However a broader comparison that takes into account the emissions at the power plant is also useful to give an idea of emissions in the total system. This is the case in the following comparisons. The comparison is from plant to wheel for electric driving while it is tank to wheel for all the other fuel sources. This gives the other fuel sources a slight advantage forehand. The overview of emissions is given in table 3 and in figure 5 to 8.

**Table 3, overview emissions for various fuel sources**

Emissions	CO <sub>2</sub> emission in g per km	PM10 emission in mg per km	SO <sub>2</sub> emission in mg/km	NO <sub>x</sub> emission in g per km
gasoline	208.1	0.006	8.9	0.10
diesel	180.5	0.046	3.7	0.80
LPG	189.3	0.005	2.8	0.07
natural gas	168.6	0.002	1.5	0.04
electricity (fossil)	117	0.0005	29.2	0.10
electricity (renewable)	0.0	0.0001	0.0	0.00

#### 4.2.1 CO<sub>2</sub> emission

Figure 5 illustrates that electric driving has a significant reduction in CO<sub>2</sub> emissions.

Driving on fossil electricity produced in the Netherlands gives a CO<sub>2</sub> emission reduction of 44% compared with gasoline and a reduction of 30% with diesel. Driving on renewable electricity reduces the plant to wheel CO<sub>2</sub> emissions to zero.

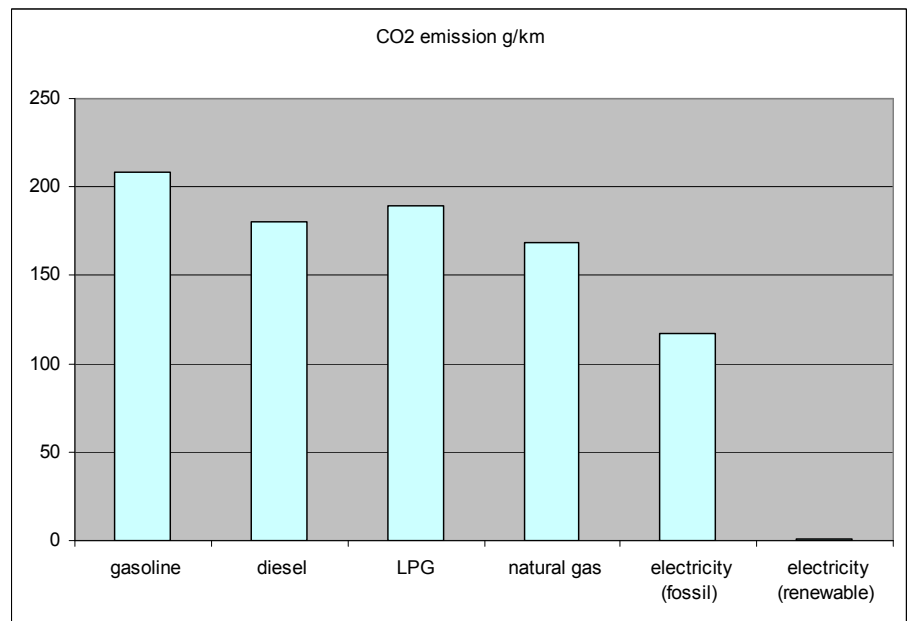


Figure 5, CO<sub>2</sub> emission in g/km for various fuel sources

#### 4.2.2 PM<sub>10</sub> emission

For PM<sub>10</sub> the emission on the road, the place where it forms the biggest health risk for other road users, is reduced to zero concerning fuels. The wearing of tires will still produce a little amount of PM<sub>10</sub>. The PM<sub>10</sub> production on site of the electricity plants is also very low as shown in figure 6. While some American studies show an increase in PM<sub>10</sub> emissions with electricity produced from coal (EPRI, 2007)<sup>22</sup> this does

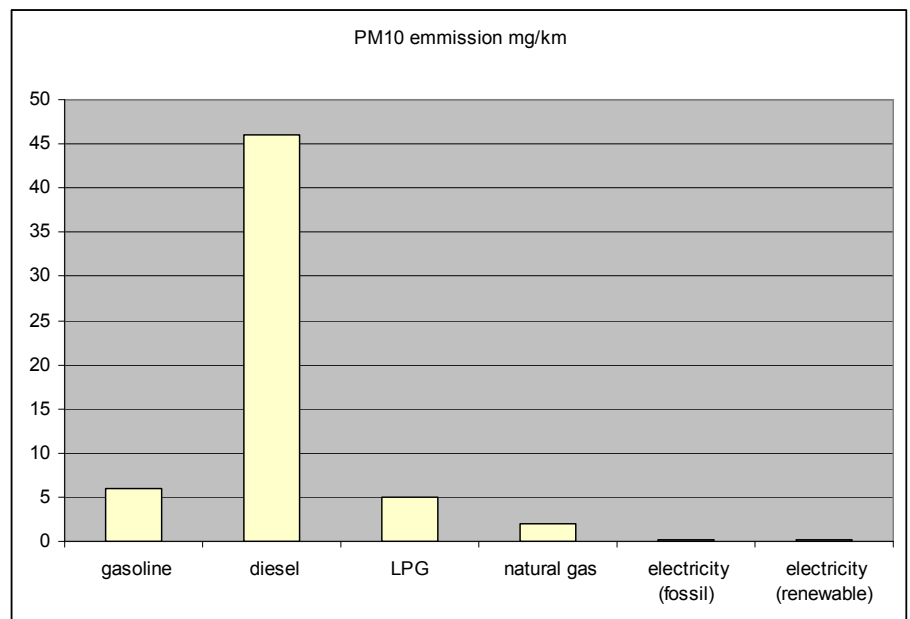


Figure 6, PM<sub>10</sub> emissions in mg/km for various fuel sources

not seem the case in the Netherlands.

ECN concludes in its report that PM<sub>10</sub> concentrations next to a Dutch coal fired power plant are negligible (ECN, 2005)<sup>23</sup> This seems to be in accordance with the report of MNP and ECN that concludes that the total electricity production industries accounts for 1% of the total PM<sub>10</sub> emission in 2002 in the Netherlands while the transport sector accounted for 35% of total PM<sub>10</sub> emissions of that year. (ECN, MNP, 2005)<sup>24</sup> Therefore

Europe has higher emission standards for their plants than America and within Europe the Netherlands are in the top concerning clean power plants according to A.J.Seebregts of ECN.

### 4.2.3 SO<sub>2</sub> emissions

SO<sub>2</sub> emissions for electricity from fossil fuels are significantly higher than from any other type of fuel as seen in figure 7. In comparison with gasoline SO<sub>2</sub> emissions are more than three times higher, in comparison with diesel this increases to a factor of eight. This rise in SO<sub>2</sub> emissions for fossil electricity is due to the 43% coal mix in Dutch fossil electricity. For renewable electricity SO<sub>2</sub> emissions are reduced to zero. This is significantly less compared with the other current emissions.

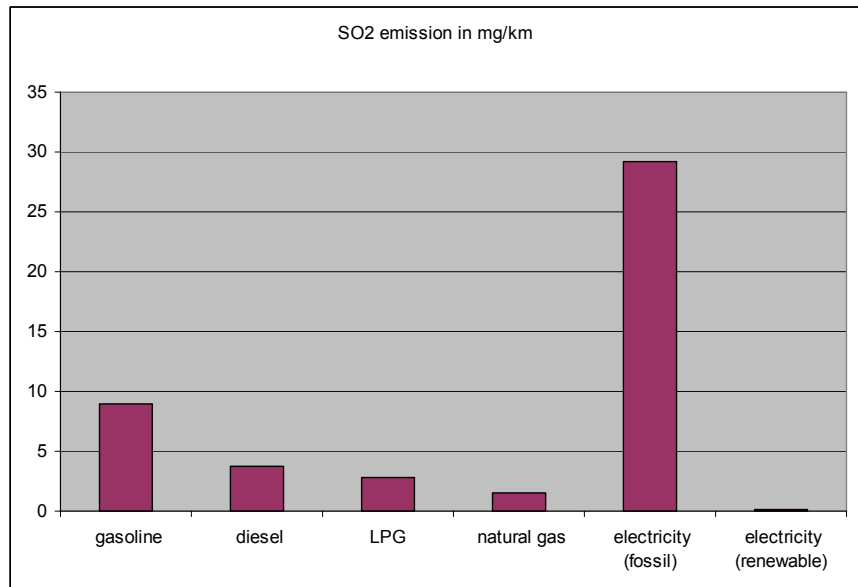


Figure 7, SO<sub>2</sub> emissions in mg/km for various fuel sources

### 4.2.4 NO<sub>x</sub> emission

Last is the NO<sub>x</sub> emission in figure 8. Fossil electricity from the Netherlands has the same NO<sub>x</sub> emissions as gasoline and is eight times less compared with diesel. Renewable electricity reduces the NO<sub>x</sub> emission to zero.

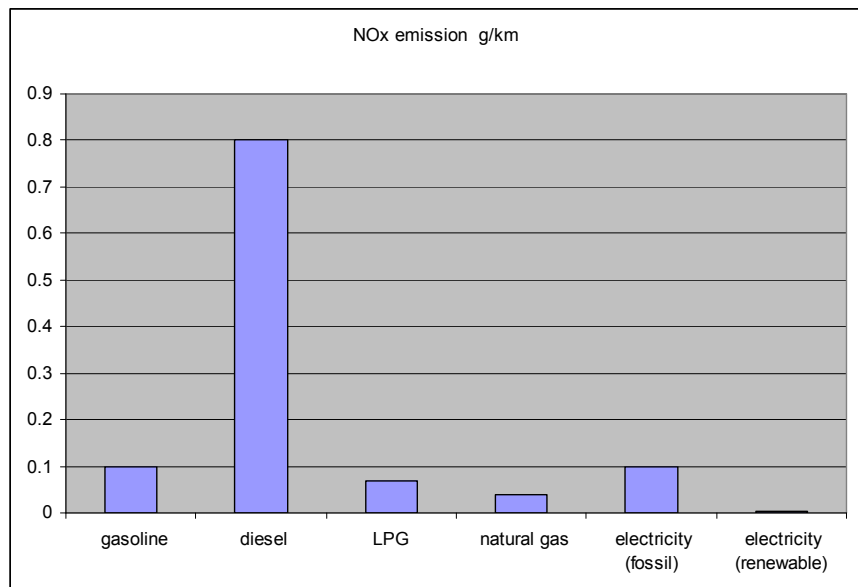


Figure 8, NO<sub>x</sub> emissions in g/km for various fuel sources

## 4.2.5 Overall emissions

The comparison of emissions of current cars with electric cars, both on fossil and renewable electricity gives insight into the advantages and disadvantages of electrical driving concerning emissions. The electric car running on fossil electricity produced in the Netherlands is performing better on the emission of CO<sub>2</sub> and PM<sub>10</sub>, is performing on an equal level for NO<sub>x</sub> but is performing worse for SO<sub>2</sub> emissions. An electric car running on renewable energy has by far the lowest plant to wheel emissions and all emissions are reduced to zero.

## 4.3 What about biofuels and hydrogen?

The preceding comparisons have left out other new upcoming technologies. In this section some of the alternatives just like electrical driving that are being considered at the moment are addressed.

### 4.3.1 Biofuels

In the previous comparisons biofuels (biogas, biodiesel, bio-ethanol, etc.) were not taken into account. This is because a lot of data on biomass shows great variations and because biofuels are just like electric driving not yet implemented on a larger scale. However a qualitative comparison on efficiencies between the two can be interesting. Therefore a system analyses is made between -biofuels with an internal combustion engine-, -biofuels that are used for electricity production in an electric car- and -photovoltaic panels that produce electricity which is used in an electric car-. All these systems use solar energy to propel the car. Figure 9 shows a comparison of these three systems.

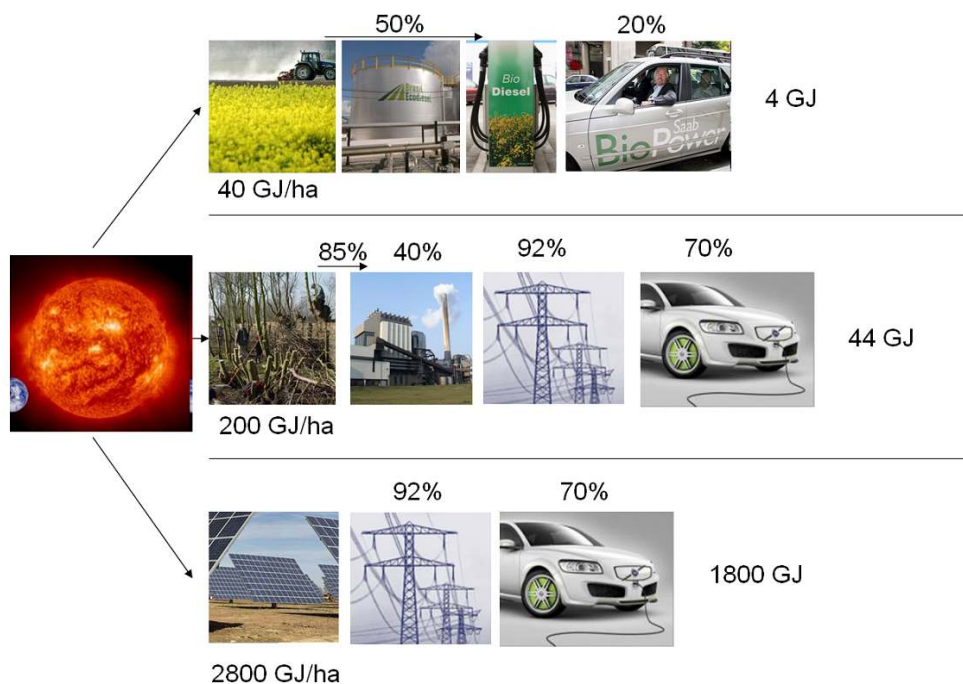


Figure 9, system comparison of three different solar energy routes powering a car

The comparison starts with a comparison of the yields in the three systems in energy per square meter. The comparison is between systems that can produce biofuels for an ICE car, rapeseed is used in this example; a system that grows biomass which can be easily used for electricity production, fast growing trees like poplar and willow is used in this example; and a system that uses PV solar panels for electricity production.

One hectare of rapeseed grown in North West European conditions give an average yield of 40 GJ/ha (Visi García Ciudad et al, 2003)<sup>25</sup>, a fast growing tree system gives an higher yield of about 200 GJ/ha (Visi García Ciudad et al, 2003)<sup>26</sup> (S.Nonhebel, 2001)<sup>27</sup>. A solar panel in the Netherlands of 100 Wp produces around 80 kWh per m<sup>2</sup> in a year. (ZPV, 2008)<sup>28</sup> This means that a hectare of solar panels gives a harvest of around 2800 GJ/ha/yr. (1kWh =3.6MJ) The significantly higher basic harvest of solar energy on a hectare with PV solar panels is mostly due to the photosynthesis maximum of plants of around 1%. Current PV solar panels have an efficiency of around 15% when converting sunlight directly into electricity.

The conversion efficiency of biomass on the land to biofuel at the pump is estimated at 50%. This estimation is made on the following assumptions. Only parts of the plants are converted into biofuel. Next to this there is energy involved in harvesting the biomass, transporting it to the biofuel plant, converting the biomass into biofuel and last transporting it to the biofuel pump.

For growing trees there is a loss of 15% of the energy to harvest it and transport it to the power plant. (Visi García Ciudad et al, 2003)<sup>29</sup>

For the PV pathway the earlier given efficiency of 92% is used for the transport and distribution of the PV electricity. Also the plant to wheel efficiencies of an ICE and an EM are used as given in table 1, although given here in one average number.

Taking the basic input of the systems and calculating the various system efficiencies of the three systems, the amount of energy that is in the end used to propel the car varies greatly.

The “biofuel-ICE pathway” yields 4 GJ of output for one hectare of rapeseed. The “biofuel-EM pathway” yields 44 GJ of output for one hectare of growing trees and the “PV solar panel- EM pathway” yields 1800 GJ of output for one hectare of solar panels. According to these calculations, the system efficiency of solar panels with an electric car is at least two orders of magnitude more efficient than a system which grows rapeseed to make biofuels. It is also at least one order of magnitude more efficient than a system which grows biomass for electricity production. Last it shows that growing biomass for electricity production is one order of magnitude more efficient than growing biomass for the production of biofuel. Because it appears from these efficiency calculations that using biomass as a fuel in cars has the worst efficiency this report will not take biomass further into account.

### 4.3.2 Hydrogen

Next to biomass, hydrogen is also an energy carrier that is often mentioned as an alternative way to propel the car. Electric driving and driving on hydrogen is actually quite alike in the way that both systems use an electromotor to propel the car. In a hydrogen car however the electricity is produced in a fuel cell that converts hydrogen and oxygen into water and electricity. The car tanks hydrogen to refuel.

The idea of hydrogen and fuel cells was developed because of the problems with electric driving on just a battery. The mass and costs

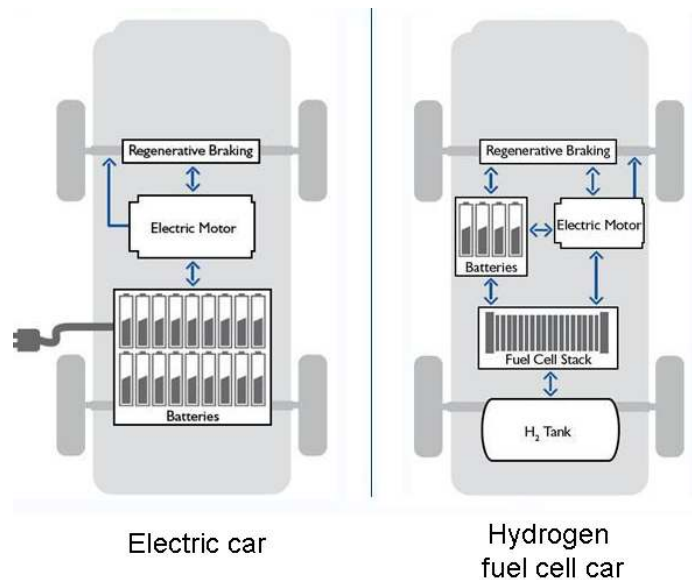


Figure 10, schematic of an electric and a hydrogen fuel cell car

of the battery were simply too high which greatly limited the driving range of the battery electric car. A solution would be to produce the electricity onboard in the car from hydrogen. This technology is however significantly more complex as illustrated in figure 10, and still relatively very expensive. Experts say however that it might take another 20 to 50 years before hydrogen could be used on a large scale. (Raad voor verkeer en waterstaat et al, 2008)<sup>30</sup> Due to recent advancement in the battery industry, because of the widespread application of rechargeable batteries in laptops and mobile phones, the earlier problems of battery electric vehicles have been partly solved. This has also caused the renewed interested in electric cars. Hydrogen however still might prove to be an interesting technology in the future as a follow up on electric cars. But since hydrogen does not seem to have much potential for the next decade, this research does not go into further detail on hydrogen.

### 4.4 The battery, the heart of the electric car

After discussing primary energy efficiencies and the emissions of various fuel sources lets zoom in on the electric car again, and specifically on the battery and the various aspects associated with the battery like, energie density, costs, mass and driving range.

There are many battery technologies available, and many are still in the development process. Due to the relative high energy density and the relative low mass, Li-ion batteries are the technology that seems dominant in current and near-future electrical cars. Therefore calculations in this research are based on Li-ion batteries.

A large scale switch from oil towards Li-ion based batteries will cause a greater demand for lithium in the world. According to literature the world reserves of lithium are large enough to switch all cars in the world today to an electric battery driving car, not once but three times. Production capacity of lithium would need to be greatly increased if the demand would greatly increase. This increase should be realizable. (Fritz G. Will, 1996)<sup>31</sup> (M.Armarand & J. M. Tarascon, 2008)<sup>32</sup>

While an electromotor is more efficient in using the available energy, the main problem of the electric car is energy storage. The total amount of energy that can be stored in a battery is much lower than the energy stored in gasoline and other liquid fossil fuels. Figure 11 (Design news, 2008)<sup>33</sup> gives a comparison of two different battery types, lead acid and lithium ion, and gasoline. The picture shows that gasoline has an energy density that is 85 times higher than lithium ion batteries. This also has implications for the mass of the batteries that needs to be carried along in an electric



Figure 11, energy density comparison of two battery types and gasoline

car. To get an energy equivalent of 10 kg of gasoline in an electric car, 850 kg of Li-ion batteries are needed. Although battery technology has made many advantages to the point that electric driving seems interesting again, the battery is still at the heart of various problems concerning electric driving.

When it is assumed that an electric car drives 6 km on 1 kWh it is possible to calculate the amount of batteries that is needed for a certain driving range. Since the costs and mass of the batteries are connected to the amount of batteries needed, one can make estimations of these in correlation with the driving range of the car.

#### 4.4.1 Battery costs and mass

Figure 12 shows both the added mass (7.14kg) and costs (\$770) per kWh for Li-ion batteries estimated on April of 2008. (Design news, 2008)<sup>34</sup> Prognoses are that once mass produced costs for Li-ion batteries will go down. The costs for mass produced Li-ion batteries is estimated at 475 \$/kWh when batteries are produced in volumes of 20,000 batteries per year and is estimated at 326\$/kWh when produced in volumes of 100,000 batteries per year. (Fritz R. Kalhammer et al, 2007)<sup>35</sup> Another reports gives the price of 330 \$/kWh once Li-ion batteries are mass

Today's Numbers		
Battery	Specific Energy (W-hr/kg)	Cost (\$/kW-hr)
Lithium-ion	140	\$770
Nickel-metal hydride	110	\$850
Lead-acid	50	\$100

Figure 12, cost and mass of current battery technologies

produced (Fritz G. Will, 1996)<sup>36</sup> Table 4 gives an overview of the mass and costs for Li-ion batteries depending on available driving range. 10<sup>1</sup>

**Table 4, overview of battery costs (\$) and mass (kg) depending on various driving ranges**

Driving range (km)	Minimal needed storage capacity (kWh)	mass (kg)	Costs (\$) price level April 2008 \$770/kWh	Costs (\$) when mass produced (20,000 / year) \$475/kWh	Costs (\$) when mass produced (100,000 / year) \$330/kWh
50	8.30	60.0	642*10 <sup>1</sup>	396*10 <sup>1</sup>	275*10 <sup>1</sup>
100	16.7	119	128*10 <sup>2</sup>	792*10 <sup>1</sup>	550*10 <sup>1</sup>
150	25.0	179	193*10 <sup>2</sup>	119*10 <sup>2</sup>	825*10 <sup>1</sup>
200	33.3	238	257*10 <sup>2</sup>	158*10 <sup>2</sup>	110*10 <sup>2</sup>
300	50.0	357	385*10 <sup>2</sup>	238*10 <sup>2</sup>	165*10 <sup>2</sup>
500	83.3	595	642*10 <sup>2</sup>	396*10 <sup>2</sup>	275*10 <sup>2</sup>
800	133	952	103*10 <sup>3</sup>	633*10 <sup>2</sup>	440*10 <sup>2</sup>

These results show that a driving range of 800 km, which can be reached with a full tank of gasoline or diesel with a standard ICE car, is very hard to reach for a battery electric car. To drive this distance without recharging would require a battery with costs over \$100,000 at current price level. To put the costs of the battery somewhat in perspective the life time of the batteries should also be included. The life time of a battery is defined as the number of cycles a battery can be recharged up to at least 80% of its initial energy storage capacity. Various Li-ion batteries have a lifetime of around 3000 cycles and around 10 years. If one reaches 3000 cycles before the 10 years the battery is finished, if one reaches less than 3000 cycles in the 10 years of time the battery is also at its end after these 10 years. (Fritz R. Kalhammer et al, 2007)<sup>37</sup>.

Next to the price however an electric car with a range of 800 km would add an additional mass of almost 1000 kg to the car. While the costs could go down rather fast once mass produced, this is not the case with the mass.

#### 4.4.2 Driving range

These numbers show that an electric car with a range of 800 km is very unlikely to be built, neither now nor in the future. The costs and mass of the battery are simply too high. However an electric car with a smaller driving range could be attractive. The electric cars that are available now and that are becoming available in the coming years actually have significantly lower driving ranges than the current cars. In an overview of electric city cars on a Dutch website there are 31 different city cars that are either already available or might become available over the next three years; their indicated range varies between 40 and 250 km. In the personal transport car department there are 32 different models with an indicated range between 70 and 400 km, (Olino, 2008)<sup>38</sup> On another website there is a total of 110 electric models, their indicated range varies between 30 and 600 km, (Zerauto, 2009)<sup>39</sup>

### **4.4.3 Recharging and/or swapping batteries**

The disadvantage of a lower driving range could be partly decreased if energy in the car could quickly be replenished. In the case of battery electric vehicles this would mean quick recharging or swapping an empty battery with a full one. However the opposite is true, filling up the tank for an ICE car takes less than five minutes. Charging Li-ion batteries from a 230 volt wall socket takes between 4 and 10 hours depending on battery size and type.

Recharging can be done when the car is parked at home or at work depending on whether there is an electrical outlet available to charge it. If a car is not used on long distances and if it is recharged every day either at the workplace or at home the rather limited driving range and the long charging times might not be a big problem. However the currently available technology of electric cars has both great disadvantages in both energy storage and recharging compared with currently available technology.

Fast charging should be able to cut down recharging times significantly. Fast charging stations are developed where the battery can be charged from 0 to 80% within 10 minutes to 1 hour in experimental settings. Some technicians however state that fast charging causes the battery to degrade faster and fast charging might also cause the battery to heat up which can be a problem to the safety of Li-ion batteries. At present there is no fast charging infrastructure in the Netherlands available and fast charging would take longer than filling up a normal gasoline tank.

Another proposed solution for replenishing energy in an electric car is a battery swap station where an empty battery is replaced with a full one. This idea proposed by Project Better Place would guarantee a faster time than a normal gas stop since it would happen within 2 to 3 minutes and would be done fully automatically so safety is also insured. This however would require an infrastructure of battery swap stations that is not available at the moment. While battery swapping could be a solution to quickly replenishing the energy of a car several issues need to be solved in a battery swap system. These include: 1) standardization of batteries, (Will all electric cars have the same battery packs in the future?) 2) ownership of batteries (If people own the battery do they want it to be swapped with the battery of somebody else? Will there be a common pool of batteries in ownership of a company and can people use batteries out of this pool against payment?) And 3) appropriate technology to insert and extract batteries for a wide variety of cars. Just like fast charging, battery swapping infrastructure is also still lacking. Plans to roll out these systems are however there; this will be addressed in section 6.5.

Combining the comparatively limited driving range of electric cars, due to the limited energy storage of batteries and consecutively higher battery costs and mass, and the longer recharging times makes electric cars, at least, for long distances unattractive. Fast charging and/or battery swapping infrastructure might improve this but for this to happen some very important issues still need to be resolved. With Li-ion technology batteries, electric cars are neither now nor in the near future able to offer the same performance as the current ICE cars in the area of driving range.

## 4.5 Cost comparison electric car vs. gasoline car

After discussing various advantages and disadvantages of electric cars we turn to the economic aspect. A cost comparison is made to give insight into the economics of an electric car compared with the current system. Due to the rapidly changing oil prices the result of such a cost analysis is also subject to changes since user costs play a big role in the total costs.

### 4.5.1 Maintenance costs

An electric motor is simpler than an internal combustion engine. An EM has fewer parts that can break down. Moreover electric cars do not need oil changes, spark plugs, distributors, timing belts, etc. If regenerative braking is installed than also the wear and tear of brakes is reduced to a minimum. This makes the maintenance costs of an electric car lower compared with an ICE car.

The ANWB, a Dutch organization that advises car owners, gives maintenance costs for both diesel and gasoline cars. These costs contain needed repairs, general maintenance and tires. For the average car (middleclass) they estimate the yearly maintenance costs are 600 Euro per year for gasoline cars (ANWB, 2008)<sup>40</sup> and up to 1300 Euro per year for a diesel car. (ANWB, 2008)<sup>41</sup>

Electric car maintenance consists mostly of new tires since repairs and general maintenance will almost totally be gone. It is assumed that new tires cost 600 Euros and they need replacement every 3 years (around 42.000 km). An additional 50 Euro per years is assumed for additional maintenance costs which would bring the estimated maintenance costs of electric cars around 250 Euro per year.

### 4.5.2 Fuel costs

The prices of gasoline, diesel and LPG are derived from the ANWB (ANWB, 2008)<sup>42</sup> Electricity prices are based on Eurostat (Eurostat 2007)<sup>43</sup> The natural gas price is based on CNGnet (CNGnet, 2008)<sup>44</sup> The average number of kilometers driven in a car is 13,840 in 2006 (CBS, 2008)<sup>45</sup>. The average number of kilometers that can be driven per unit of fuel source is based on data from TNO (P. Hendriksen et al, 2003)<sup>46</sup>, the driving range of natural gas is derived from fuelswitch (fuelswitch 2008)<sup>47</sup> and the driving range of electrical driving is derived from EV world and SenterNovem (EVworld, 2008)<sup>48</sup> (SenterNovem, 2008)<sup>49</sup> The results are presented in table 5.

**Table 5, driving costs in Euros for various fuel sources**

	Price (Euro)	Driving range (km)	Price in Euro (km)	Yearly costs in Euro (13,840 km)
Gasoline (liter)	1.57	12	0.131	1811
Diesel (liter)	1.33	15	0.089	1227
LPG (liter)	0.77	8.5	0.091	1254
Natural gas (kg)	0.72	14	0.051	712
Electricity price domestic (kWh)	0.283	6	0.047	653
Electricity price industrial (kWh) (Maximum demand: 4000kW, annual load: 6000 hours)	0.109	6	0.018	251

The result in table 5 shows that the user costs of electricity per km, for the average person who pays domestic electricity prices, are lower than the user costs per km for gasoline, diesel and LPG. Also the prices of domestic electricity are slightly lower than those of natural gas. It should be noted that prices of all these types of fuel can greatly change.

### 4.5.3 Battery costs

The costs and mass of the battery of an electric car have been given earlier in table 4, in table 6 the numbers are given again but prices are given in Euro so battery costs can be taken into consideration for the cost comparison. The conversion rate from dollar to euro was set on 1.40

**Table 6, battery costs in Euros for various driving ranges**

Driving range (km)	Minimal needed storage capacity (kWh)	Mass (kg)	Costs (€) price level April 2008	Costs (€) when mass produced (20,000 / year)	Costs (€) when mass produced (100,000 / year)
50	8.30	60	$458 \cdot 10^1$	$283 \cdot 10^1$	$194 \cdot 10^1$
100	16.7	119	$917 \cdot 10^1$	$566 \cdot 10^1$	$388 \cdot 10^1$
150	25.0	179	$138 \cdot 10^2$	$848 \cdot 10^1$	$582 \cdot 10^1$
200	33.3	238	$183 \cdot 10^2$	$113 \cdot 10^2$	$776 \cdot 10^1$
300	50.0	357	$275 \cdot 10^2$	$170 \cdot 10^2$	$116 \cdot 10^2$
500	83.3	595	$458 \cdot 10^2$	$283 \cdot 10^2$	$194 \cdot 10^2$
800	133	952	$733 \cdot 10^2$	$452 \cdot 10^2$	$310 \cdot 10^2$

### 4.5.4 Overall costs comparison

For this comparison the assumption is made that cars drive the average distance of 13,840 km a year. (CBS, 2008)<sup>50</sup> And that consumer prices are paid for all fuel sources. It is also assumed that the battery will last for 10 years. (This is the case when taking into account the average driving distance a year and the 3000 cycle lifetime of the battery. This means that a car should drive at least 46 km each charge before it is recharged to reach its age of 10 years.) The result is given in table 7.

**Table 7, overview of maintenance costs for the electric, gasoline and diesel car**

Cost comparison	Fuel costs per year (€)	Maintenance costs per year (€)	Total user costs per year (€)
Electric car	653	250	903
Gasoline car	1,811	600	2,411
Diesel car	1,227	1,300	2,527

The results in table 7 show that electric driving saves around 1500 Euro a year compared with a gasoline car and 1600 Euro compared with a diesel car. In the time span of 10 years this means a saving of 15000 Euro compared with gasoline and 16000 Euro compared with diesel.

It comes down to the size of the battery to determine the overall most cost effective option. These numbers can be used to see how big a battery can be bought. With current

prices a battery with a driving range of about 150 km (179kg added mass) or lower would result in cheaper overall lifetime costs for the electric car (10 years). A battery of 200 km or more would make the electric car more expensive during the 10 years it is used than a gas or diesel car.

Assuming that batteries can be mass produced (100,000 a year) then the break even point of the battery is around a provided driving range of 350 to 400 km. A battery with a driving range of 350 km (added mass of 416 kg) or less would result into the electric car being cheaper over the 10 years of use. (This assumption could be too positive since the added mass of the battery could reduce the efficiency of the electric car again.) While a battery with a driving range of more than 400 km would result in the gasoline and/or diesel car being cheaper over its 10 year use.

The calculations thus far have shown that the driving range of electric cars is limited due to the added costs and mass of the batteries. A driving range of 800 km with an electric car would add too much mass to the car and the costs of the battery would far exceed the lower user costs. At current prices a battery with a driving range of 150 km or less would be cost effective and when batteries are mass produced this can shift to a battery with a driving range of around 350 km. Electric cars therefore seem to be economically feasible only when the driving range is kept low.

#### **4.6 Overview of pros and cons of the electrical car**

So far the advantages of electric cars are the increased energy efficiency from plant to wheel. The zero tailpipe emission of electrical cars on the road, and the lower overall emissions when the electricity used to drive electric cars come from renewable sources. When driving on fossil electricity produced in the Netherlands, electric cars produce lower CO<sub>2</sub> and PM<sub>10</sub> emissions but higher SO<sub>2</sub> emissions. NO<sub>x</sub> emissions are lower for diesel and equal for gasoline.

However the batteries of the electric car, and the associated mass and costs of the batteries cause the electric car to have significantly lower driving ranges. Taking costs into account an electric car with a driving range less than 150 km can be economically viable and when prices of Li-ion batteries go down due to mass production this can be increased to 350 km. Next to lower ranges the replenishment of energy in electric cars is also more difficult compared with its ICE counterpart. Slow charging requires infrastructure at home and/or at work and takes a long time. Fast charging and battery swapping are both in experimental stages at this moment and have several problems they need to overcome.

These results show that the electric car is far away and unlikely to be able to reach the performance of its current ICE counterpart considering issues like driving range. Electric cars however might prove to be preferable as a car with a limited driving range. If the driving range is below 150 km, the lower overall and zero tailpipe emissions and the lower cost during 10 years of use of the electric car give the electric car a substantial advantage over its ICE counterpart. To determine whether there would be a potential demand for such type of car in the Netherlands, the Dutch mobility patterns are studied.

## 4.7 Dutch mobility patterns

### 4.7.1 Average Dutch mobility distances

74% of the daily mobility of the Dutch population for 2007 is between 0 and 10 km per day. This has increased to 90% between 0 and 30 km and is 95% between 0 and 50 km (CBS, 2008)<sup>51</sup>. This number would suggest that an electric car with a range of 150 km or less could easily service at least 95% of all daily transportation in the Netherlands. This might be true if it concerns cars that are used solely for smaller distances. But while the average user usually does not drive more than 50 km in 95% of the cases it could also mean that once every 20 days the driver wants to drive further than the normal relatively small distance. It is almost certain that the average user that drives a car would want to drive certainly a couple of times more than 150 km during the 10 years of the ownership of the car. A closer look into the motor vehicle park of the Netherlands might give some insight into which vehicles could actually do with a limited driving range during their whole lifetime.

### 4.7.2 Motor vehicle fleet of the Netherlands in 2008

In table 8 an overview of various motor vehicles in the Netherlands. The numbers in the table are derived from CBS (CBS, 2008)<sup>52</sup>

**Table 8, the Dutch motor vehicle fleet in 2008**

Total number of passenger cars.	7,391,903
Number of non primary passenger cars in households*	1,730,000
Delivery vans	862,303
Special vehicles (garbage collecting cars, cleaning cars, etc.)	61,030
Motorcycles (scooters, etc)	585,204
Busses	11,091

\* In 2007 there were 7,191,000 Dutch households (CBS, 2007)<sup>53</sup>. Of these households 24.1% had more than one car in their household (CBS, 2008)<sup>54</sup>. This means that in the personal car department 1.73 million cars in the Netherlands are not used as the primary car of the household.

Vehicles that could be likely candidates for electrical driving on this moment should drive only relatively small distances per day during their 10 year battery live. Non primary passenger cars are cars that are often used for traveling between work and home. Longer distances, like taking a holiday or visiting family far away, can be done with the primary car. Therefore these 1.7 million passenger cars are considered as candidates that could be replaced with electric cars.

A certain number of delivery vans has fairly known routes within a limited range, especially those that operate within cities. Urban transport vans or postal vans would be two examples. Part of the delivery van fleet is therefore also considered as a candidate to convert to electrical vehicles. Garbage collector trucks and/or cleaning trucks of local municipalities need limited driving ranges since they also have known and routes that do not require great driving ranges. So part of the special vehicle fleet is also a candidate for

electrification. Busses are more problematic. The needed driving range can be quite great so on this aspect they might not be an ideal candidate, but from a viewpoint of health and environment it would be very interesting to at least partly electrify buses since they often operate in densely populated areas. However they are not considered as likely candidates for full electric driving in this research. And last but not least are the motorbikes and scooters. Electric two wheelers are already widely available on the market. In some countries like China many of the two wheelers are already electric and their numbers continue to grow. (Weinert et al, 2008)<sup>55</sup> These motorized two wheelers are also considered to be an interesting candidate in the Netherlands as vehicles that can be electrified.

From this overview of the Dutch mobility park appears that there would be over 2.000.000 potential vehicles that could be switched to electrical driving in the Netherlands taking into account the various advantages and disadvantages electric mobility currently faces. With this in mind we end the first part of this research about the electrical car itself and start the research into transition theory.

## 5 Transitions Theory

### 5.1 Transition pathways

Electric cars are used only very marginally at the moment; a transition is needed if (part of) the two million potential vehicles in the Netherlands would actually become electric vehicles. Next to the electric vehicles themselves, a whole support system has to arise around electric mobility as well; supporting or regulating policy needs to be made, infrastructure to charge the vehicles has to be created, information to customers and salespeople needs to be available, etc.

Much research has been done into transitions. In this research basic theories around transitions will be studied and used. Important to note is that a transition will not always succeed; in fact most of the new products never make it to the big market. Figure 13 shows the various possibilities that can happen in a transition as it develops over time.

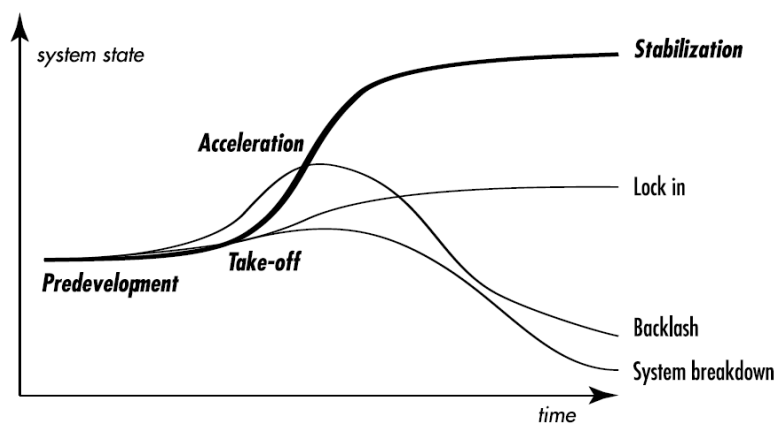


Figure 13, possibilities of system development in a transition (Rotmans 2005)<sup>56</sup>

Figure 13 gives various transition paths. The transition is successful when the upwards curve is followed and the system state enters the stabilization phase. But a transition can also fail. By making important system choices too soon or due to very rigid behavior of important actors, the system can enter a lock in and does not develop to its full potential. While doing experiments with the technology or product etc. in transition, it might become clear that the product technology does not have enough advantages or it can appear that it even has obstructing disadvantages. This can create opposition to the technology which can result in a backlash of the technology or a system breakdown, depending on when this becomes clear in the transition. The timeframe shown in figure 13 is very open and in reality is not as smooth as represented in the figure. A product or technology can be in the predevelopment for a long time for example but also very shortly, the same goes for the other stages as well. The time between predevelopment, take-off, acceleration and stabilization therefore can greatly vary.

Another representation of a transition system is shown in figure 14. This figure describes that a transition has to grow along three different levels to end up as a success at the end.

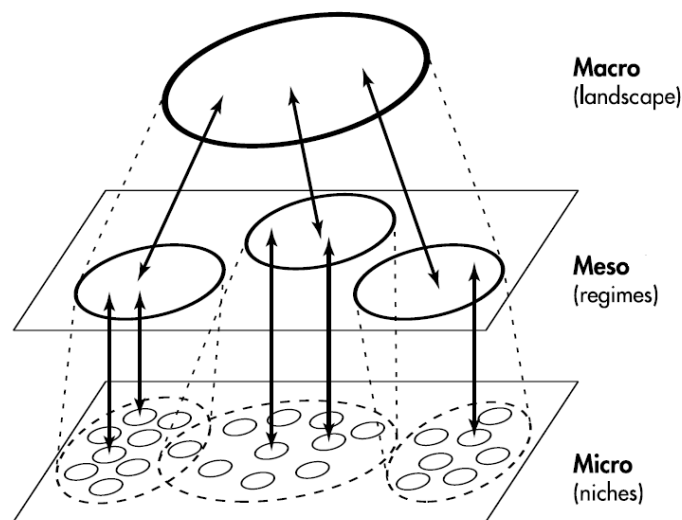


Figure 14, transition model with micro, meso and macro level (Geels & Kemp, 2000)<sup>57</sup> (Rotmans 2005)<sup>58</sup> (Kemp & van den Bosch, 2006)<sup>59</sup>

In this representation three levels are identified.

**The micro level;** in this level are many different technologies in use and being developed that are different from the dominant technology that is used in the overall landscape. Electric driving for example can be in one or more of these niches. When a certain technology in a niche starts to offer sufficient advantages compared with the current landscape technology the cooperation between actors around the niche product can increase and clusters of actors that start working together can be formed. When this happens the technology takes a transition step up and reaches the meso level.

**The meso level;** this is the level where regimes (clusters of important actors) are formed. Close networks of relevant actors are working together and policy is being developed for the specific technology and the needs surrounding the technology. This formation of

regimes and closer cooperation between important stakeholders cause the technology to become more embedded in the society. Several of these regimes can start to exist in a parallel way for the technology in transition. If sufficient enough of these regimes start to appear and when various regimes start to cooperate and form complex clusters of the important actors involved, actors of the technology itself and the various affairs surrounding the technology, the technology can take another step up in the transition and it can rise to the macro level. According to this theory, meso level technology can start to generate opposition from the macro field. This can set an extra barrier for the technology that needs to be taken before it can reach the macro level.

**The macro level;** this is the dominant landscape. In this landscape complex and elaborate actor networks are working together and are constantly being recreated to make sure that the technology, product etc. keeps its dominant position in society. Policy is dominantly focused on the technology in this level, and there is a great focus from the other actors on the macro level aimed at this technology. Because of this dominance the macro level can intentionally or unintentionally form barriers to technologies on meso and micro level. An example is the clear policy that is focused on the current infrastructure for ICE cars with fuel stations; this causes the field to be very clear for those actors. For electric driving this policy or a lack of specific policy for electric mobility infrastructure can be a significant force that is preventing or slowing down the growth of electrical driving.

The last theory, where a transition takes place through the micro, meso and macro level, puts a great emphasis on actor networks. An illustration of the complexity of a multi actor network which consists of both technological and societal aspects on the macro level is shown in figure 15.

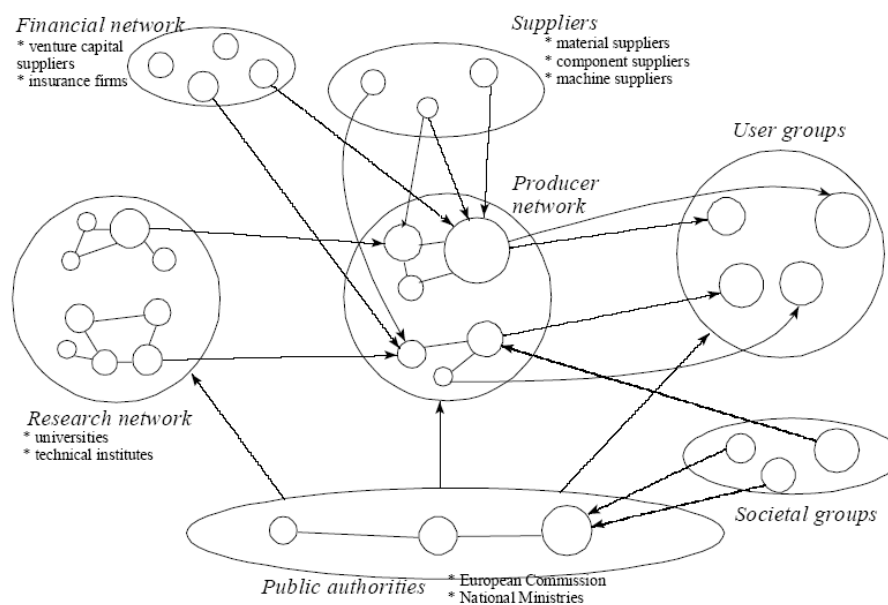


Figure 15, impression of the multi-actor socio-technical network (Geels & Kemp, 2000)<sup>60</sup>

This illustration shows the complexity of such a network on the macro level and it becomes clear therefore that a product that starts a transition needs to grow from micro to

meso level before it is able to get to the macro level. Many of the technologies and products that start a transition will never reach the macro level. Where figure 13 shows this with one road of transition success and three roads of transition failure, figure 14 shows that many technologies and products in transition never make the first growth step from micro to meso level and even less make the second step from meso to macro level. The focus of this research is on the possibilities of public authorities to stimulate electric driving. Figure 15 shows that public authorities are only a small, but essential, part of the whole socio technical actor network. Therefore the success of a transition is also just partly dependant of the role of policy makers.

## **5.2 Taking transition steps**

After exploring these theories about transitions, the next question is how steps are taken within a transition; how does a technology or product progress and grow within the system? Rotmans theorizes that a transition can be partly guided and so the success of a transition can be influenced (Rotmans, 2005)<sup>61</sup>. A new technology that wants to evolve from a niche product to a more dominant market product should have the potential to offer advantages to all relevant stakeholders without having obstructing disadvantages to any of them. However before being able to offer these advantages some barriers and obstacles a niche product faces should be successfully overcome. This can be done during the transition process. But even armed with transition theories and a good product or technology it is difficult to predict how a transition will exactly evolve and whether it will be successful or not. The following quote of 1922 Nobel price winner in physics summarizes it nicely:

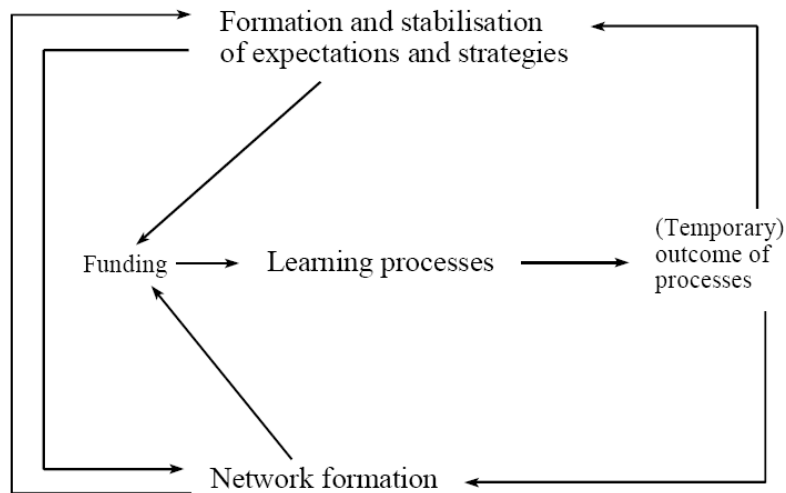
**“Prediction is hard, especially when it concerns the future”  
-Niels Bohr-**

This being said a further exploration is made into how to progress within a transition. There are various theories about taking transition steps.

Geels & Kemp state that a transition path consists of a repetitive process with the following ingredients:

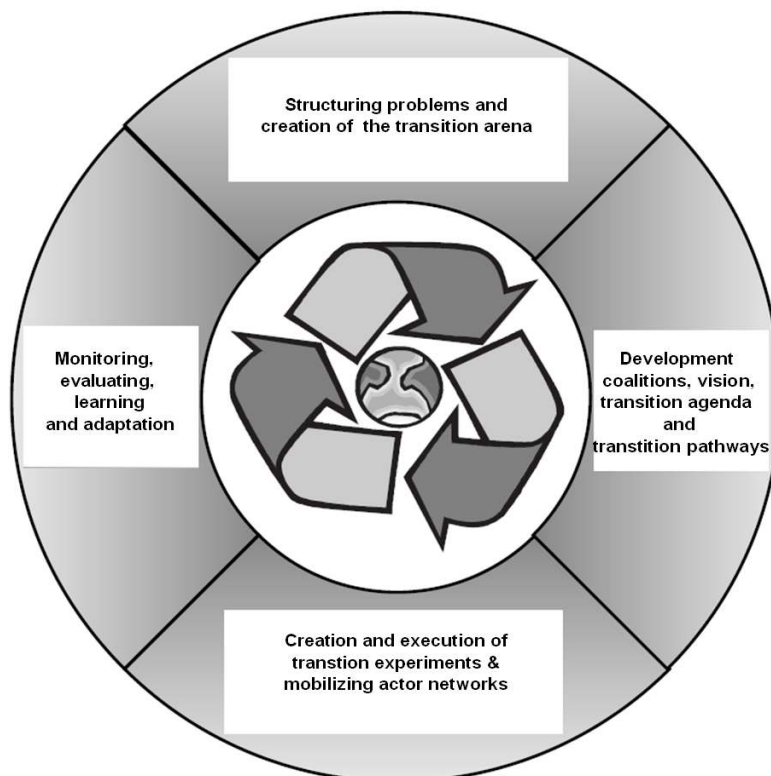
- A) Formation and stabilization of expectations and strategies.
- B) Learning processes (about technology, consumer wishes, infrastructure etc.)
- C) Formation and stabilization of the network.

These three main ingredients are not followed one by another but are constantly influencing each other as represented in figure 16. During the process knowledge is increasing about the product or technology in transition and if this knowledge leads to higher expectations, more funding and experiments can be set up with an expanded network formation etc. The system works as a continuing feedback mechanism; if results are positive the transition will continue, if results are negative or less positive than expected one might consider to stop further experiments and so (temporarily) stop the transition.



**Figure 16, ingredients of the learning path of a transition (Geels & Kemp, 2000)<sup>62</sup>**

Another theory about steps within a transition is given by Rotmans. (Rotmans 2005)<sup>63</sup> He proposes a cycle with four consecutive steps, see figure 17, which can be repeated again and again. When one full cycle is finished, depending on the result, a new cycle can be started. During each of these full cycles knowledge about the product is increased just like the actor networks. These cycles can continue until the transition is complete.



**Figure 17 the cycle of transition management according to Rotmans (Rotmans 2005)<sup>64</sup>**

Both theories as shown in figure 16 and 17 overlap on several points. Both theories state that learning processes and actor networks are central in taking steps forward. Lessons can be learned by doing experiments. With the results that are gained with these experiments new expectations can be made about the technology in transition and the relevant actor network that should be approached for this experiment. Then results are gained and the cycle can start all over again if results are positive.

It remains difficult to predict if a niche product will become a market product. If the potential seems to be there, than experimenting with the technology according to these two theories can result in a step by step increase of a technology from niche to market product and a transition could be successful.

### **5.3 The role of national and local authorities in transitions**

From this transition theory it can be derived that national and local authorities can do two different things, although both activities can be linked

The first one is making policy to provide clarity for the whole actor network involved. In figure 15 it is shown that policy is only part of the whole actor network but the important role they have to play becomes clear in the micro, meso and macro theory. On the meso level policy starts to appear for a certain technology to create clarity for the other actor networks that start to evolve around the technology. This policy is vital to form the necessary regimes that are needed to eventually grow to the macro level. On the macro level policy for the existing landscape can pose barriers to a new technology. So local and national authorities should also look and try to prevent that current policy that was created for the ICE landscape can damage or slow down the growth of electric vehicles. Existing policy with all its detailed regulations for ICE cars and the surrounding actor network should be made as facilitating as possible for electrical driving.

The second one is that national but mostly local authorities can play a leading role in taking transition steps by setting up experiments with electric driving to gain experience with the technology and to see what electric driving is capable of at the moment and what this means for the future of electric driving in the Netherlands. In these experiments the actor network that is invited to participate in these experiments is crucial. Next to this, research has been done to see what specific policy is available and what policy has been successfully used by policy makers to stimulate electric driving.

## **6 Policy analysis for electric mobility**

First an overview of policy measures is given to show what options policy makers have. Next several pilot projects with electric driving have been studied, interviews have been held with electric driving experts from four different countries, two large scale introduction schemes and the specific role of the national government in such introductions have been studied and seven Dutch electric driving actors have been interviewed to determine the policy demand in the Netherlands.

This information is used as input for the policy advice for national and local governments. But first it is discussed why policy is needed.

### **6.1 Why is policy needed?**

Policy is needed to provide clarity for the actors involved and to pave the way for growth of these actor networks. Another important reason is given in the following quotation:

“In order to enter the vehicle market successfully, electric vehicles must offer advantages – or at least no disadvantages – to *all* relevant stakeholders. Since electric vehicles cannot offer advantages to all relevant stakeholders under existing framework conditions, supporting measures that aim to change these framework conditions are necessary.” (SEI, 2008)<sup>65</sup>

Thus policy is needed to overcome current barriers by giving electric driving certain advantages in the framework. First an overview of policy measures is given.

## 6.2 Overview of policy instruments

Different policy instruments are available to different policy levels. An overview of policy instruments has been given by the International Energy Agency in a 2002 report called “Deployment Strategies for Hybrid, Electric and Alternative Fuel Vehicles” An addition was made to this list by the report of Sustainable Energy Ireland from February 2008 which is called “Review of worldwide experiences in the use and measures to stimulate the uptake of battery electric and hybrid electric vehicles”

The following list of policy measures is largely based on these two reports. Examples are given to clarify the different policy measures. In the list a subdivision is made in this research to make clear which level of government can implement the given policy measure. A subdivision is made between the European level (**EL in blue**) the National level (**NL in orange and italic**), and the Local level (**LL in green and underlined**)

### 6.2.1 A) Command and control instruments

- **(EL)** Standards (fuel use, emissions, technology, safety etc.)
- **(EL)** Vehicle emission regulations ([PM10] and CO<sub>2</sub> regulations)
- **(EL)(NL)** Mandates (x% of the fleet should be full electric, or x% of cars sold should be zero emission cars)
- **(LL)** Exemption of clean vehicles from certain restrictive regulations (access to certain areas to clean vehicles: express and bus lanes, restricted zones, restricted parking zones, longer delivery hours in cities, etc.)

### 6.2.2 B) Economic instruments

- Targeted at electric vehicles

- **(EL)(NL)(LL)** Direct investment (In R&D, in infrastructure, in demonstration projects, etc.)
- **(EL)(NL)(LL)** Subsidies (Vehicle purchase and conversion subsidies; subsidies for infrastructure construction, battery development, etc.)
- **(EL)(NL)(LL)** Financing schemes (for back up of costly investments)

- Targeting transport, generally

- **(NL)** Registration/purchase taxes
- **(NL)** Circulation taxes (road taxes)
- **(NL)** Fuel taxes
- **(NL)** Subsidies (e.g. energy label based subsidies)
- **(NL)** Taxation of benefit in kind (lease cars, taxation based on CO<sub>2</sub> emissions)
- **(LL)** In use and parking charges (road pricing, congestion charging or parking charges)

### 6.2.3 C) Procurement instruments

- (EL)(NL)(LL) Green procurement (both voluntary and mandatory approaches)
- (EL)(NL)(LL) Leadership by example (use of clean vehicles by the initiators of the program or famous people and the spread of their experiences)
- (EL)(NL)(LL) Common procurement (buying larger numbers of EV at one time)

### 6.2.4 D) Collaborative instruments

- (EL)(NL) Certification and labels
- (EL)(NL)(LL) Voluntary agreements
- (EL)(NL)(LL) Public-private partnerships and private-private partnerships (local authorities and public transport operators; partnerships of fuel suppliers and fleet.)

### 6.2.5 E) Communication and diffusion instruments

- (EL)(NL)(LL) External information and awareness campaigns
- (EL)(NL)(LL) Marketing activities (position EV as modern technologies that have much to offer, focus the message on positive images of clean vehicles)
- (EL)(NL)(LL) Vehicle buyers' guides and vehicle labeling information
- (EL)(NL)(LL) Education and training packages (for vehicle sales/retail personnel and mechanics for both good pre and after sales)
- (EL)(NL)(LL) Persuasion and lobbying activities

This overview shows there are various policy options available to policy makers at different levels. To determine which of these policies might be useful this research studied introductions of electrical vehicles both at small and large scale. In addition interviews have been held with persons that have first hand experience with electric mobility pilot projects and last but not least interviews have been held with various actors in the field of electrical driving to determine the policy demand within the Netherlands in the electric mobility field.

## 6.3 *Experience from electric driving pilot projects*

Transition theory illustrates the importance of experiments and learning from these experiments to help the technology in transition. An important source of information is pilot projects that have already been carried out with electric driving. There have been several small scale introductions of cleaner transportations methods, including electric vehicles. For this research several of these introduction projects have been studied to gain information about electrical driving projects and what policy was used to stimulate the uptake of electrical mobility. In total these experiments encompass the introduction of over 500 electric vehicles in 20 different European cities.

### 1) **European Zero Emission Vehicles in Urban Society (ZEUS) program (1996-1999)** (European Commission, 2000)<sup>66</sup>

#### **Aim of the program:**

The Zeus program focused on how cities and regions can help overcome the market obstacles that restrain zero and low emission mobility.

**Targets:**

Each of the participating cities had its own specific targets to increase zero and low emission mobility, ranging from stimulating people to bike to introducing clean vehicles.

**Description / Results for electric driving:**

In the ZEUS program 271 electric cars and vans were introduced and 7 electric Lorries and special purpose vehicles. A total of 278 electrical vehicles were introduced in 6 European cities; Stockholm, Copenhagen, London, Coventry, Palermo and Athens. The electrical cars were introduced in the municipal fleets of the participating cities. No specific results for electric driving were given in the report.

**Evaluation:**

ZEUS has shown that European cities can greatly improve the conditions for zero and low emissions mobility.

**Policy recommendations:**

The report gives the following 8 recommendations:

- 1) Reduce and manage the high marginal cost of zero and low emission vehicles by buying in bulk together with other cities.
- 2) Take advantage of any available purchase subsidies, and factor both long and short term costs into the equation.
- 3) Take an active role in facilitating refueling and recharging accessibility. This may include financing infrastructure directly or partially, planning sites, and monitoring use, or creating partnerships with competent organizations in the public and/or private sector
- 4) When monitoring vehicles, test vehicles in "real world" situations and complement automatic systems with manual log-book systems. Use fairly mature alternative fuel technologies when using vehicles in municipal service or car sharing. When retrofitting a large fleet, rely on fairly mature alternative fuel technologies. However, you may also want to test one or two vehicles using experimental or prototype technology in cooperation with a local university or national research board.
- 5) Introduce one type of fuel at a time to avoid complications and confusion in the transition to zero and low emission vehicles. Consider single-supplier contracts to further simplify service and maintenance planning.
- 6) Plan for service and maintenance of alternatively fuelled vehicles. At the procurement stage, ensure that maintenance, training support, and spare parts accessibility issues are adequately dealt with. Allow for extra time during the transition period, and train all technicians, drivers, and safety personnel.
- 7) Increase user acceptance for new vehicle technologies by conducting market surveys, clearly signing vehicles and infrastructure with clear signage, and providing direct experience by lending vehicles or offering test drives using loaner or demonstration vehicles.
- 8) Improve pre-trip and real-time information using telematics to increase public transit and car sharing customer satisfaction.

## **2) Electric Vehicle Deliveries (EVD) in Postal Services (1998-2000)** (European Commission, 2001)<sup>67</sup>

### **Aim of the program:**

The overall objective of the EVD-Post project was to demonstrate the technical and economic viability of EVs in the regular operations of postal services in Europe.

### **Targets:**

EVD-Post was set up to address the following objectives:

- 1) To test advanced battery technologies under different operating and climatic conditions.
- 2) To compare different battery systems with regard to technical and economic criteria.
- 3) To establish a comprehensive knowledge of electric vehicles and battery types in Europe.
4. To promote the wider use of electric vehicles in postal services and other applications.

### **Description of the project:**

In this project a total of 59 electrical vehicles were deployed in 15 different cities for postal service deliveries. Participating parties were the five postal organizations from Germany, Sweden, Finland, France and Belgium, three non-postal partners from Finland, CITELEC (the association of cities interested in electric vehicles), and a group of five observers comprising the postal services from the UK, Portugal, Italy, Ireland and Norway. The use of electrical vehicles in postal services was chosen since postal routes have known driving distances, a lot of stop and go driving and batteries can be charged overnight at the workplace.

### **Results and Evaluation:**

All in all, the project succeeded in verifying some principal merits of EV operations in postal and other delivery services, i.e. the provision of reliable transport services without adding to local air pollution and noise emissions. The vehicles were well received by both drivers and the general public, despite the impression of performance reductions against conventional petrol or diesel vehicles for some of the EVs. Range limitations were usually not a problem as the vehicles had been carefully matched with adequate delivery duties well within the performance levels of the respective EV model. On the downside, EVs still show a remarkable lack of economic maturity expressed as high procurement costs, limited product diversity, and little or no after sales support. Overruns in delivery dates and costs are a frequent experience rather than exceptions. This leaves EVs highly unattractive to potential users, especially those exposed to commercial competition.

In conclusion, despite the generally good performances of electric vehicles in demonstration projects, there are still substantial barriers for wider deployment that leave EVs ill-prepared to compete with the acting market champion's petrol and diesel. Despite the good experiences from pilot projects, interest to proceed beyond this stage with large-scale deployments of EVs is negligible as neither users nor industry, i.e. manufacturers

and energy suppliers can be expected to sustain prolonged investments in technical options without hope of commercial return.

### **3) European Electric Vehicle City Distribution (ELCIDIS) program (1998-2002)** (European Commission, 2002)<sup>68</sup>

#### **Aim of the program:**

The overall objective of ELCIDIS was to demonstrate a varied set of hybrid electric trucks and electric vans in the heavy application of urban goods distribution, where necessary combined with the creation of an urban distribution centre (UDC).

#### **Targets:**

More concretely the following targets have been distinguished:

- 1) To demonstrate the economic, technical and social viability of urban distribution with electric vehicles.
- 2) To analyze the environmental benefits of the deployment of electric vehicles for urban goods distribution.
- 3) To gain insight into the technical specification of (hybrid) electric vehicles, operating in urban distribution activities.
- 4) To analyze the logistic efficiency of a newly created UDC.
- 5) To demonstrate the acceptance of urban distribution with (hybrid) electric vehicles by transport companies, shopkeepers, businesses, residents and shoppers.
- 6) To investigate the value of incentives to promote environmentally-friendly vehicles.

#### **Description:**

This program focused on electrical vehicles in city distribution, it introduced 52 electrical vans, trucks and cars (of which 16 were hybrid electric vehicles) in 6 European cities; Rotterdam, Stockholm, La Rochelle, Erlangen, Regione Lombardia and Stavanger. These vehicles were introduced in both municipal fleets and in delivery service companies where driving distances were regular and known.

#### **Results and Evaluation:**

The project has provided indisputable proof that there are no predominant objections to the use of hybrid and electric vehicles in urban distribution, neither from company managers nor from drivers, and certainly not from local authorities. Recharging at the home base during the night (or weekend) period for those vehicles does match perfectly with this type of use.

Based on the gained experiences, it is however also obvious that price performance ratio, reliability, maintenance and servicing must be set at the same (high) standard as for ICE equivalents, in order to attain a larger market share in this specific niche.

#### **Recommendations:**

First in line is the necessary improvement of the hybrid and battery electric vehicles themselves, this concerns not only the vehicle, but certainly also the batteries. Second is the upgrading of the product diversity, which should be leading to much more choice on the market of these types of clean vehicles.

For local authorities, wishing to set-up similar distribution concepts, the following major recommendations can be made:

In order to implement such distribution concepts successfully, it takes conviction on the part of the partners, of the operation's validity and genuine determination in policy-making. All parties involved need to co-operate very closely, not only in preparation, but also in the operational phase.

All public authorities, whether they are local, regional, national or European, must really emphasize their desire for a future with clean vehicles, by introducing beneficial incentives for buying as well as using zero emission vehicles. In this respect, the request from transport companies to receive advantages in exchange for the use of clean and silent vehicles in the future should be granted. Most important for them are extensions of delivery hours and possibilities to enter areas, which are, or should be closed for ICE vehicles, for example pedestrian areas and public transport lanes.

#### 4) European City-Vitality-Sustainability (CIVITAS) program (2002-2006) & European CIVITAS II program (2006 - 2009) (European Union, 2008)<sup>69</sup>

These programs encompass another number of European cities who are greening their urban transport, there is a lot of information online about the various cities and what kinds of cleaner transport they are testing. It includes electrical car projects in Rome where they test 42 electrical buses and the introduction of 132 electrical cars into the municipal fleet of Lille. The projects are very broad in set up. Therefore a description like the previous projects is very difficult. In the clean vehicles section they however give an impression of the barriers and drivers of clean vehicles. This includes all clean(er) vehicles, so not just electric cars. The overview is given in figure 18

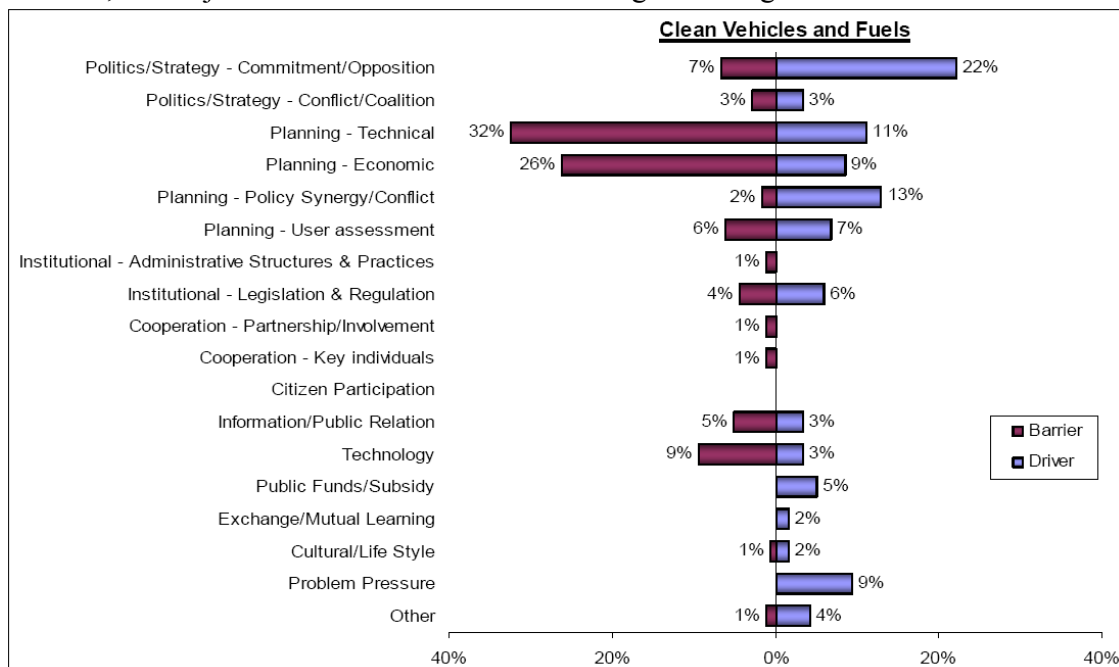


Figure 18, barriers and drivers for clean vehicles and fuels (European Commission, 2006)<sup>70</sup>

Figure 18 shows that the greatest barriers for clean vehicles are the technical (32%) and the economic aspects (26%) involved for these vehicles. Together this forms 58% of the barriers for clean vehicles and they therefore form an important focus point to stimulate clean vehicles.

### **6.3.1 Evaluation**

These different projects have all been set up according to transition guidelines, this means that the projects are not just projects on themselves but the focus is to determine what the state of electric driving at that point was and to share this knowledge. What then can be learned from these projects that can be used in future experiments?

These projects show that electric driving is successful if they are used in the correct niches. These niches include relative short distance transport with regular distances, and a place to charge the vehicles overnight. Delivery transport in cities, and post delivery are both interesting niches for the electric car. Electric driving can greatly improve inner city environments in these cases due to the low noise and zero tailpipe emissions.

The experiments also show that the technology is not yet successful in the market, there is a lack of available vehicles, the ones that are available are very expensive and repair options are still a problem. It shows that large parts of a successful actor network that deals with electric driving is in the worst case totally lacking and at best very poorly functioning.

## **6.4 *First hand experience of electrical vehicle experts***

Next to this information out of literature, first hand information was gathered. Contact was sought with actors who participated in a pilot project with electrical driving. Fourteen questionnaires were sent out to actors that gained experience with electric driving, four responded. The responding parties were people that had participated in projects in Monaco, Switzerland, Sweden and the Netherlands. While the response rate is somewhat low, the results however are usable since each of the responses is a first hand experience with electrical driving and gives a great amount of information on an electric driving pilot projects. This information can serve as input for the cycle of transition management to determine and help set up useful future electric driving pilot projects.

The information that was gathered focused on the motives of the pilot projects, the experiences with the electric vehicles, the most important barriers of electric driving, evaluation of the project and on recommendations for new projects. This information was sought to see which sectors of the multi-actor socio-technical network as presented in figure 15 are developed and to which stage. It might also become clear which sectors need development before a next step can be taken in the transition of the electrical car to a wider mark.

First, questions were asked about the motives to start the pilot projects. The result is given in table 9. The scores range from 1 to 10 with 1 being not important as a motive and with 10 being a very important motive.

**Table 9, motives of starting a pilot project with electrical cars**

Motive	Average score
Improve the (local) air quality	10.0
Reduce CO <sub>2</sub> emissions in the transport sector/save energy	8.3
Lower operational costs per km of electric driving	3.3
Decrease the dependence of oil in the transport sector	6.5
Decrease the noise levels in the transport sector	8.3
Experiment with the use of electrical cars as a storage system with renewable electricity sources like wind or solar energy.	4.5
Stimulate local employment	1.5
Improve image	7.5
Demonstrate the viability of electric mobility	9.3

The top 3 of motives to start the projects with electrical driving were:

- 1) **Improve the air quality.**
- 2) **Demonstrate the viability of electric mobility.**
- 3) **A) Reduce energy and reduce CO<sub>2</sub> emissions in the transport sector.  
B) Decrease noise levels in the transport sector.**

Table 9 shows that electric driving and the motives to start these pilot projects came mostly from a climate and environmental point of view. Electric driving is considered as a niche that can provide clean and low noise urban transport.

Next questions were asked about the experience with various aspects of electrical driving. Grades were given between 1 and 10 with 1 being very negative and 10 being very positive. The result is shown in table 10.

**Table 10, grading various aspects of electric cars**

Aspect	Average score
Availability of electrical vehicles	1.5
Accurate specifications of available electrical vehicles	5.0
Price of electric vehicles	3.8
Procurement of electric vehicles	6.5
Delivery of the electrical vehicles after acquisition	6.8
Reliability of the electrical vehicles during the testing period	7.3
Repair options if electrical vehicles broke down during the testing period	5.3
Driving range of electric vehicles	5.8
Recharge time of electrical vehicles	5.5
Reliability of the battery during the time of the experiment	6.8

Driving comfort of the people driving the electrical vehicles	9.0
Reactions from the public concerning the electrical vehicles	8.3
Maintenance costs during the time of the experiment	6.3
Driving costs during the time of the experiment	8.5
Other ...	
How do you feel about the whole project with electrical vehicles?	7.0

These data show that the worst experience of these projects is with:

- 1) **Availability of electric vehicles.**
- 2) **Price of electric vehicles.**
- 3) **Accurate specifications of available electrical vehicles.**

On the other hand, the most positive experiences are with:

- 1) **Driving comfort of the people driving the electrical vehicles.**
- 2) **Driving costs during the time of the experiment.**
- 3) **Reactions from the public concerning the electrical vehicles.**

Table 10 shows that, in congruence with the results from the studied literature, the availability of electric cars is the greatest barrier; also the price of the vehicles is seen as an important barrier. In third place are the accurate specifications; these actors experienced that if electric cars are available they often cannot live up to the technological promises made by the producers. This is another indication that the actor field where it concerns the production of electric cars that are technically capable of what is promised needs improving.

However the user aspects of electric cars are valued very positive. While drivers can be reluctant in the beginning to try a new technology like the electric car, they started to appreciate the electric car once using them. Especially the low noise level of electric cars inside the car was considered an improvement compared with ICE cars.

Next some open questions were asked.

The first one is an inventorisation of the top three of problems the individual actors experienced, and what the ideas of the electric driving experts were to solve these problems.

### **Switzerland:**

What are in your opinion the three most important barriers towards electrical driving based on the experience gained with the project of electrical mobility? And what would be solutions to these barriers in your opinion.

Most important barriers:

1	Poor availability of electric vehicles
2	Strong (psychological) dependence of public on gasoline cars
3	High buying price

Solutions to barrier 1:

Cooperation between government and manufacturers
Incentives for the car industry (e.g. no import taxes, reduced road taxes, ...)

Solutions to barrier 2:

Promotion and getting people used to electrical vehicles
Test fleets available at very low fees

Solutions to barrier 3:

Cooperation between government and manufacturers
Incentives for the car industry (e.g. no import taxes, reduced road taxes, ...)

**Monaco:**

What are in your opinion the three most important barriers towards electrical driving based on the experience gained with the project of electrical mobility? And what would be solutions to these barriers in your opinion.

Most important barriers:

1	Suppliers having no long term policy
2	Prices too high
3	Maintenance not assured

Solutions were not given by this party.

**Sweden:**

What are in your opinion the three most important barriers towards electrical driving based on the experience gained with the project of electrical mobility? And what would be solutions to these barriers in your opinion.

Most important barriers:

1	Short driving range
2	Availability of different models (no battery electric cars available in my country today)
3	Early bad experiences have given them a bad impression

Solutions to barrier 1:

Plug in hybrid cars with a possibility to fuel i.e. E85 and/or biogas
Better battery technologies – more research
Car-pools – where you can choose different cars depending on your needs. Electric cars for shorter distances, other fuels when going on vacation and so on

Solutions to barrier 2:

Coordinated procurements
Message to car industry that we want these vehicles

Solutions to barrier 3:

Information
New available electric cars that operates well

**The Netherlands:**

What are in your opinion the three most important barriers towards electrical driving based on the experience gained with the project of electrical mobility? And what would be solutions to these barriers in your opinion.

Most important barriers:

1	People don't know electric cars so people will not use it quickly
2	Image of electric cars
3	Overall mass of the cars

What would in your opinion be good solutions to overcome these 3 barriers?

Solutions to barrier 1:

Much and good communication about electric cars
Use famous popular Dutch persons to make it known, let them give the example
Organize events in which electric cars play an important role. Cars that drive along in a marathon could be electric so runners do not have to run in gasoline fumes

Solutions to barrier 2:

Have cool sportive cars like the Tesla, the Venturi and the Lotus Electric
Make sure people can get experience with electric cars
Also involve car dealers

Solutions to barrier 3:

This technological barrier might be solved now with new Li-ion technologies
Plug in Hybrids might be a good solution

These results show next to the results some interesting ideas to solve these problems. This will be taken into account when forming policy advises.

Following the barriers and solutions, the actors were asked what lessons they learned from their experiment with electrical mobility and what they would advise people that want to start a pilot project.

**Switzerland:**

What are the most important lessons you learned from your experiment with electrical vehicles?

The response time of the market is very long
Manufacturers have no patience to wait this long time
Public recharging infrastructure helps a lot to support the buy of EV
Unfortunately people are not used to calculate mileage costs (mileage TCO <i>Total cost of ownership</i> )

What would you advise people setting up a new project with electrical vehicles?

Have good/strong commitment of the politicians
Start only long term projects (>10 years)
Search for cooperation with manufacturers
Look for a wide support (politicians, manufacturer, dealers, private economy, ...)

**Monaco:**

What are the most important lessons you learned from your experiment with electrical vehicles?

Use of EVs is more adequate for fleets operating in cities
Public is ready for EVs, if the service is OK and the price reasonable

What would you advise people setting up a new project with electrical vehicles?

Do not have any confidence in the promises from automakers
A successful experiment is no guarantee that there will be a real implementation

**Sweden:**

What are the most important lessons you learned from your experiment with electrical vehicles?

They can run and work very well if used by the right interested driver and in the right application. Some models have been very good and liked by drivers
Fast charging is not essential for the use of electric vehicles
Drivers are afraid of the short driving range and feel somewhat insecure
Leasing of batteries is a good way to secure the economy and make sure you always have good batteries
Coordinated procurements can introduce the electric technology in countries where they

have not been available before. Very important measure!
Fuel cell technology is still on the prototype stage but show great potential
Electricity in my country is very cheap. The operation costs for a pure electric vehicle would be about 7-10 times lower than for a petrol or diesel car (and even more if oil prices go up which they will...). What will happen to the driving pattern in our city if people get large access to that type of cheap driving? Will they drive more?
Electric vehicles still congest and take up space and parking places and so on. Still better to walk, bike, use public transport, telephone meetings - than to use an electric car and travel alone
Very positive with the low noise level – however you have to consider safety aspects as people are not used to cars hardly making any noise i.e. pedestrians crossing road and so on. A positive problem to solve and be aware of!!
Hybrid electric cars & electric scooters work well and are popular! Be, however, aware of the traffic safety issues when using two-wheelers!

What would you advise people setting up a new project with electrical vehicles?

It takes time! Be patient!
Find your friends and work with them first – early adopters (i.e. interested companies)
One dedicated person can really make a change – find them and work with them – i.e. a fleet manager, a mayor, a manager at an electric utility company
Local authorities are the key actors to start the development
If possible start with heavy vehicles operating in fleets – or cars operating on different shorter routes

### **The Netherlands:**

What are the most important lessons you learned from your experiment with electrical vehicles?

Don't trust the manufacturers; make sure to make deals about the cars that you buy perform as to what was promised. Include fine systems i.e. to have some guarantee
Also be sure to know how much km the people that are using the vehicles really need. People have the tendency to ask for a much greater driving range than actually need
Fast charging is not necessary in practice; it can however be a sign of promotion and of security towards the outside world
With electric scooters, be aware that they are very interesting for thieves as well

What would you advise people setting up a new project with electrical vehicles?

Look for cooperation with other cities that are also experimenting with electrical driving both within the country as with cities from other countries
Together you can use common procurement and this can make cars cheaper

Also involve as many actors as possible to create support in a wide area. They become your support base for electric driving but are also needed to tackle problems. For example involve energy companies; they have an interest in electrical driving. But also building corporations for people that want to be able to recharge at their own place. Now in apartments in the bicycle storage there is no 220 volt outlet. So this needs to be changed, also involve actors that do this, look at the whole picture

These advices can be used both for advice on policy as well as learning for future pilot projects.

### **6.4.1 Evaluation**

While individual experiences do not differ too much from the earlier studied literature it is interesting that this is very case specific information and therefore useful for setting up future pilot projects with electric driving along the lines of transition management. These first hand experiences also show that for urban niches electric driving has some great advantages, but they also show that the actor network especially on the production and maintenance side of electric cars is not developed and needs to improve.

## **6.5 National governments going electric**

Next to the earlier done pilot projects with electric driving and the first hand experience of people involved in electrical driving, there is also information available on planned large scale introductions of electrical driving. These introductions are being planned for both Israel and Denmark. This research will especially focus on the role of the governments in these planned introductions.

The small scale introductions of electric vehicles indicate a shortage of available electrical cars; this problem increases if a country would like to introduce electric vehicles on a larger scale. Next to car availability, lacking infrastructure can be a problem when introductions would be made on larger scale. This presents a chicken and egg problem. Electric car manufacturers are waiting on a large scale demand so they can be sure they can sell their electrical cars when they produce them on a large scale. When they would produce greater numbers of electric cars they can bring the costs of electrical vehicles significantly down. Energy companies have an interest to create the infrastructure for electrical driving but they will only do this if electric driving will be done on a large scale and they can be sure that their infrastructure will be used so they will sell sufficient extra electricity to these electric car owners. The public however is reluctant to buy electric vehicles on a large scale if they are not assured that they can use their electrical vehicle easily. Without an electrical driving infrastructure and with high prices of electric vehicles it is not very attractive to buy an electric car. Large scale adoption of electrical vehicles is unlikely to occur unless prices of the vehicles go down and more certainty is created on the area of available infrastructure. National and local governments are willing to help introduce electric vehicles but have only limited power. If all of these important actors (electrical car manufacturers, actors involved in infrastructure implementation, consumers and policy makers) keep waiting for the other actors to minimize their own risks, a large scale introduction of electrical vehicles is very unlikely to occur.

To resolve this chicken and egg problem some national governments have expressed a specific choice for electrical transport in their country. These governments have chosen to largely introduce electrical cars in cooperation with Project Better Place and hope to solve this waiting problem and start to get electrical driving on the road. Better Place based in Palo-Alto California is a venture-backed company that aims to reduce global dependency on petroleum through the creation of a market-based transportation infrastructure that supports electric vehicles, providing consumers with a cheaper, cleaner, sustainable, personal transportation alternative. (Betterplace, 2009)<sup>71</sup> Two examples of national governments that want to make large scale introductions of electrical driving in their country in cooperation with Project Better Place are Israel and Denmark.

### **6.5.1 Israel**

In January of 2008 Israel announced to introduce electric driving on a large scale in their country. Their goal is to be almost fully electric in 2019. Cooperation between Project Better Place, Renault/Nissan and the Israel government should realize these ambitions. They all play their part.

Project Better Place will deliver the infrastructure in Israel. The infrastructure will consist of many charging points on parking places, at home, at work, downtown and at large shopping centers. In this way owners of an electrical car should be able to plug in their car to the grid whenever you are not driving in it. Better Place also wants to create battery swap stations on highways for people who travel more than 150 km at one time. With these battery swap stations people can quickly continue their journey when the battery runs out of power when driving long distances. Swapping the almost empty battery with a full one should take less time than filling up your current car at a gas station according to Better Place.

The problem of the relative high costs of the battery is dealt with through a system that looks a lot like the current cell phone systems. Rather than becoming the owner of the battery as a driver, instead you have a contract with Better Place about a certain amount of km you drive, and pay for this through a monthly fee. In this case the battery remains the property of Better Place. This system takes away a big financial risk for the driver of the electrical cars and also allows for switching batteries at the battery swap stations during the user period. Better Place also indicates that additional electricity that will be needed for the electrical car park will be bought from renewable energy companies. In Israel the planning is to build large solar energy farms that would become a “virtual oil field” for driving the electric cars.

Renault Nissan committed to deliver electric cars on a large scale within the time scales that have been agreed upon. They promised that they will deliver “normal cars”, which means that the electrical cars are big enough for a whole family; they are fast enough and are fun to drive. The range of the cars is around 150 km and they have a feature that allows the battery to be easily taken out and replaced with another one, which makes battery swapping available. The production will start in 2010, and in 2011 nine models of electric cars should be mass produced.

The last partner that has a vital role in this plan is the government. The Israeli government is very eager to get rid of oil. Israel is surrounded by countries that earn a lot of money with oil and which are not on good footing with Israel. Israel has a direct strategic reason to make itself less independent of oil but also to show the world that it is possible to get rid of oil. To help the large scale introduction of electrical vehicles in Israel the government created long term policy that stimulates the uptake of electrical vehicles.

On Jan 13th, 2008, the Cabinet approved a proposal to tax new cars based on their emissions levels. Regular new cars will be taxed 72%, hybrids 30%, and zero-emission vehicles which include the full electric cars 10%. (Businessweek.com, 2008)<sup>72</sup> These tax rates will be increased depending on the sales of electric cars over the years with steps of adding 10% extra taxes for all categories. In this way the early adaptors benefit most and when larger groups of people start buying electrical cars both tax levels are raised. The total mix of incoming taxes should remain 50% during this transition with ending tax levels of 110% for oil based cars and 50% taxes on full electric cars. (Shaiagassi.typepad.com, 2008)<sup>73</sup>

With these various actors all cooperating and benefiting from this project, it seems an interesting project of a large scale introduction of electrical cars in a country. It did inspire the Danish government as well to contact Project Better Place and make an agreement with them.

### **6.5.2 Denmark**

In March of 2008, the government of Denmark also chose for a large scale introduction of electrical cars in cooperation with Project Better Place. The role of Better Place, delivering the infrastructure and their business model, and Renault/Nissan, delivering the electric vehicles is largely the same. However the motive and role of the government is slightly different.

The main motive of the Danish government to switch to electrical driving has to do with the great amount of wind energy that the country produces. The government and energy company DONG Energy see electric driving as a way to balance the relatively instable output of wind energy. The idea is that the wind energy produced at night can be used to charge the batteries in the electrical cars, in this way the wind energy isn't lost when demand is lower than production. Next to this advantage, the idea is that in peak demand moments, electrical vehicles can feed back the energy from their battery to the grid. This is the so called Vehicle to Grid (V2G) concept and could be used for peak shaving during high demand moments. Next to a different motive, the policy of Denmark is also different. In Denmark the registration tax on cars is 105% on the first part (first 76400 DKK) and 180% over the additional value. Zero emission cars which include the full electric cars have a purchasing tax of 0%. (Skatteministeriet, 2008)<sup>74</sup> While this was already the case till at least 2012, the Danish government wants to keep the 0% rate after 2012. This tax exemption for electrical cars compared with the heavily taxed other cars, makes the economics of electric car very attractive for consumers. Especially the combination of electric vehicles and renewable energy, which combine in a symbiotic way, offer a solution for both the climate problem and the shrinking amount of fossil fuel resources.

### **6.5.3 Transition theory on nation wide introductions**

It is difficult to give a prediction about the success rate of these large scale planned introductions, but there are certainly some important risks with such a large scale introduction. This approach is totally contrary to the transition theories discussed earlier. Instead of the bottom up approach and taking small steps while learning and expanding the actor network at each step, this approach tries to implement electrical driving from a top down approach and in a relative fast way.

One risk of this approach is that it is very easy to overlook certain actors that on the first hand might not play an important role but are actually vital for the success.

Another risk of this national choice for electrical driving is that a lock in might occur. Important choices have been made already which shut out other possible solutions.

Additionally, there is no room for small failures that can be solved, if one of the technologies in the whole chain fails, for example the battery swapping, than the whole system can break down.

Another risk is that it is difficult to create a product that really fits consumer needs, normally in a transition there is continues feedback which can be taken into account in the next step, this is missing now. What if the system would work but consumers are not happy with the cars, or the charging spots? It might look like a small aspect especially when one considers the ambitious plans but it is important that all actors are happy in the end.

A last somewhat unavoidable problem is the difference in viewpoints of actors involved in this situation. For Renault/Nissan electric cars are a niche product considering their whole production chain, while for the various national governments, Better Place and the investors this is their whole market. Renault/Nissan could step out if they would lose confidence in the project with relative small consequences while this would be a very big problem for the other actors involved.

It is however very easy to see the risks in such an ambitious plan. Better Place could also succeed; they have organized various meso level activities with their plan. They themselves organize the infrastructure, they found Renault/Nissan and their whole network to deliver the cars, and they work closely together with the government to assure that policy is made in a way to best suit implementing electrical driving. If these actors cooperate well and are able to attract additional important actors it could be that they succeed.

One may conclude that it is -at least- a very bold plan and the risk to failure is present. On the contrary, this approach takes into account and solves various barriers that electric driving is facing on the moment in its transition. If they succeed electric driving will have succeeded in its transition much sooner than would have been possible doing it from the bottom up. And if they fail Better Place has surely put electric driving under attention of various big car producers.

For the Netherlands it is definitely very interesting to follow the progress in these countries and it is also interesting to see what Better Place demands from these governments to increase the implementation of electric cars.

Both the Israeli and Danish governments focus their policy to the acquisition of a new car. By giving discounts on electric cars they are promoting the acquisition of an electric car over the normal ICE car. The system of taxation of Israel seems to focus both on stimulating electric cars on short term but guaranteeing the income from taxes for the

government while doing this. In Denmark the tax incomes for the government could become significantly lower if the introduction of electric cars will indeed become a success. It seems that from these two countries the policy of Israel is best focused on both the short and long term.

#### **6.5.4 Evaluation**

The role of the national governments in the Better Place model is focused on stimulating consumers to buy an electric car instead of an ICE car. Both governments give great tax discounts on buying the electrical car. In this manner the economic barrier to electrical cars is removed.

### **6.6 Policy demand from Dutch electric vehicle actors**

Next to studying these cases of both small scale and large scale introductions of electric driving, Dutch electric vehicle actors were asked about their policy demands. Interviews were done with three municipalities that are focused on electric driving; Leeuwarden, Amsterdam and Rotterdam. With SenterNovem since they host the platform renewable mobility, with the ministry of Transport (ministerie van Verkeer en Waterstaat), with Duracar a Dutch producer of electrical delivery vans and with energy company Essent/Enexus. Also ECE was asked for an interview since they currently are converting ICE cars to electrical cars; however they did not respond to the request.

The parties were asked to give their opinion on what national and local authorities could and should do to stimulate electrical driving in the Netherlands. Here the results:

#### **6.6.1 Policy demand on national level**

Since many of the actor's responses were similar a summary is made instead of giving all the answers from each actor separately. Specific opinions only given by one actor are given afterwards.

The following question was asked to all actors:

**What could the national government in your opinion do to stimulate electric driving in the Netherlands?**

Dutch actors see it as vitally important that there is consistent long term policy both from Europe and the Dutch national government concerning electrical driving. Many actors are happy with the fact that there is quite a good policy for electric driving with no road taxes (MRB) and no import taxes (BPM) for electric cars. However this should somehow be guaranteed for the long term and this should be clearly communicated to the actor field to attract electric car producers to the Dutch market.

Another point of policy demand is for clear policy about charging spots and other issues surrounding electrical driving. Without this, involved actors will strand in bureaucracy and this will delay the progress of electric driving. The government should allow experiments without enforcing too much of the current policy and make sure that this legislation is not obstructive. This policy should also be communicated well to the actor

field so that there will be as little confusion as possible. This rule applies mostly on national level but also to a certain degree on local level.

The actors also state that they see more use in setting emission limits for cars in general than to make specific policy that benefits just one technology. Policy on a certain amount of biofuel or policy that requires a certain amount of electric cars is seen as undesirable. It is better to set general standards and to let the market decide how to reach that target.

Last, various actors see an important role for the national government on the point of infrastructure. It is hard to say who is exactly responsible for this, although most actors agree that energy companies are, but the government can play an important role in various aspects of a nation wide infrastructure like standardization. According to these actors the government can provide a platform for the various parties to discuss about this and agree upon various issues.

In addition some actors gave some specific policy recommendations that were only given by them or examples that are worth noting:

**Municipality of Rotterdam:**

In the Netherlands many people live in an apartment and have no garage and therefore no charging outlet to their disposal. Something should be arranged for these people elsewhere to make sure they can charge their electrical car. Also for electrical two wheelers this problem exists. In many bicycle storage places in apartments there is no 220 volt outlet, if one wants to start using electric vehicles on a larger scale this should be changed and this must be done on the national level in the building regulations. Also we had to wait eight months before we heard from the local government that a charging outlet does not require a building permit and therefore can be easily installed. If they had told us directly we could have had the first charging spot 8 months earlier.

**Municipality of Leeuwarden:**

The national government could support us with our pilot project financially. Especially the organization of the actor networks is quite time consuming and expensive.

**Duracar:**

The national government could help the small innovative companies that are producing these cars. They can also be a good launching customer.

### **6.6.2 Policy demand on local level**

The following question was asked to all actors:

**What could local government in your opinion do to stimulate electric driving in the Netherlands?**

The actors state that local governments can stimulate electric cars locally. Examples of doing this are: cheap or free parking for electric cars, longer delivery hours for electric delivery vans and allowing electric cars access to bus and taxi lanes.

Another issue is that local governments can promote electric driving in events. One example is the “schoner vervoer toer” a parade where only vehicles with very low emissions are allowed to participate. But also providing an area where people can test drive electric vehicles is given as an example.

Last but not least is the recommendation that local government can start pilot projects in which they include the development of infrastructure.

In addition some actors gave some specific policy recommendations that were only given by them or examples that are worth noting:

**Ministry of transport (Ministerie van Verkeer en Waterstaat):**

Municipalities also give out concessions on what kind of public transport is allowed to drive in the city. They could use this to stimulate electric or hybrid electric public transport.

**Municipality of Leeuwarden:**

It is important to show your ambitions with electrical driving. In that way you can attract the right actors to make electric driving a reality. Next to that in our municipality we give electric cars an additional subsidy of 1000 euro and a yearly free parking permit.

Local governments can plan and assemble the needed actor field for electrical driving. We are currently working with various parties to establish electric mobility companies in our vicinity. This is good for local employment and it assures supply of vehicles.

### **6.6.3 Evaluation**

The policy demand in the Netherlands is largely consistent with all actors in this field on both the national and the local level. It is also noteworthy that the theoretic policy demand from the transition theory, like clear on policy to help the actor network grow and prevent policy made for other uses from obstructing electric driving, is named by the parties in the field so explicitly.

## **6.7 Current policy in the Netherlands**

Before giving policy recommendations, the current policy of the Netherlands that stimulates electric driving is given.

### **6.7.1 Exemption from purchasing taxes**

At the National level full electrical cars are stimulated by tax breaks. Purchasing tax which is called BPM (Belasting van Personenauto's en Motorrijwielen) in the Netherlands is set at 42,3% on the net price of the car since the first of February of 2008. (Belastingdienst, 2008)<sup>75</sup> For electric vehicles the BPM is 0% which means that persons buying a full electrical car have a significant discount. This policy is set to last till the first of July in 2013. (Energyvalley 2008)<sup>76</sup> To give an indication of the amount of the discount an overview is given in table 11 of various models of cars and the BPM of them:

**Table 11, BPM on various car models**

<b>Car type and specification</b>	<b>BPM (€)</b>
Renault Megane Scenic; 1598 Benzine 82 kW	6,276
Volkswagen Touran; 1896 Diesel 66 kW	8,893
Opel Zafira; 1910 cm3 Diesel 74 kW	8,259
Citroen Berlingo; 1.6HDI 66,2KW 1560 cm3 Diesel 66 kW	6,918
Chrysler Voyager; 2.5 CRD 2499 cm3 Diesel 105 kW	11,046
Hyundai Tucson; 2.0I 2WD 1975 cm3 Benzine 104 kW	5,390
Peugeot Partner; 1.6 16V 1587 cm3 Benzine 80 kW	4,009
BMW 1er Reihe; 118I 1995 cm3 Benzine 95 kW	8,005
Mini Cooper; COOPER 1598 cm3 Benzine 85 kW	6,084
Volvo V50; 1.8 92 kW Benzine	5,977

### 6.7.2 Exemption circulation taxes

Next to purchasing taxes electric vehicles also are exempted from paying circulation taxes, in the Netherlands called MRB (motorrijtuigenbelasting). This tax is based on mass class, the type of fuel used in the car and the province you live in. (Belastingdienst, 2008)<sup>77</sup>

In table 12 the MBR is given for the same cars that were also seen in table 11. The cheapest province is Flevoland and the most expensive province is Zuid Holland. The table gives an idea how much circulation tax a person saves each year with an electric car.

**Table 12, overview of MRB tax for various car models**

<b>Car type</b>	<b>Mass (kg)</b>	<b>MRB per year lowest (€)</b>	<b>MRB per year highest (€)</b>
Renault Megane Scenic; 1598 Benzine 82 kW	1,390	612	704
Volkswagen Touran; 1896 Diesel 66 kW	1,402	1,188	1,280
Opel Zafira; 1910 cm3 Diesel 74 kW	1,513	1,304	1,404
Citroen Berlingo; 1.6HDI 66,2KW 1560 cm3 Diesel 66 kW	1,215	956	1,024
Chrysler Voyager; 2.5 CRD 2499 cm3 Diesel 105 kW	1,925	1,764	1,912
Hyundai Tucson; 2.0I 2WD 1975 cm3 Benzine 104 kW	1,437	612	704
Peugeot Partner; 1.6 16V 1587 cm3 Benzine 80 kW	1,226	464	532
BMW 1er Reihe; 118I 1995 cm3 Benzine 95 kW	1,205	464	532
Mini Cooper; COOPER 1598 cm3 Benzine 85 kW	1,050	312	360
Volvo V50; 1.8 92 kW Benzine	1,274	540	616

Both these policies make electric cars more interesting for the consumer to buy. Knowing the policy that is already in place in the Netherlands to stimulate electrical driving, policy recommendations can be given.

## 7 Policy recommendations

Policy has two important functions; the first one is to create clarity for the actor network of electrical driving. Regulations need to be made for electric cars, infrastructure, safety issues surrounding electric driving etc. With clear policy it is easier for actors to form

stable connections and so form clusters of electric driving networks. Policy of this kind is needed to make a transition from the micro level to the meso level easier.

The second function of policy is to compensate for the current disadvantages of electric driving compared with the current dominant technology. By giving support to electric mobility, electric driving can be enabled to develop so that the technology can start to gain sufficient advantages for itself without the need of policy.

Next to policy governments can also help take transition steps for a technology by starting and doing or facilitating pilot projects. In the case of electric driving local governments seem ideal candidates since electric driving has some great advantages that benefit the local municipality, like cleaner air and more silent traffic.

The biggest barrier at the moment for electric driving is the lack of available electric vehicles, caused by a lack of available battery packs that are needed for the electric car. The next important barrier is the higher price for electric vehicles. Without a solution for these very basic problems it is unlikely that the electric car can progress to a more widely used product. Therefore the main focus of policy in the current situation should be on solving these problems. The Netherlands is a relative small country and therefore it has only limited influence on the availability of electrical vehicles. Yet this does not mean that they are powerless in trying to get electric cars to the Netherlands. With this in mind the following policy advice is given.

### **7.1.1 National level**

- 1) Currently the greatest problem of electric driving is the availability of electric cars. There is a need for electric cars that have honest, accurate specifications and that have good pre and after sale options available. The signal for the need for these cars should be clearly sent out to the market. Emission and usage standards of cars are decided upon on European level, just like most affairs that have to do with the aspects of cars themselves. The lack of electrical cars therefore could best be addressed on this level. The government can propose to give a European signal to the car market that there is a demand for electrical vehicles and make regulations or specific standards to stimulate the market to produce them.
- 2) The national government should pro actively create (and clarify) policy for electric mobility in the Netherlands. This includes policy about infrastructure, safety issues etc. This policy should be made in cooperation with the actors in the field and once established, this policy should be clearly communicated to the whole actor field to speed up the formation of actor clusters and thereby the growth of electric mobility in the Netherlands.
- 3) While energy companies are seen as the problem owners and most likely responsible for the electric car infrastructure, the government can play a facilitating role in discussions about standardizations of the infrastructure and so speed up this complicated process.

- 4) The national government should clearly communicate their ambitions with electric driving. It is important to keep in mind the symbiotic relation between electric driving and renewable energy. This can create a greater enthusiasm with the public and can help the government in reaching their aims to reduce CO<sub>2</sub> emissions and become less dependent on fossil fuels. Producers of electric cars are most likely to deliver their first cars to countries that have stated their (green) ambitions with electric driving and which have long term policy to stimulate electric driving.
- 5) The Netherlands already have a good policy to stimulate electric cars; zero purchasing taxes (BPM), and zero road taxes (MRB) make buying an electric car economically interesting in the Netherlands. It is important to assure this policy for the long term to create stability for the actors involved, and to communicate the policy to the actor field. The policy of Israel can serve as inspiration for the Netherlands; their system assures the tax income for the government while giving electric cars a great advantage. In this way their system assures the long term stimulation of electric cars. This last point is unlikely with the current policy of the Netherlands, once electric cars would become popular. In the same respect of creating long term stability, the government should clearly state how electrical cars will fit in the new way of taxation that is coming in the Netherlands with the road charge, in Dutch “kilometer heffing”. And last it would be good to know that if electric driving becomes more popular, electricity will not start to be heavily taxed, which would nullify the advantageous economic aspect that electric cars have.
- 6) The national government should keep in close contact with countries like Denmark who are introducing electric driving on a large scale in combination with Project Better Place. This can provide valuable information on how well the Better Place model is working in implementing electric driving on a large scale. Next it can provide important information on how electric driving can be combined with wind energy. Denmark is a leading country in wind energy and both countries are planning to produce more electricity out of the wind. Using an electric car park as a storage place of irregularly produced wind energy seems very attractive.
- 7) Last, national governments can serve as a launching customer by taking up electric cars in the car fleet and help local governments setting up pilot projects.

### **7.1.2 Local level**

1. Local governments can stimulate electric mobility by making electric driving (temporarily) locally attractive. Examples of this can include: longer delivery hours for electric delivery vans since they are both clean and silent, access to bus and taxi lanes for electric vehicles, lower or free parking fees for electrical cars, etc.

2. PR activities can be organized by local governments to stimulate electrical driving. The “Schoner vervoer Tour” is a good example that is already successfully being organized. Other ideas are free test driving areas or days with electrical cars and creating public charging spots to attract the attention of the public to electrical driving.
3. Most importantly, local government can start or facilitate pilot projects with electric mobility. Pilot projects introduce electric driving to the city and valuable experience will be gained. It is important that these projects are set up in the line of transition theory and that the experience gained is also made available to others. Starting a pilot project will give clear insight into the possibilities of electric driving at this moment and with this knowledge the future of electrical driving can more precisely be determined. When local governments are among the first parties to use electrical driving in the area, policy is likely to co-develop. Also on local level clear policy to create clarity for the involved actors is of great importance.

### **7.1.3 Recommendations on setting up a pilot project**

On the basis of the researched literature studies about electrical driving, the first hand experience of four experts and the interviews with 7 Dutch actors in the electrical driving arena, a lot of information was gathered on how to set up successful pilot projects. This knowledge can be used as input, according to the transition theory, for new pilot projects. When setting up a new pilot project it would be advisable to do this along the lines of the transition management theory. In this way the results can also be made publicly available and used in future experiments with electrical driving. Here are some recommendations on setting up a pilot project based on the information from earlier projects:

1. Involve as many relevant actors as possible in the experiment. Not only does the transition theory show the importance of actors, also experts in the field acknowledge the key role of actors. More actors will create a broader interest in e-mobility which automatically is a promotion for electrical driving. Next to this advantage, the involved actors can solve important problems that are going to be encountered with electric driving during the experiment. If the pilot is not started by the local government then ensure the long term support from local government to the project. This will prevent that the pilot has to be altered or stopped every time the local regime changes due to elections.
2. Know where to introduce electric vehicles. Electric vehicles are ideal for regular small distances (up to 150 km a day depending on battery size) Electric cars are especially interesting for city traffic, due to the zero tailpipe emissions. Municipal fleets and city distribution systems are ideal candidates to introduce electric vehicles due to high visibility of the vehicles and the high environmental benefits. As a passenger car, electric vehicles are most likely to be

- used by families that have more than one car. In this way the limited driving range and long recharge times are less of a problem. If electric cars are used in areas where they are likely to fail or to perform less than their ICE counterparts this is negative for electric driving and the ideas people will have about electric driving.
3. When buying electrical cars for a pilot project prices are often very high. This is due to the high battery costs and low production numbers of electric cars. An important way to, at least partly, solve this issue is to work together with other projects both within the country as with cities from other countries and order the vehicles together, this is also called common procurement. If cars are bought together in greater numbers, costs per individual car can go down significantly and the negotiation position is much better.
  4. It became clear from experience that electric car dealers are not always fully honest about the specifications and capabilities of their vehicles. Also after-sales like repairs to the cars when they have broken down can be a problem. Therefore good contractual agreements about quality, performance and after- sales of the cars with the supplier should be made.
  5. If electric cars are unavailable one should consider starting with electrical two wheelers. Scooters have the additional advantage that they can replace a car, in the worst case however they could also replace a bike. In this way the concept of electric mobility can already be brought to the public attention. When greater numbers of electric cars start to become available over time they can be added to the experiment.
  6. The results showed that commitment and enthusiasm of the people starting and leading the project is of great importance. A good project requires sufficient time; pilot projects should be set up for longer times; 10 years has been indicated by one of the experts.
  7. For small scale pilot projects, public (fast) charging infrastructure is not actually needed when the electric cars are used on regular routes and if the cars can be recharged in garages or at the workplace by simply plugging the car into the grid. Earlier conducted experiments show that charging spots in public places were hardly used during the course of those experiments. Charging points in visible areas can however be a promotion for electrical driving in general and remove psychological barriers people might have about electric driving. It is however not a prerequisite for a successful pilot project.
  8. If infrastructure is placed in public areas it is important to do this in cooperation with the individuals that already have and use electrical vehicles. These early adopters have first hand experience with electric driving in a place without charging spots and will be able to indicate what would be practical places for charging spots.

## 8 Conclusion and Discussion

The aim of this research is to determine if electric driving can be successfully implemented in the Netherlands within a 5 to 10 year timeframe. The emphasis has been on the role of the national and local government, and their possibilities to stimulate electrical driving in the Netherlands. After answering the main research questions the conclusion for the basic research aim will be formulated.

### 1) What are the current advantages and disadvantages of battery electrical driving?

From an efficiency viewpoint, electric driving has an advantage over ICE cars. An electric car fuelled with renewable electricity is three to four times more efficient from plant to wheel than its ICE counterpart that runs on fossil fuels. Electric driving with renewable energy also has great advantages considering emissions; these are all reduced close to zero. Electric cars, also those fuelled with electricity from fossil sources have zero tailpipe emissions and are more silent than ICE cars. If pollution due to the generation of fossil electricity is produced, this pollution is produced centrally and therefore easier to contain than when this occurs diffusely in a multitude of cars on the road.

Looking at the capabilities of electric cars concerning driving range and refueling times, electric cars perform much worse than the current standard of ICE cars. Due to the mass and high prices of batteries (Li-ion) it is unlikely that electric cars will be able to reach the ICE equivalent in the near future. Where an ICE car can drive 800 km on a full tank, electric cars at this moment can have a driving range of 150 km and be cost effective. In the future due to lower production costs of batteries this driving range can be increased up to 300 to 400 kilometers. Above this range, the additional costs of the battery cause the electrical car to be more expensive in its use than the ICE counterpart during its lifetime. Also the added mass of the battery can become a serious barrier at higher driving ranges. However if a person is comfortable with lower driving ranges, electric driving can be significantly cheaper due to lower usage and maintenance costs over the lifetime of the car.

Next to the lower driving range the refueling of an electric car takes significantly longer. Slow charging at a standard household electricity outlet can last from 5 to 14 hours, fast charging and battery swapping are both ideas that are being thought about but are both facing several challenges. At this moment no infrastructure has been built in the Netherlands to facilitate either of them.

The shorter driving range and longer refueling/recharging time of electric cars strengthen the inability of electric cars to compete with ICE cars at the point of driving range.

Taking the various advantages and disadvantages of the electrical car into account, the current electrical car does not seem to be a likely candidate now or in the future to replace the current dominance of the ICE car; it can however replace ICE cars in certain areas. Electric cars are attractive for use at regular but limited distances. In city areas where beneficial effects of zero tailpipe emissions and lower noise levels greatly contribute to a better living environment, electrical cars offer several advantages over their ICE counterparts. In the Netherlands about 2,000,000 vehicles or 20% of the total motor vehicle fleet can be potentially replaced with electrical vehicles.

**2) How does a transition work, what are the mechanisms that cause some products to go to a transition and become a success while other products never become a success?**

There are different theories about a path of a successful transition. These theories however agree on what are the most important factors in a transition. Experiments that show the status of the technology and which increase the knowledge about the product or technology are of prime importance. Another vital factor is the actors involved. During subsequent experiments both the knowledge about the technology as well as the actor network should continuously grow for a successful transition. This process can take various amounts of time. In the case of electric cars various experiments are still needed to let electric driving progress in its transition towards a more commonly used technology.

**3) What are currently the most important barriers of battery electrical driving, and can these barriers be effectively solved to start a wider application of electric cars in the transport sector?**

Currently the greatest barrier is the lack of electrical cars. It is difficult to purchase electrical cars and when they are available they often do not live up to the specifications that were promised by the producer. Next to the low availability the higher price of electrical vehicles is an important problem. The problem of the low availability of electric cars should be solved by the market and the future looks hopeful, many electric cars are being developed and it seems that in 3 to 5 years this problem could be solved by the market. The higher price of electric cars will automatically decline once cars and especially the batteries are starting to be mass produced. Meanwhile the higher price of electric cars can partly be addressed by governments that give tax exemptions and subsidies on electric cars.

**4) What can the Dutch government, at national and local level do to effectively stimulate electric car use in the Netherlands?**

The Dutch government, both at national and local level, should pro-actively make clear policy for electric mobility in cooperation with the important actors in this field. Once established this policy should be clearly communicated. Lacking or unclear policy can lead to unnecessary delays and can significantly slow down or even prevent actors from forming important actor clusters.

The Dutch national government has only limited power to solve the biggest barrier, the low availability of electrical cars. What they can do to help on this point is to, preferably with other countries on a European level, stress their ambitions with electrical driving and give a signal to the market that there is a demand for good electrical cars that live up to their expectations.

To overcome the higher prices of electric cars the current system in the Netherlands of zero purchasing taxes (BPM) and zero road taxes (MRB) are measures that already make

buying an electrical car in the Netherlands economically interesting. It would be very useful if this policy could be transformed to a long term stimulation system that can also be sustained when larger numbers of people start buying an electric car. The Israeli policy on electric vehicles can serve as inspiration in this respect for the Netherlands.

The most important action local governments can take is to start pilot projects with electric driving set up along the line of a transition experiment. This can provide important steps in the transition of electric driving to a more widely used technology.

With these answers to the sub questions a conclusion for the research aim is formed.

**The aim of this research is to determine if electric driving can be successfully implemented in the Netherlands within a 5 to 10 year timeframe. The emphasis is on the role of the national and local government, and their possibilities to stimulate electrical driving in the Netherlands.**

Due to the current state of technology of electric cars and the advantages and disadvantages that are attached to this, electric cars are very unlikely to become the new dominant type of passenger car. However, electric cars have an advantage over their ICE counterparts when used at regular and limited ranges and the zero tailpipe emissions and lower noise level make it an ideal car for the city.

About 2 million vehicles or 20% of the total vehicle park in the Netherlands are candidates that could be switched to electric. For the coming 5 to 10 years this creates room for a potential successful but relative small scale introduction of electric cars in the Netherlands.

On this moment the availability of electric cars is the most important barrier. Apart from giving a signal to the market that the Netherlands is interested in electrical cars there is little the government can do to solve this. Several car manufacturers are busy with the development of an electrical car and in the coming 3 to 5 years the problem of the low availability of the cars could start to be solved. To anticipate on these vehicles becoming available, the Dutch government should be pro-active in making policy for electrical vehicles in the Netherlands so that it is clear for the actor field what the regulations around electric mobility in the Netherlands are.

The current tax exemptions on electric cars in the Netherlands make electric cars economically interesting for consumers. However this policy should be transformed to a long term policy so that stability can be given to the actors involved. Inspiration to do this can be drawn from the Israeli policy.

One of the biggest roles for introducing and implementing electric cars in the coming 5 to 10 years in the Netherlands lies with the local governments. By starting pilot projects they can introduce electric driving in various places in the Netherlands and gain relevant experience with the current capabilities of electric cars. The experience that is gained with these experiments should be made publicly available according to transition theory. Based on the results from the pilot projects the future of electric driving for the Netherlands can be more closely determined.

**Discussion:**

During the course of this research both the car and oil market have been and continues to be in great turmoil. Oil prices reached a peak in August 2008 just over \$140 a barrel, and since then have crashed down to prices under \$40 a barrel in February of 2009. What will happen to the price in the coming half year is also very unclear. Some people claim this price will keep constant, on the other hand the IEA tells the world to prepare for an energy crisis that starts in 2010 (IEA, 2008)<sup>78</sup>, which could force oil prices up again to the level of August 2008 and maybe even higher. It is very hard to predict what will happen with the oil price in the coming months, let alone what will happen to it in the coming 5 to 10 years. However oil prices are likely one of the biggest driver of the success or failure of electric driving. If a cost comparison is made between electric driving and ICE cars than a price of \$140 or \$40 per barrel of oil makes a huge difference. If oil prices are high, than logically electric driving is much sooner economically viable. On the other hand, a constant oil price of \$40 dollar per barrel could cause many auto producers that just started to take an interest in electric cars to go back to the internal combustion engine again. Oil prices are also important for the strategic choices national governments make. When oil prices are high, the economic dependence of national governments on certain countries can become very high. To avoid this risk, governments can choose for a transportation method that allows a country to be less dependant of oil just like the Israeli government did. If oil prices are high these strategic shifts are much more likely to occur then when they are low, while these strategic shifts can also have a big impact on electric driving.

Next to the oil prices, the car industry has seen big changes as well. Car sales have greatly dropped in the last half year. Till September 2008 car sales in the Netherlands were 1.2% higher than the year before (Bovag, 2008)<sup>79</sup> but then car sales started to decline rapidly. In the Netherlands the car sales of November 2008 were 22% lower than the car sales a year before (Bovag, 2008)<sup>80</sup>. This trend has been observed worldwide and basically all car producers have seen a great decline in their sales. On top of this the credit crunch has caused great hardship on many car manufacturers worldwide. Many car companies were supported with government-funded capital injections. Especially American car producers like General Motors and Chrysler have been driven to the brink of bankruptcy in the past few months. On the other hand some newcomers in the auto industry like Tesla Motors have started to sell their first electrical car models and see a growing demand for their cars in the market.

Meanwhile in the background of this turmoil in both the oil and the car sector, the climate crisis is getting more urgent every day and the countries around the globe are getting more and more aware that fossil fuels cannot continue to fulfill our energy needs indefinitely.

These factors may have caused the governments of Australia, California, Hawaii and Ontario to join the Better Place Network in recent months. With these additional supporters, Better Place has now gained the support and cooperation of over three national governments and several large states. With all this support, Better Place is becoming a factor of more and more importance even though their plans may appear (too) bold from a scientific point of view.

It is important to consider what is happening on the background when making predictions about electric driving in the coming 5 to 10 years in the Netherlands. And it becomes clear that the future of the electric car is largely shaped by factors that cannot be influenced by the Netherlands themselves. However this does not mean that the Netherlands should not make its own plans with electric driving. To this affect, starting pilot projects remains one of the most important steps the Netherlands can take. And from these results the future of electric cars in the Netherlands can be determined more precisely.

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