Electric vehicles: sustainable and feasible in practice
Summary of a practical trial of electric vehicles
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Introduction

Electric vehicles: sustainable and feasible in practice

Electric vehicles are an attractive option for making car use more sustainable. This is demonstrated by a trial conducted by Rijkswaterstaat, TNO research institute and LeasePlan, in which over 20 electric cars were tracked for a year. As the first such trial, one of the most important findings was that, in practice, the energy costs of an electric car are less than half those of a modern petrol-engine car.
Though a relatively new phenomenon, electric vehicles are developing rapidly. The Dutch government believes that electric vehicles are of strategic importance in increasing the sustainability of car mobility and energy supplies and in strengthening the economy. However, more practical information about the performance and usability of electric cars is needed.

At the start of 2011, Rijkswaterstaat and TNO therefore joined forces to set up a large-scale measurement programme that has now produced a wealth of practical data. This data makes it possible to paint an accurate picture of the utility and benefits of electric vehicles on the basis of actual measured use.

**233,000 kilometres**

For one full year, Rijkswaterstaat and TNO monitored 24 electric and two plug-in hybrid cars of various makes on their daily trips. The drivers were Rijkswaterstaat employees. They used the cars for their daily commute and business travel. Altogether, the participating vehicles covered more than 233,000 kilometres under electric power.
The vehicles’ use and energy consumption was monitored continuously during the trial. TNO also conducted in-depth interviews with the car users and everyone else involved about their experiences with the electric vehicles. The most important findings were:

- In practice, the energy costs of an electric car are half those of a modern petrol-engine car.
- The average range during the trial was between 85 and 102 kilometres. This is less than that advertised by manufacturers, but still suitable for daily business travel.
- Participants became increasingly enthusiastic about using the electric cars.

Electric fleet is feasible

The purpose of this study was to obtain crucial initial knowledge and experience of electric vehicle use in practice. Rijkswaterstaat intends to convert a quarter of its own fleet to sustainable vehicles by 2015. One important conclusion to emerge from the study is that this appears to be very feasible, even extending to the potential use of electric cars throughout the central government. However, achieving this will require investments in an effective charging infrastructure, which currently does not exist. The absence of such an infrastructure was also one of the key points to come out of the user survey.
The cars

For the purpose of the trial, Rijkswaterstaat chose the three electric vehicles that are currently most commonly used: the Nissan Leaf, the Mitsubishi i-MiEV and the Peugeot iOn. A hybrid vehicle was also tested: the Toyota Prius Plugin.
A total of 26 vehicles took part in the trial: 12 Nissan Leafs, six Mitsubishi i-MiEVs, six Peugeot iOns and two hybrid Toyota Prius Plugins. During the trial, the vehicles were fitted with advanced measurement equipment in order to collect data during driving and charging. Over the entire study period, this generated five million pieces of data including vehicle data, GPS positions, battery status and kilometerage.

Measurement results from Toyota plug-in hybrid
TNO carried out measurements with two Toyota plug-in hybrid vehicles for around two weeks. This shorter trial period was due to the fact that measurements could not be carried out automatically during charging, but had to be done manually. These findings must therefore be viewed with some caution, but do give an initial indication.

> During the trial period, a consumption of 4.4 litres of fuel and 3.4 kWh per 100 kilometres was measured.

The measurement results show that electrical energy consumption by plug-in hybrids is less than the electric Nissan Leaf’s consumption. This is to be expected as the hybrids spent a lot of time running on petrol (around 80 percent). The vehicles operated solely on electrical power primarily at lower speeds. The Toyota plug-in hybrid’s actual consumption proved heavily dependent on the type of journey and the driver’s willingness to charge the battery.
### Electric vehicles

<table>
<thead>
<tr>
<th>Quantity x model</th>
<th>Model</th>
<th>Type</th>
<th>Battery capacity</th>
<th>Reported range</th>
<th>Top speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Nissan Leaf</td>
<td>Fully electric</td>
<td>24 kWh</td>
<td>160 km</td>
<td>145 km/hr</td>
</tr>
<tr>
<td>6</td>
<td>Mitsubishi i-MiEV</td>
<td>Fully electric</td>
<td>16 kWh</td>
<td>150 km</td>
<td>130 km/hr</td>
</tr>
<tr>
<td>6</td>
<td>Peugeot iOn</td>
<td>Fully electric</td>
<td>16 kWh</td>
<td>150 km</td>
<td>130 km/hr</td>
</tr>
<tr>
<td>2</td>
<td>Toyota Prius Plugin hybrid</td>
<td>Electric/petrol</td>
<td>4.4 kWh</td>
<td>25 km electric - 730 km petrol</td>
<td>85 km/hr electric - 185 km/hr petrol</td>
</tr>
</tbody>
</table>
The most important study finding is that the energy cost for electric cars is less than half that of a modern petrol-engine car.
The total cost of using an electric car – or ‘total cost of ownership’ – is determined chiefly by the purchase price, the residual value and the number of kilometres travelled. Despite their low energy costs, electric vehicles are still relatively expensive, particularly for private users. This is mainly due to the high purchase price. For example, a Nissan Leaf costs more than one and a half times as much as a comparable petrol-engine car such as the Renault Megane. The fixed depreciation is also higher – an electric car loses its value faster, due in particular to uncertainty about the battery lifespan. However, as the purchase price of electric cars – and particularly batteries – is expected to fall over the coming years, their residual value will increase. Batteries are expected to improve in quality, thus providing greater certainty about the reliability of electric cars.

**Variable return on investment times**

The current return on investment time for an electric car depends heavily on who buys it. For example, a company can benefit from tax breaks that are not available to Rijkswaterstaat and private buyers, both of whom must pay VAT and receive no tax breaks.
For Rijkswaterstaat, this currently means a return on investment time of over seven years, based on a driving distance of 15,000 kilometres per year and a purchase discount of 20 percent on both conventional and electric cars. Rijkswaterstaat benefits from low energy costs, as a result of which the energy costs for an electric car are one quarter of those for a conventional car.

Companies benefit most from existing tax breaks and subsidies. Given a local subsidy of €5,000, the return on investment time for an electric car is immediate. For companies, the energy costs are less than half those of a conventional car.

Private buyers currently have the longest return on investment time. This is because they pay VAT and receive no tax breaks. If they have the option to lease an electric car through work, however, they incur no additional tax liability and can save €2,000-3,000 a year.

Return on investment times shorten dramatically when coupled to higher residual value or fuel prices. Given the same depreciation percentage, the return time for Rijkswaterstaat could then fall to one year, and to seven years for private buyers. As experience with electric car use and battery lifespans grow, residual values will become easier to determine.
Financial incentives currently constitute an important factor in opting for an electric car. Electric vehicles are starting to become financially appealing particularly for business drivers – that is, companies or individuals with lease cars. Various subsidy schemes (e.g. the investment allowance) are now available that are making it cheaper to drive an electric vehicle.

Companies can take advantage of various allowances for electric cars that make it possible for the price per kilometre to remain relatively low. The difference in the kilometre price is greatest for private users; however, whether it is financially worthwhile for them to buy an electric car still depends on local circumstances, such as local government incentives or the availability of cheap electricity.

Costs of charging infrastructure
An accurate comparison of the costs of electric and conventional vehicles must also account for the costs of the charging infrastructure. This calculation is difficult to make on the basis of the infrastructure Rijkswaterstaat has already constructed. However, Rijkswaterstaat, TNO and LeasePlan have made an estimate of the costs of charging an electric car at home and at work.

<table>
<thead>
<tr>
<th>Financial arrangements</th>
<th>Rijkswaterstaat</th>
<th>Company</th>
<th>Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car model</td>
<td>Leaf</td>
<td>Megane</td>
<td>Leaf</td>
</tr>
<tr>
<td>MIA 36% Environmental Investment Allowance</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>KIA 28% Small Investments Allowance</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>VAMIL 75% Discretionary Allowance for Environmental Investments</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Exemption from BPM (car tax)</td>
<td>yes</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Local subsidy</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Saving on additional tax liability</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* If the individual has a lease car from work

Table 1: applicable financial benefits
Charging scenarios

**Home**
- Public and private domain
  - Linked to registration number
  - Included in contract
  - Substantial role for leasing company

**Work**
- Private domain
  - Often not linked to registration number
  - Charging card often not needed
  - Very limited role for leasing company

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**Cost of a charging point at home**
The purchase price of a home charging point is between €500 and €1,700. This depends on whether the buyer opts for a simple solution (a power socket on an outer wall) or a special charging station on the wall, which is what manufacturers recommend.

**Cost of a charging point at work**
The cost of installing a charging point at the place of employment differs from situation to situation, but can be substantial. The basic installation costs between €500 and €15,000, with charging point options ranging from relatively simple wall power sockets (such as in a covered car park) to advanced charging stations in open-air car parks that require separate cables to be laid.
Electric car range in practice

As part of the trial, TNO measured the actual range of the different electric cars. With a practical value of from 85 to over 100 kilometres, the ranges were less than what car manufacturers claim for their respective models.
‘The weather has a significant impact on the range of an electric car’

The range of electric cars is reasonable, and in any case is sufficient to meet the daily work requirements of central government employees. This means Rijkswaterstaat’s goal is operationally feasible and that a quarter of the fleet could be in the form of electric cars.

As measured in the trial, the Mitsubishi i-MiEV and Peugeot iOn had a range of 85 kilometres, which is 57 percent less than the manufacturer-claimed range of 150 kilometres. The Nissan Leaf had an actual operating range of 102 kilometres, or 64 percent of the claimed total of 160 kilometres. These measurements include the use of air conditioning, heating and lighting over the course of the year.
Weather effects
The weather has an important impact on electric car range as the battery also provides the power for heating and air conditioning. Given the current limited energy storage capacity of batteries, use of climate control has a major influence on electric car range. The same applies for meteorological effects such as temperature and wind speed. This study shows that electric cars can consume up to 50 percent more energy in changeable conditions (wind, rain, cold or heat) than in favourable weather. This is then reflected in the actual observed range as compared to the advertised range.
Electric cars are expected to require less maintenance than conventional cars. Whether this is the case and, if so, how much less, still needs to be established.
 LeasePlan anticipates that electric cars will require 10 to 20 percent less maintenance than equivalent petrol-engine cars.

 Manufacturers suggest that electric cars require up to 40 percent less maintenance.

 Because the trial was conducted with new cars and did not exceed one year, it is not yet possible to make substantiated statements about electric car maintenance.
**Little known about maintenance**

While there is plenty of information available regarding the maintenance requirements of ordinary petrol-engine cars, based on years of accumulated experience and statistics, there is no comparable practical data available regarding the maintenance of electric cars as their use is still relatively new. Nonetheless, it is possible to make some reasoned assumptions.

**Electric engine is reliable and wear-resistant**

In theory, an electric car requires less maintenance because less wear and tear occurs. This is mainly due to the electric drive unit, which is much simpler than a petrol engine. The casing of an electric motor is sealed, since no fuel needs to enter. Nor do any exhaust gases need to escape. The only moving part is the axle driving the wheels. A petrol engine has far more moving parts, which are therefore more prone to wear.

**Minor damage**

The trial generated relatively little experience with maintenance as the electric cars were new and only a few required servicing. Consequently, there is no significant maintenance data. However, there were a few minor damage incidents (bodywork damage, parking accidents) and minor defects. In three or four instances a car stopped charging because the lights had been left on, draining the battery. In the case of one model, the importer replaced all the charging cables due to defects in the existing cables.

The general impression obtained from the trial is that the tested cars did not have any defects attributable to the electric power source. Charging cables and particularly the various plugs sometimes can cause difficulties. It is therefore not possible to state with certainty on the basis of this trial alone whether there is a significant difference in the maintenance characteristics and costs of electric cars versus conventional cars.

**Tyre wear**

There no reliable data about tyre wear on electric cars as this only becomes clear after longer use. However, LeasePlan does anticipate a difference in tyre wear between electric and conventional cars. Electric cars have a relatively high acceleration power at low speeds, and therefore more tyre wear is anticipated. In conventional cars, tyre wear is particularly linked to engine power: the more power, the more wear.
User experiences

Electric car ratings on steady rise

Trial participants were enthusiastic about the electric cars’ performance and the ratings they gave the cars even increased during the trial. Stumbling blocks that remained were the range and charging.
Over the course of the trial, driver range anxiety in particular improved (decreased) considerably. Whilst the drivers were initially very wary about driving more than 30 kilometres, they developed a better feel for the possible range over time.

Participants’ initial fear that the electric vehicles would not be noticeable enough in traffic due to their silent electric engines proved unfounded, with participants reporting that other people were aware of their cars.

Ambassadors
The participants were interviewed extensively about their experiences with the cars both during and after the trial. Many of those interviewed felt themselves to be ambassadors for electric vehicles. As such, they reported sharing their experiences with immediate colleagues as well as those working in other central government divisions. As the trial progressed, the interviewees gave increasingly positive answers to the question ‘Would you recommend electric vehicles to colleagues for business travel?’ Their general appreciation for electric cars was also found to increase over the course of the trial, pointing to positive experiences. The overall rating for these cars was therefore very satisfactory.

Range
Notwithstanding the general enthusiasm about electric vehicles, there were two important and closely related stumbling blocks: the usable range and charging.
The specific ranges reported by manufacturers (as required by law) were not achieved (actual ranges were 57 to 64 percent of the reported ranges), particularly in unfavourable weather conditions (cold, heat, wind and rain). This limited operating range is a practical factor that contributes to the decision of whether or not to use an electric car. In situations where arriving on time was essential, the participants still regularly opted for a conventional car. Clearly, confidence in electric vehicles is not yet rock solid.

**Charging**

Charging was found to be simple and often took less time than specified by manufacturers. Most users appear to have quickly become accustomed to charging the battery, many getting into the habit of connecting the charging cable immediately on arrival from the outset of the trial. In the vast majority of cases, charging posed no problems. Unfortunate situations could arise when participants changed their routine or forgot to charge the car. This stumbling block will have to be removed if electric cars are to be used as pool cars.

The limited number of charging points remains a problem for users wishing to travel greater distances. Also, not all participants were well-informed about where the location of changing points. Communication about these locations could be an added task for fleet managers.
‘Using an electric car involves planning; it makes you an aware driver’

Peace and quiet
The users found electric cars to be considerably quieter than conventional cars. Nonetheless, awareness of the cars by other traffic was just as good. One notable experience that several users had was that they became far more aware drivers themselves, thanks to the lower noise production and limited range. They drove more slowly and consciously thought about energy consumption and the distance to be covered. This was found to make little difference in terms of time. The sense of peace reported whilst driving appears to be part of the electric car experience.
“Range and charging infrastructure: these are the biggest challenges for the use of electric vehicles’

Feeling
The fleet manager prefers to allow an individual’s transport requirements to determine the type of car they use; thus, an electric car for short trips and a conventional or hybrid car for longer trips. But people’s preference for a particular car is not always based on rational choices. Many of those interviewed remarked that driving is also about feeling. Often, it is not just the transport need, but also certain emotions and perceptions that determine which car a person chooses – for example, a car that drives more smoothly and/or is seen as larger and more attractive. Confidence in the characteristics of an electric car, as mentioned above, can also factor into this.
Environmental benefit

Electric cars do not emit any exhaust gases and do not produce engine noise. They make the outdoor environment more pleasant and are much cleaner than conventional petrol-engine cars.
Use of electricity as an energy source has cut petrol consumption by Rijkswaterstaat vehicles by nearly 5,000 litres in the space of one year. This is a total savings of 33 barrels of oil.

The use of electric cars has resulted in a demonstrable reduction of greenhouse gas emissions and particulates.

**Reduced greenhouse gases and particulates**

The practical trial involved using electric cars where Rijkswaterstaat employees would normally use petrol-engine cars. This yielded an undeniable environmental benefit, since the use of electric cars instead of petrol cars contributes to a reduction in harmful emissions, most notably carbon dioxide (CO2), nitrous oxides (NOx) and particulates, all of which contribute to global warming and are harmful to health. As the summary below shows, the participating cars produced 5.6 kilograms fewer nitrous oxides, amongst other things. These quantities of avoided emissions may be modest in themselves, but should be considered in the light of the limited size of the electric fleet and the comparatively short distances covered.

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1 Based on the Dutch electricity mix used
‘An electric vehicle uses energy much more efficiently than a petrol-engine car.’

How good are electric vehicles for the environment?
Do electric vehicles yield the same environmental benefit if the energy does not come from sustainable energy sources? This is a frequently asked question when it comes to electric vehicles. The answer is an unequivocal ‘yes’. It is clear that there is a real environmental benefit (fewer toxic emissions) and also a real climate benefit (fewer greenhouse gas emissions) if a conventional vehicle is replaced with a comparable vehicle that runs on the current mix of Dutch electricity. Moreover, this benefit will only increase as more of the energy used to power electric cars is sustainably sourced.
An electric vehicle also uses energy much more efficiently than a conventional petrol-engine car. This provides a net benefit even if the energy comes from power stations with a relatively low yield (less than 50 percent). Continued electric vehicle testing is also of major importance in its own right, providing substantive knowledge that can facilitate the wider transition to efficient cars that run on sustainable energy.

Through July 2012, the trial achieved a savings of 33 barrels of oil (one barrel equals 159 litres).
Conclusion

Electric vehicles, a promising future

The trial of the use of electric vehicles for central government has generated a wealth of practical data. One notable result is that the drivers reported an increasing appreciation for their vehicles as the trial progressed. But there are also points about which users were dissatisfied. These can be attributed to the limitations of the technology, which is still in its early stages. Most importantly, they felt the range of the cars to be inadequate and, allied to this, that there are still too few charging facilities.
In spite of the limitations of this still-developing technology, participants in the trial saw good prospects for the cars. The challenge in the trial was to make increasing use of the cars – and in this it was successful. The total distance covered in the last monitoring quarter (63,281 km) was more than in the two preceding quarters combined (49,318 km). These figures provide the best proof possible of the growing appreciation for electric vehicles amongst participants in this trial.

Cost
Financial incentives are currently an important factor in the acceptance of electric cars. These incentives can work in one of two ways, either by subsidising electric vehicles (such as the investments allowance) or making the use of petrol-engine cars more expensive (such as the additional tax liability). At present it is clear that electric vehicles are particularly interesting in terms of costs for business users (companies and lease car drivers). For private users, electric cars are still relatively expensive, particularly because of the high purchase price. As the purchase price decreases and residual value improves, the total cost of an electric car will also decrease.

Factoring charging infrastructure into the total costs is difficult and a bit of a chicken-and-egg problem. Without sufficient charging facilities, people will be less inclined to consider electric cars; without electric cars, investing in charging points does not immediately repay itself. These costs have therefore been included as estimates in this study.

Environment
In terms of the environmental consequences of electric vehicles, there was found to be a clear positive effect. This is principally because Rijkswaterstaat used the electric cars where petrol-engine cars would otherwise have been used. At a total of 233,000 electrically powered kilometres, this is equivalent to reductions of 333 grams of particulates and 5.6 kg of NOx nitrous oxides (local) and 15.1 tonnes of CO2 (global). This CO2 figure also takes account of the chain emissions relating to power generation. Greater use of electric vehicles would result in (substantially) higher avoided emissions.

Use is feasible
One important conclusion of this trial is that the large-scale use of electric vehicles at Rijkswaterstaat seems feasible, and that the targeted percentage for 2015 is also within reach. Rijkswaterstaat would need to take account of the types of use for which electric vehicles are suited, however, which currently means trips over relatively short distances. But even then, the targeted conversion to 25 percent electric vehicles seems achievable without any major problems.
This trial of electric vehicle use was a collaboration between Rijkswaterstaat, TNO and LeasePlan.
Electric vehicles: sustainable and feasible in practice

Summary of a practical trial of electric vehicles