# Impacts of Electric Vehicles - Deliverable 4

## Economic analysis and business models

**Report**
Delft, April 2011


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# Publication Data

**Bibliographical data:**
Bettina Kampman, Willem Braat, Huib van Essen, Duleep Gopalakrishnan
Impacts of Electric Vehicles - Deliverable 4
Economic analysis and business models
Delft, CE Delft, April 2011

Electric Vehicles / Production / Government / Industry / Investment / Research / Market / Economy / Analysis

Publication number: 11.4058.06

CE-publications are available from www.cedelft.eu

Commissioned by: European Commission.
This study has been produced by outside contractors for the Climate Action Directorate-General and represents the contractors' views on the matter. These views have not been adopted or in any way endorsed by the European Commission and should not be relied upon as a statement of the views of the European Commission. The European Commission does not guarantee the accuracy of the data included in this study, nor does it accept responsibility for any use made thereof.

Further information on this study can be obtained from the contact person Huib van Essen.

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# Contents

# Summary

## Introduction

This report focuses on the economics of Electric Vehicles, and the role that government policies and business models can play to make the economics more attractive to potential owners and users.

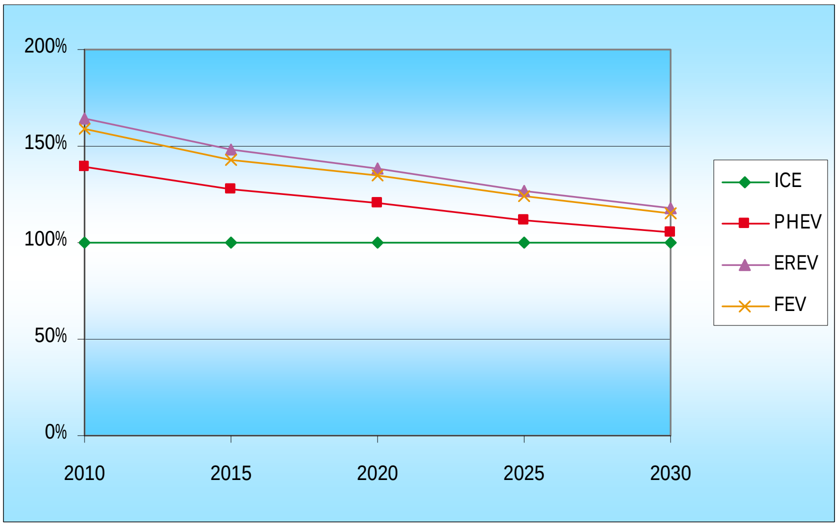
One of the main barriers to short- and medium-term uptake of Electric Vehicles (EVs) are their cost, in particular the cost of the batteries, and uncertainties regarding vehicle and battery lifetime. Even though the cost per kilometre (vehicle use) is generally lower, the current high battery costs typically result in both a different cost structure and in unfavourable total cost of ownership (TCO), compared to conventional vehicles (ICEVs) of comparable size.

## Total cost of ownership

In order to compare vehicles that have different cost structures, one should use the TCO over the lifetime of the vehicle rather than only look at purchase costs – significant differences in cost of use are then taken into account. However, there are quite a large number of variables involved in these calculations, ranging from vehicle cost, vehicle taxes and subsidies, fuel and electricity use per kilometre and cost per unit, annual kilometres, battery lifetime, etc. As many of these parameters are still relatively uncertain, especially the cost and performance data related to the Electric Vehicles, it is difficult to provide an accurate prediction of developments of TCO.

In order to still provide insight into the trends and developments that might be expected, a basic set of assumptions was derived, for all the parameters needed for this TCO calculation. These data result in TCO curves for the different types of vehicles investigated in this project: ICEV, PHEV, EREV and FEV. Some illustrative results are shown in Figure 1, where the calculated TCO is shown for medium-size petrol cars. Clearly, the ICEV has the lowest TCO in during the whole time frame analysed, but, as it is assumed that the purchase cost of the EVs reduce over time and vehicle (and battery) lifetime increases, the TCO of the EVs move towards that of the ICEVs. With the assumptions used, the additional cost of PHEVs is lower than that of the vehicles types with more batteries on board (EREV and FEV), resulting in a more competitive position at an earlier time.
Note that no government subsidies or vehicle taxes are assumed in this graph. These can obviously change the relative cost of the various vehicle types. Also, external developments may well affect the outcome of these calculations. A sensitivity analysis shows that especially a cost reduction of the vehicles (either due to reduced vehicle cost or due to government incentives) and a fuel price increase may have quite significant impact on the TCO comparison.

**Figure 1** **Illustration of the TCO of medium petrol vehicles - compared to the TCO of a comparable ICEV (ICEV=100%) - with fuel and electricity taxes but without vehicle taxes or subsidies**




## Government policies

Throughout the EU, there are quite a number of both financial and non-financial policies in place, aimed at promoting EV market uptake, R&D and charging point developments. The financial policies are implemented on member state or regional level, and vary from no incentives to several thousand Euro per car in some countries. This can be a subsidy, or (more often) due to $CO_2$-differentiated vehicle registration and/or circulation tax. On a local level, policies such as free parking spaces of free charging points are also applied. These type of policies typically impact on the TCO of the vehicles. On EU level, various policies have been implemented that support the development and market uptake of EVs, including the $CO_2$ and cars regulation and the current development of charging standardisation. These policies are in many cases relatively recent, and It is very likely that especially the national and regional policies will remain dynamic for some time as they are adapted to market developments.

## Business models

Due to the relatively high up-front battery purchase cost and the current uncertainties associated with these cost (because of limited experience regarding lifetime, resale value, etc.), a number of new business models are being derived, aimed at minimising the financial risk and uncertainty for potential buyers. Currently, there are still a number of options open, and the nature of future EV ownership and usage models is still uncertain. In the short medium term at least, they are likely to focus around a business model where batteries are excluded from the up-front cost of the vehicle and incorporated into an on-going usage-related service charge.

## EV economics and their market uptake

The economics of the EVs will not be the only parameter that determines market uptake of these vehicles, but it is expected to be the main driver for EV sales. As long as the performance of the vehicles is similar of less than that of comparable ICEVs (and there is no reason to believe that this will change in the near future), their market share will only increase significantly if the TCO is lower than that of the ICEVs. Government policies, investments in R&D and charging infrastructure are all needed to reduce TCO and make these vehicles an attractive alternative for consumers.

# 1 Introduction

## 1.1 Introduction to the project

Electric Vehicles (EVs) are a promising technology for drastically reducing the environmental burden of road transport. More than a decade ago and also more recently, they were advocated by various actors as an important element in reducing $CO_2$ emissions of particularly passenger cars and light commercial vehicles as well as emissions of pollutants and noise.

At the same time, EVs are still far from proven technology. There exist many uncertainties with respect to crucial issues like:

- The battery technology (energy capacity in relation to vehicle range, charging speed, durability, availability and environmental impacts of materials).
- Well-to-wheel impacts on emissions.
- Interaction with the electricity generation.
- Cost and business case of large scale introduction.

For EU policy makers, it is important to get a reliable and independent assessment of the state of the art of these issues in order to develop targeted and appropriate GHG reduction policy for transport. Therefore DG CLIMA commissioned CE Delft, ICF and Ecologic to carry out a study on the potential impacts of large scale market penetration of EVs in the EU, with a focus on passenger cars and light commercial vehicles. This study includes an assessment of both the transport part (e.g. composition of vehicle fleet) and electricity production and the impacts on well-to-wheel GHG emissions, pollutant emissions, other environmental impacts, costs, etc.

In this study three types of EVs are distinguished:

- Full Electric Vehicles (FEVs) that have an electric engine and no internal combustion engine (ICE).
- Plug-in Hybrid Electric Vehicles (PHEVs) that have both an ICE and an electric engine, with a battery that can be charged on the grid.
- Electric Vehicles with a Range Extender (EREVs) that have an electric engine and an ICE that can be used to charge the battery and so extend the vehicle’s range. The battery of an EREV can be charged on the grid.

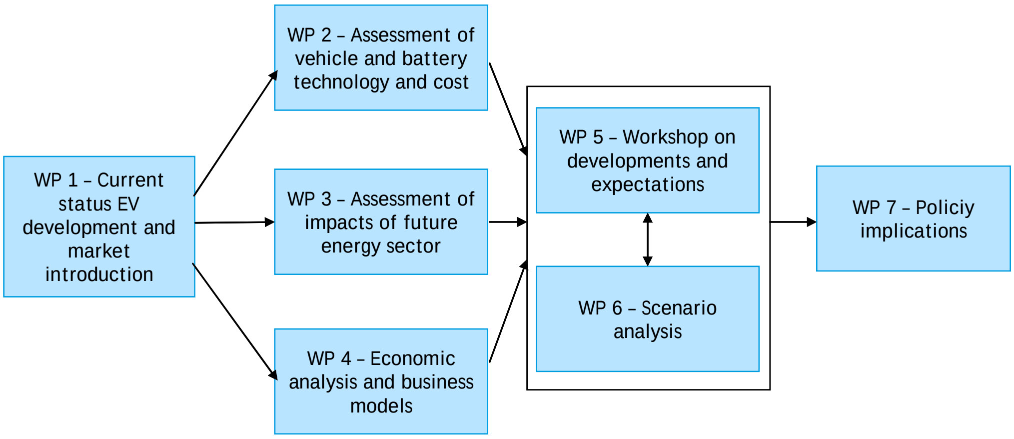
The results of the study should help the Commission with developing GHG policy for transport, in particular in the field of EVs and in relation to the wider EU transport policy and EU policy for the electricity sector.

The project is organised around seven work packages (WPs):

WP 1 Current status of EV development and market introduction.
WP 2 Assessment of vehicle and battery technology and cost.
WP 3 Assessment of impacts on future energy sector.
WP 4 Economic analysis and business models.
WP 5 Workshop on developments and expectations.
WP 6 Scenario analysis.
WP 7 Policy implications.

Figure 1 gives an overview of the main interactions between the various WPs. The approach for each WP is explained in the following paragraphs.

**Figure 1 Project overview**




The results of this project are presented in five deliverables: Deliverables 1 to 4 presenting the results of WP 1 to 4 and a final Deliverable 5 with the results of WP 5, 6 and 7. In addition there is a summary report, briefly summarizing the main results of the entire project.

This report is the fourth deliverable of the project and includes the results of WP 4.

## 1.2 Contents of this report

This report focuses on the economics of Electric Vehicles and the role that government policies and business models can play to make the economics more attractive to potential owners and users.

As was discussed in the report of WP 1, cost of the vehicles, cost of purchase and possibly intermediate replacement of their batteries and cost of EV use differ from that of the cost of conventional vehicles. This is a barrier to further market uptake, in two respects:
1. Total cost of ownership (TCO) is currently in most cases higher than that of conventional cars.
2. The cost structure is different from ICEVs, with relatively high purchase cost and relatively low cost of use (cost per km). In addition, significant investments may be required during the lifetime of the vehicle, if the batteries need to be replaced.

Resolving these barriers can be expected to be crucial to achieving significant market uptake in the future.

The main aim of this report is to illustrate the developments of total cost of ownership over time that are currently expected and the potential impact of government policies on the economics of these vehicles. Business models that can help make Electric Vehicles more attractive to car owners are discussed, and the impact of these developments on market uptake are assessed[1].

[1] This report assesses market uptake only in rather qualitative terms. A more detailed, quantitative analysis will be made in WP 6 of this project.

In Chapter 2, we discuss and illustrate how the costs of mobility may change due to EVs. In the following chapter, we address government policies and assess how policies can provide effective incentives for the parties involved in the role-out of EVs: consumers (car buyers), car manufacturers and the electricity and infrastructure (grid) sector. There we also discuss expectations regarding future developments in policy. Business models for EVs will be discussed in Chapter 4. The economics will undoubtedly play an important role in the potential future market uptake of EVs, this is discussed in Chapter 5.

# 2 Electrification will change costs of mobility

## 2.1 Cost structure of Electric Vehicles

As can be seen in Deliverable 1 and 2, various costs items of Plug-in Hybrid Vehicles (PHEV), Electric Vehicle with Range Extenders (EREV) an Full Electric Vehicle (FEV) are expected to be quite different than those of comparable conventional vehicles (with an internal combustion engine only, ICEVs): purchase costs of the vehicles are probably higher due to high battery cost, and energy costs per kilometre will be lower.
However, alternative business models are also considered to bring the cost structure more in line with the current (ICEV) situation: if the battery pack is leased rather than bought by the car owner, for example, the initial purchase price of the vehicle (excl. battery packs) could be much lower. The battery cost could then be recovered by paying a fee per kWh, or per kilometre.

It may also be expected that maintenance costs will be lower, especially in FEVs and EREVs as they have fewer moving parts, and electro-motors typically require less maintenance than the current combustion engines.

Looking at total cost of ownership (TCO) of a vehicle, quite a number of parameters play a role:

1. Purchase cost of the vehicle, including taxes and subsidies.
2. Lifetime of the vehicle, or resale value after a certain number of years.
3. In case of battery purchase: lifetime of the battery and, possibly, residual value.
4. In case of battery lease: battery cost per kWh, or per kilometre.
5. Annual number of kilometres.
6. Fuel and/or electricity use per kilometre (in litre/km and kWh/km).
   a ICEVs will only use fuel, EVs only electricity but PHEVs and EREVs may use both, depending on the trip length and driving style.
7. Fuel cost, including taxes.
8. Electricity cost, including taxes.
9. Maintenance cost.
10. Insurance cost.
11. Circulation tax or other taxes related to car ownership.

Parameters 1 and 2 determine the annual depreciation of the vehicle, the remaining parameters determine the annual cost of vehicle use (where 3 and 4 give annual battery depreciation, and 5, 6, 7 and 8 are related to energy use).

In addition, car owners may have to invest in a charging point at their home.

Currently, as costs of these Electric Vehicles, battery lifetime, etc. are still quite uncertain, it is difficult to predict the cost of both purchase and use of these vehicles. It is, however, very likely that consumers will be faced with changes in both the fixed and variable costs of their vehicles, when changing from ICEV to one of the electric type vehicles. They will have to familiarise themselves with the new situation and have to learn to compare ‘total cost of ownership’ of vehicles rather than purchase price alone, as may car buyers do now. That will be the only way to realistically compare the cost of these different types of vehicles.

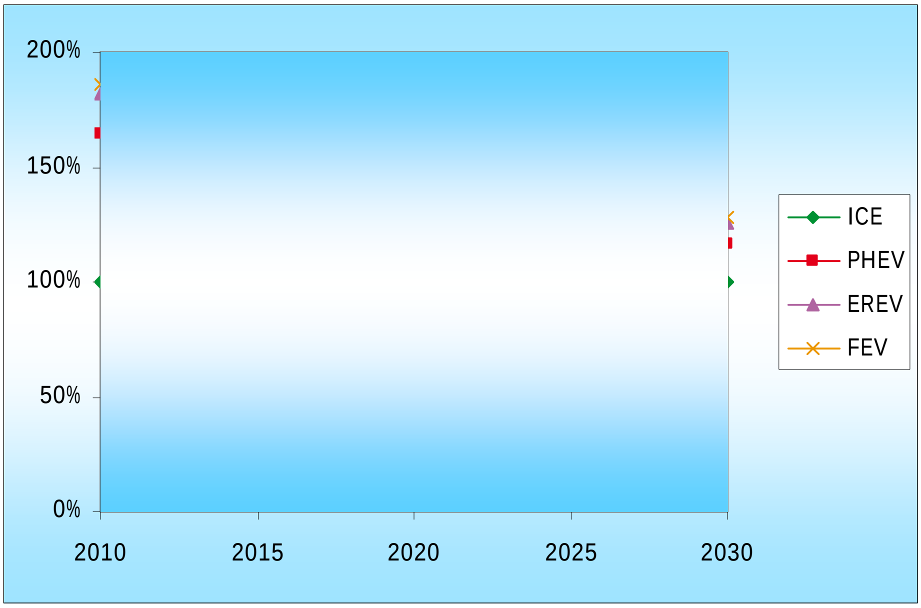
## 2.2 Comparison with costs of ICEVs

To provide an indication of how the total cost of ownership of EVs compare with that of ICEVs of comparable size and performance, a baseline set of assumptions was derived, for all types of vehicles. These assumptions are based on the results of WP 1 and 2, on data from the Vehicle Emissions project (from Ricardo and TNO), on literature and, in some cases, on own assumptions. These assumptions are, of course, highly uncertain, and will be varied in the scenario study WP 6 to provide a much more comprehensive view of the potential future cost (and impacts) of EVs. The data shown here are therefore not intended to be accurate predictions of TCO, but rather to illustrate potential TCO developments. The impact of variation of some of these parameters on the TCO will be shown later in this section.

A full list of the assumptions used in the calculations for this report can be found in Annex A. As can be seen, we distinguish three types of vehicles: small, medium and large (in line with the TREMOVE categories <1.4 l, 1.4–2.0 l, >2.0 l), as well as between petrol and diesel vehicles. The latter is important because of different fuel prices, annual kilometres, etc. Note that we do not assume any vehicle registration or circulation taxes or purchase subsidies here, because these vary significantly between EU Member States (the potential effect of subsidies of differentiated taxes is illustrated in Section 3.5). However, fuel taxes are included and a VAT of 19% is assumed.

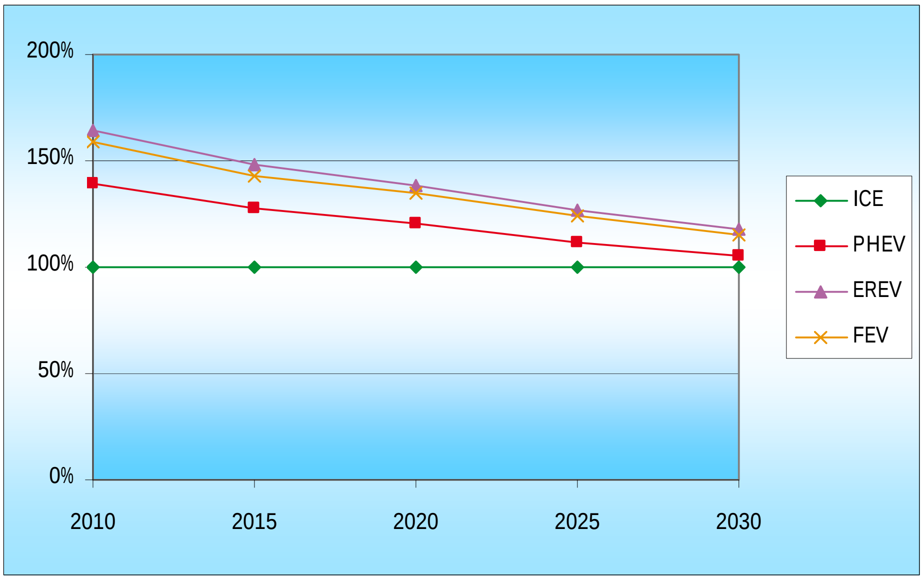
Using these assumptions, we have calculated the development of the TCO for small, medium and large (petrol fuelled) ICEV, PHEV, EREV and FEVs. These are compared to the ICEV TCO in the following figures (expressed as a percentage, compared to the TCO of ICE).

**Figure 2** **TCO of small petrol vehicles - compared to the TCO of a comparable ICE (ICE=100%)**



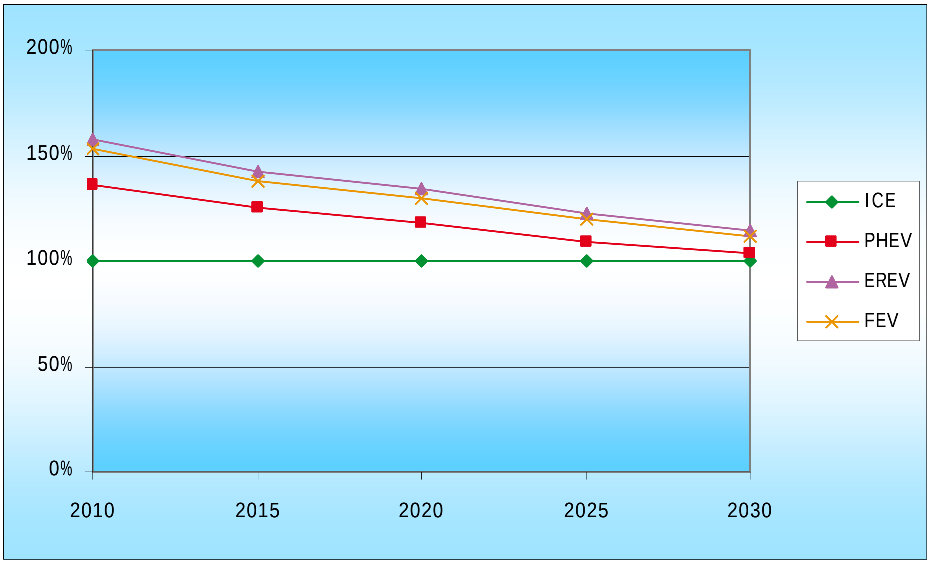

NB. Including fuel and electricity taxes, excluding purchase or registration taxes and subsidies.

**Figure 3** **TCO of medium petrol vehicles - compared to the TCO of a comparable ICE (ICE=100%)**




NB. Including fuel and electricity taxes, excluding purchase or registration taxes and subsidies.

**Figure 4** **TCO of large petrol vehicles - compared to the TCO of a comparable ICE (ICE=100%)**




NB. Including fuel and electricity taxes, excluding purchase or registration taxes and subsidies.

As a number of cost and performance improvements are assumed for the EVs, the currently relative high TCO of EVs will to reduce over time. In the small vehicles, the relative cost difference is the highest, in particular due to the high purchase cost and the relatively low annual mileage (a higher purchase price can be recovered due to the lower cost per kilometre). Comparing the three types of EV, the PHEVs have the lowest TCO, whereas the lifetime cost of FEVs and EREVs are quite comparable - with the input data assumed here.

The results also show that with the assumptions used, the TCO for any of the EVs will not be comparable to ICEs before 2030. In the medium and large segment the TCO of especially PHEVs become quite similar to that of ICEs in 2025-2030, but the lines do not cross.

However, as the input values are based on averages of quite large vehicle categories (for example, medium sized petrol cars), comparable costs will mean in reality that the EVs will be cheaper than ICEs for half of the vehicle owners in that category, and more expensive for the other half.

Of course, there are several external developments and government measures that may reduce the difference in TCO in the coming years and decades, such as:

– Government policies such as subsidies, differentiated vehicle taxes, etc.
– Technological breakthrough in EV cost, in particular the battery cost and, to a lesser extend, battery lifetime.
– Changes In transport fuel price or energy efficiency of the vehicles.

The impact of government policies will be discussed further and illustrated in the next chapters. In the following graphs, the impact of different vehicle and fuel cost is shown in Figure 5 and Figure 6. Here, the medium petrol fuelled vehicle segment in the year 2020 is used as example. The base case assumptions (shown in Figure 3) are taken to be the 100% case in this graph.

These results confirm that vehicle catalogue price and petrol prices are important factors in the TCO comparison. In this vehicle category and with the assumptions used here, a 40% decrease of PHEV catalogue prices can be expected to result in a match with the ICE TCO, whereas the FEVs and EREVs need a 55% and 50% reduction. A fuel price increase will also help the EVs to achieve competitiveness with the ICE, but the increases needed to achieve competitive TCOs are quite significant in this case.

**Figure 5 Catalogue price sensitivity analysis - medium petrol vehicles, 2020**

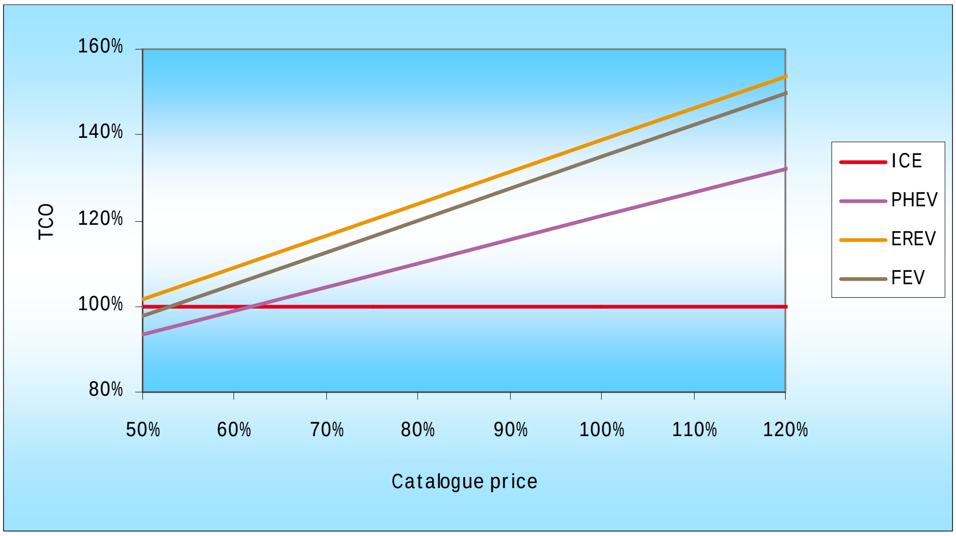
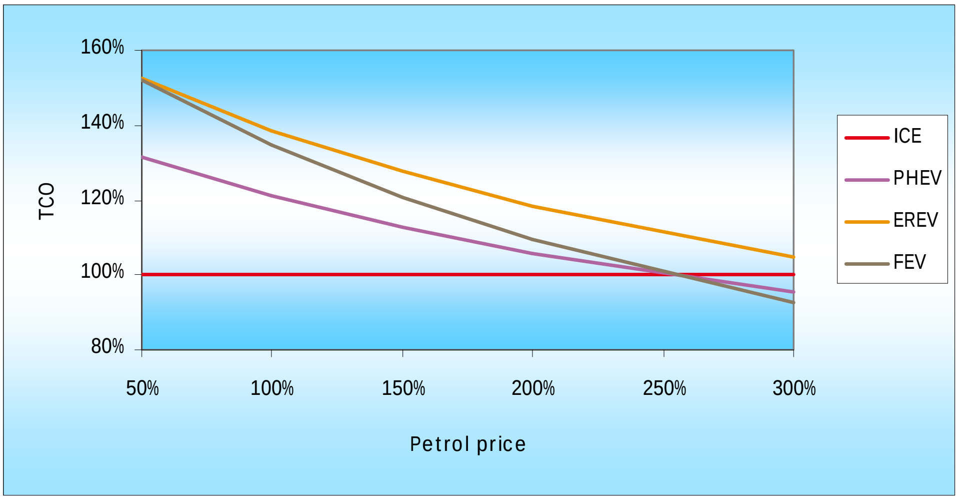
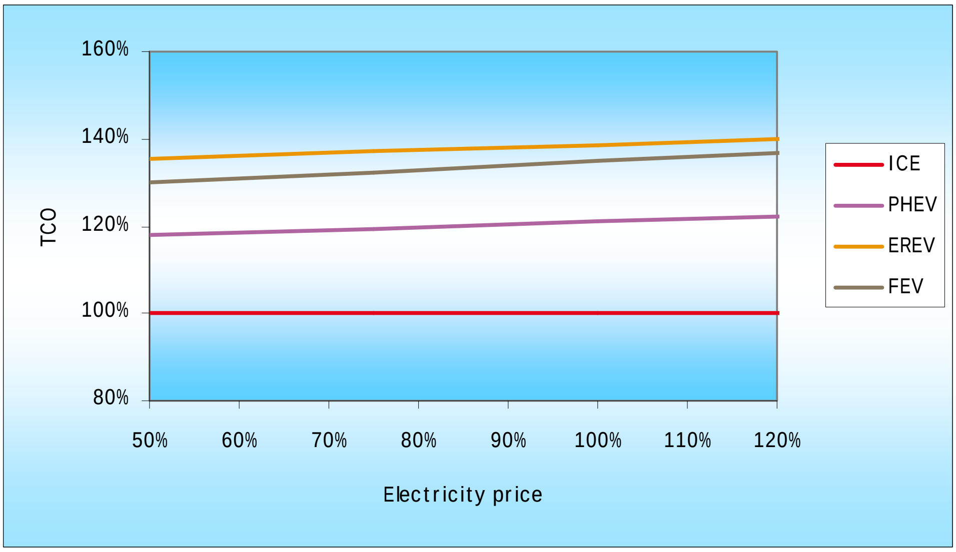


**Figure 6** **Fuel costs sensitivity analysis - medium petrol vehicles, 2020**



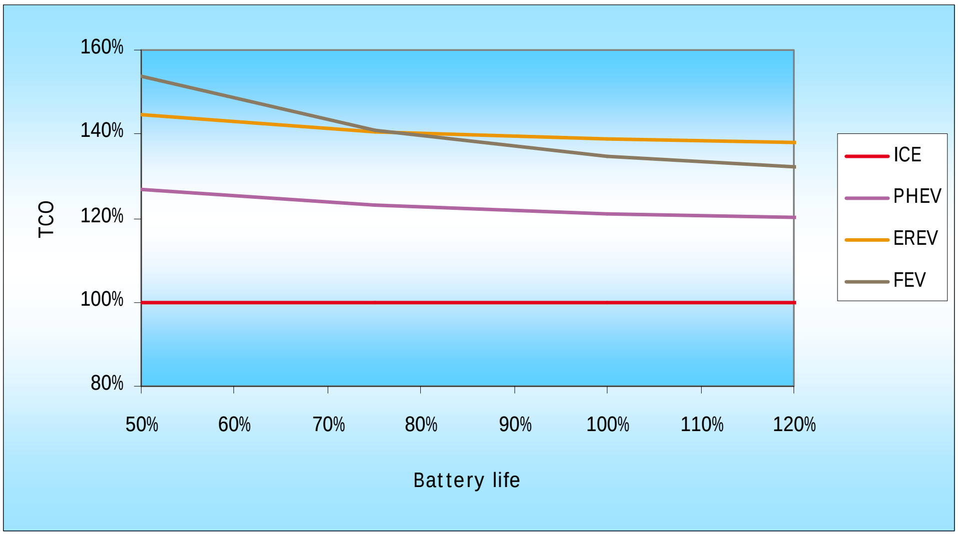

The TCO comparison is much less sensitive to the price of electricity, as shown in Figure 7.

**Figure 7** **Electricity price sensitivity analysis - medium petrol vehicles, 2020**




Another still uncertain issue in EV TCO calculations is the battery life expectation. Our analysis shows that this parameter, even though it comprises a high share of the purchase price, does not influence TCO as much as the catalogue price or fuel costs (see Figure 8). As can be expected, the FEV TCO is influenced the most by the battery life since it has the largest battery pack of EVs and therefore has the highest share in vehicle costs compared to PHEVs and EREVs.

**Figure 8 Battery life sensitivity analysis - medium petrol vehicles, 2020**



# 3 Government policies that may affect the economics of EVs

## 3.1 Introduction

There is a general consensus that without government policy, Electric Vehicles will not enter the market in any significant share, until, at some point in the future, oil prices increase so much that high petrol and diesel prices make EVs competitive. This may be partly because, at least until recently, the ICE technology and fuels were intrinsically superior to that of EVs and therefore more attractive to car buyers. The battery technologies we have known so far were technically less suited and more expensive for energy storage in a car or a truck than the petrol and diesel we use for ICEs. However, another reason for this is the many decades of intensive development of the ICEs, that resulted in huge advantages: high production volumes that result in relatively low cost, high reliability and driving range, well developed refuelling infrastructure and good performance. The world wide development of EVs has only just started[2], resulting in the current situation of low production volumes and thus high cost, limited recharging capabilities, etc.

In order to achieve significant market uptakes of EVs at current oil prices (and at oil prices predicted for the coming decades), both issues need to be addressed: battery technology needs to improve, and the market needs to develop and grow in order to climb the learning curve and reduce cost by increasing the scale of production. As the benefits of EVs are largely for the society rather than for individuals, governments have to help this development by providing the right incentives.

In recent years, we have seen an increasing number of government incentives being implemented throughout the EU, both financial and non-financial. These policies are implemented at different government levels, ranging from EU directives to national and local policies. Some of these policies are aimed at R&D to improve the technology, others are aimed at market uptake of the existing technology, standardisation of charging systems or at increasing the number of charging points.

In many cases, it is expected that these incentives will only be needed temporarily, as costs and performances will improve once a certain market share and customer acceptation is achieved. It is currently not known whether the EVs will be able to fully compete with ICEs at some point or whether government policies will always be necessary to ensure a desired market share of EVs[3]. In any case, the EV market developments in the coming one or two decades are considered to be strongly dependant on government policies and incentives.

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2 Several car manufacturers have tried to develop EVs in the past decades, production volumes have never been significant.

3 Note that government incentives could be justified also in the long term, for example because of lower $CO_2$ emissions, lower air pollutant and noise emissions, etc.

In the following, we first provide an overview of the policies currently in place in the EU – not with the aim to be comprehensive, but rather to illustrate the variety of policies in place. Then, we will discuss how these policies may affect the market uptake of EVs. We will assess potential policy developments in the future in the last section of this paragraph.

## 3.2 Financial policies

Quite a number of financial policies are currently in place throughout Europe to encourage the development and sales of EVs. An overview of incentives for FEVs is provided in Table 1.

In some of the countries listed in the table, $CO_2$ differentiation of vehicle registration and circulation taxes are the reason for the tax exemptions or discounts stated. In these cases, policies are technology independent. However, in other countries, the tax discounts (or other financial incentives) are specific to FEV.

**Table 1 Overview of financial policies implemented to promote FEVs**

| Type of policy | Aimed at | Examples |
|---|---|---|
| Subsidy for EV purchase | Market uptake of the vehicles | Austria, Belgium, Cyprus, Germany, France, Italy, various regions in Spain, Sweden, UK (also for Plug-in Hybrids) |
| Discount on or exemption of vehicle registration tax | Market uptake of the vehicles | Tax exemption in the Austria, Netherlands, Denmark, Greece (also for Hybrids), Portugal, Romania; discount in Belgium, bonus in France due to low $CO_2$ emissions |
| Discount on or exemption of vehicle circulation tax | Market uptake of the vehicles | Tax exemption in Austria, Czech Republic (EVs for business purposes only), the Netherlands, Ireland, Germany (first 5 years after purchase), Greece |
| Reduction of VAT | Market uptake of the vehicles | Austria |
| Favourable fiscal treatment of leased cars | Market uptake of the vehicles | Netherlands, UK |
| Discount on or exemption of congestion charge | Market uptake of the vehicles | UK (London), Sweden (Stockholm) |
| $CO_2$ differentiated fuel and energy tax | Market uptake of the vehicles | |
| Free parking places for Electric Vehicles | Market uptake of the vehicles | Cities in Italy, the UK, Denmark, the Netherlands, |
| Subsidies for the installation of charging points | Charging point availability | Cities in the Netherlands, UK, etc. |
| Subsidies for R&D (car manufacturers and research institutes) | Improving technology, reducing cost | Netherlands, UK, … |

Source of the country examples: ACEA, http://www.acea.be/images/uploads/files/20100420_EV_tax_overview.pdf, AVERE and own data.

Clearly, most financial incentives are aimed at reducing the cost for consumers, in order to create a market for these vehicles despite their currently high cost. These are typical policies on a national and sometimes regional level. All types of taxation for vehicles can be used for this. In addition, various countries and local governments provide financial support (subsidies) for the installation of charging points, in some cases the local governments themselves install these charging points, making them available to all EV users.

Note that in addition to these policies that are explicitly implemented for to provide incentives for EVs, the current rules on energy taxation in the EU provide a clear incentive as well: Directive 2003/96/EC fixes higher minimum tax rates for transport fuels than taxes on electricity, and these are reflected in higher national rates in almost all countries of the EU. In conjunction with the relatively low energy use of EVs (per kilometre), this leads to a much lower energy tax for EVs than for ICEs, per MJ but even more so per kilometre.

So far, not much attention has been given to PHEVs and EREVs in policies, but this might change once their sales increase. However, even in the current tax systems, they can be expected to fall into lower tax categories for vehicle registration and circulation taxes, as these are differentiated to $CO_2$ In an increasing number of countries.

**The impact of VAT on vehicle cost**

The catalogue price of electric vehicle is currently significantly higher than that of comparable ICEs, and this is expected to remain the case at least in the near to medium term future. Since all EU member states levy VAT on the purchase of vehicles which is a percentage of the catalogue price, the VAT that has to be paid on these cars is higher than that of comparable conventional cars.

For example, if an ICE costs € 10,000 and the VAT is 20%, the VAT will amount to € 2,000.
If an electric vehicle of the same size costs € 20,000, the VAT will add up to € 4,000. The VAT will thus increase the additional cost of the electric vehicle by € 2,000.

This effect should thus be taken into account when assessing the potential impact of a subsidy or purchase tax differentiation. In this example, a subsidy or tax differentiation of € 2.000 would only compensate the higher VAT payment. A higher subsidy or level of differentiation is needed to reduce the actual difference in catalogue value.

## 3.3 Non-financial policies

Besides direct financial incentives, governments may choose to implement non-financial incentives to encourage the sales and use of EVs. These are listed in Table 2, again with examples of countries were these are currently in force. These policies clearly range from local initiatives to EU directives.

**Table 2** **Overview of non-financial policies implemented to promote EVs**

| Type of policy | Aimed at | Examples |
|---|---|---|
| $CO_2$ and cars regulation: super credits, counting EVs as zero emissions cars | Supply of vehicles | EU regulation |
| Fuel Quality Directive: $CO_2$ reduction over the fuel chain | Market uptake of the vehicles? | EU Directive |
| Standardisation of charging systems | Enabling market expansion | EU (also some national initiatives) |
| Access to restricted areas such as environmental zones in city centres | Market uptake of the vehicles | Some cities in Italy |
| More flexible access times for goods delivery in city centres | Market uptake of the vehicles | Various cities in the Netherlands, ...? |
| Permission to use bus lanes | Market uptake of the vehicles | Sweden |
| Government procurement | Market uptake and supply of the vehicles | UK |
| Obligation to install charging point infrastructure in new offices and industrial estates | Market uptake of the vehicles through charging point availability | France (ref. Bains rapport) |

## 3.4 Future developments in EV government policy

As shown in the previous tables, policies may have different aims that can all contribute towards increasing the uptake of EVs in the coming decades. As the EV market is still in its infancy and many different barriers still exist (e.g., high cost, lack of charging points, etc.), many different types of policy are currently considered to be necessary to remove these barriers and to encourage industry and stakeholders to invest in these developments.

The policies listed above address the following key issues of EV development:
- Improving charging point accessibility, i.e., the number of charging points available to EV users.
- Encouraging car manufacturers and OEMs to invest financial resources and effort into the development of EVs and their parts (e.g., batteries).
- Encouraging car manufacturers and OEMs to increase the production of EVs.
- Encouraging customers to buy EVs.
- Facilitating the market uptake by standardisation of, for example, charging systems.

These are clearly currently the most relevant issues for governments to focus on.

However, it is likely that over the coming years and decades, the policies will change.
- Firstly, policies will be adapted to changing market circumstances and political developments.
- Secondly, the currently policies can be expected to become much more expensive once the market share of EVs increases.

Regarding changing market circumstances, governments will want to focus on different issues over time. Policies may aim to remove barriers to successful EV deployment, but once these hurdles are taken, these policies may be reduced, modified or stopped. Other barriers may then arise, which require different kind of policies.
In the short term, policies will need to focus on creating a first market for these vehicles and on encouraging R&D efforts in the industry. Once production and sales of the EVs have increased, the need for incentives for consumers may reduce: cost should have gone down over time and the number of vehicles has increased so that installing charging point may start to become commercially viable. Once these developments occur, subsidies for EVs and charging points may be reduced. Governments may then need to rather focus on other issues, such as ensuring that the local power grids have sufficient capacity for larger scale EV charging. They may then also want to modify their taxation or road pricing policies in order to properly and fairly include these vehicles in the existing taxation system. For example, current registration and circulation taxes are often based on car $CO_2$ emissions, cylinder capacity or weight. FEVs, PHEVs and EREVs may need different bases to differentiate taxes on. If the cost of using EVs (i.e., kilometre cost) becomes much lower than that of current vehicles, there might also be a need to implement policies that prevent transport volume growth that might result from this, in order to limit transport energy use (and emissions) and to prevent negative impacts on accessibility.

The second issue is related to government revenues and cost. Clearly, the cost to governments of subsidies and tax reduction per vehicle is still very limited in the early stages of market introduction of EVs, but increases once the market uptake increases. It can be expected that the policies will then gradually be reduced and perhaps even eliminated in the medium or long term. Both vehicle taxes and transport fuel taxes contribute significantly to government revenues, governments can be expected to adapt their policies once EVs become a success.
As this would be done as production volumes increase, this might not be a problem for the EV market uptake: the incentives can then reduce in line with costs reductions, and overcompensation can be avoided. It may, however, result in a barrier to market uptake if costs of EVs do not go down as expected, for example because of increasing cost of materials.

Potential negative impacts will also occur with non-financial incentives for EVs. Providing free parking spaces or access to bus lanes may be very effective in the short term, but may not be viable policies in the longer term. The same may hold for super credits for EVs in the $CO_2$ and cars regulation: these may have positive effects in the short term, but they are expected to lead to higher $CO_2$ emissions of road transport in the longer term as the car park will become less fuel efficient when the sales of EVs increases (CE, 2010).

Note that in many cases, a different design of the policies can prevent or alleviate the negative impacts without reducing the incentive for EVs. For example, financial policies can be designed cost-neutral for governments, for example with a bonus-malus system or a differentiated tax rather than with a subsidy or a tax reduction only. Technology neutral tax differentiation, for example based on well-to-wheel $CO_2$ emissions could then potentially be an effective and financially sustainable policy. This differentiation would then need to be adapted in regular intervals to account for market changes.

We would therefore expect that the current EV policies in the EU and its Member States are only a start, and that these will be refined and further developed over time. The resulting policies will depend on issues such as the EV market shares and cost development, on political developments such as climate goals, energy and taxation policies and on technical developments such as ICE fuel efficiency. In addition, there are still unanswered questions such as whether it will be possible to distinguish electricity use for transport and for other uses (e.g., households). If a monitoring system in the vehicles enable separate taxation for transport, governments would have the option to put a higher tax on electricity for road transport than for domestic use, and thus compensate for the reductions in fuel tax revenues in the longer term. If not, they may need to consider other options (e.g., road pricing or higher fixed taxes).

It is probably too early to predict how these government policies will change in the future. In WP 6 of this project, some scenarios will be build that include different policy scenarios.

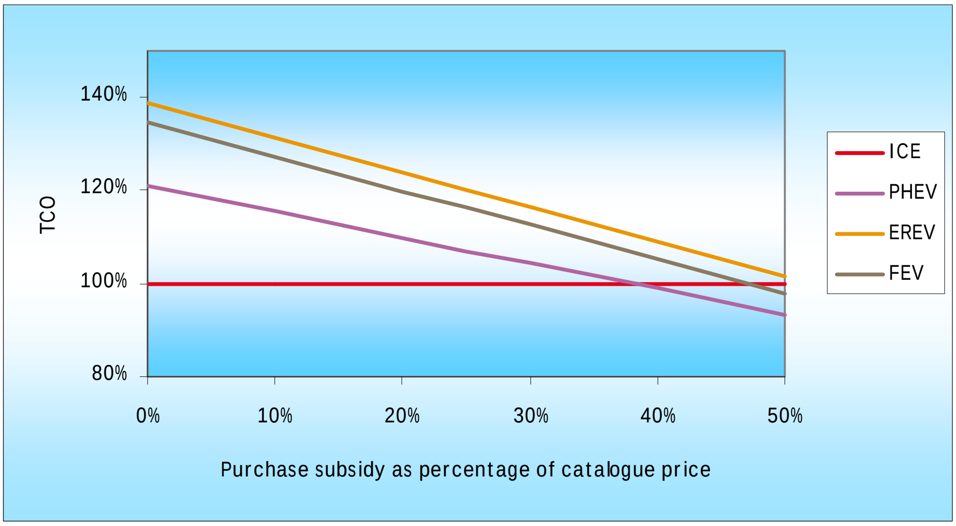
## 3.5 Potential impact of government policies on EV economics and market uptake

As the EV policies vary significantly between EU Member States and are in fact still quite dynamic (as are the EV cost), we focus here on providing an illustration of the effects of government policies rather than exact data.

Using the baseline assumptions introduced in Section 2.2 and listed in Annex A, the impact of a EV purchase subsidies on the TCO of these vehicles was determined. This subsidy could be a direct purchase subsidy or due to a $CO_2$ differentiation of the registration tax, the details of policy implementation do not affect the TCO comparison (they do affect the TCO of the vehicles, but not the difference in TCO between ICEs and EVs).

The result is shown in Figure 9, for the medium-size petrol vehicles using the cost and performance assumptions of 2020. On the x-axis the purchase subsidy is varied as percentage of the catalogue price of the vehicle. Note that this graph is closely related to that of Figure 5 in Section 2.2, where the sensitivity of the TCO to changes in catalogue price of the vehicles was shown – the impact of a vehicle cost reduction on the TCO will be equal to that of a vehicle subsidy.

**Figure 9** **Influence of purchase subsidies on TCO for medium petrol vehicles**




This graph shows at what level of purchase subsidies (or tax differentiation) the TCO of the various EVs will be equal to that of the comparable ICEs: for PHEVs, about 40% of the catalogue price would be needed, EREVs and FEVs would need about 45-50% of the catalogue price.

As these data are for the 2020 base case, the subsidies would need to be higher before that year if governments would aim to level the TCO to the ICE level – the cost difference is much higher in the short term, see Figure 3 – but can be slowly reduced over the years.

# 4 Business models for EVs

## 4.1 Introduction

As the cost structures of Internal Combustion Engine (ICE) vehicles vary considerably from that of Electric Vehicles (EVs), it is likely that different business models will develop as the cost structure evolves through technology developments and increases in production volumes.

ICE vehicles generally exhibit lower capital costs and higher operational (fuel) costs than EVs. The higher capital cost associated with EVs, largely due to the battery pack, contrasts with lower operational costs in the form of electricity and reduced maintenance costs in terms of engine, transmission and brake servicing.

There are concerns that current business models focused around vehicle ownership may not be optimal for EVs. The key issues influencing future business models are:

– There is currently some uncertainty, or perception of uncertainty, around the longevity of the battery units. The need to replace a significant component of the vehicle before the end of its useful life will mean that second hand EV value will be closely linked to battery condition. This raises large uncertainties regarding resale values and annual depreciation of the whole vehicle.

– Most car buyers are currently not accustomed to evaluating the full life-time costs of vehicle ownership. Customer focus remains largely on the purchase price, with less emphasis on assessing the operational costs. As such, the upfront cost seen by buyers of EVs will often be compared with that of ICE vehicles.

– Different actors are involved in the EV supply and operation chain, which opens up the likelihood of innovative business models evolving. For example, the market is characterised by having a greater number of smaller vehicle manufacturing companies, partnerships in new areas such as electronics and batteries, and, perhaps most significantly, electricity companies rather than oil companies providing the energy input.

– There is the need for investment in charging infrastructure, and perhaps even electricity infrastructure too as demand grows. Given the uncertainties over future market uptake and charging characteristics, these investment risks may influence the evolution of business models. In addition, the introduction of vehicle-to-grid (V2G) systems as a way to provide energy storage for the electricity system has implications for the battery life and, as such, is unlikely to be compatible with privately owned vehicle batteries.

- EVs reduced maintenance requirements will perhaps lead to a reduced ongoing role for vehicle manufacturers in servicing and maintenance. This could limit opportunities for downstream revenue generation and therefore have an influence on business models.

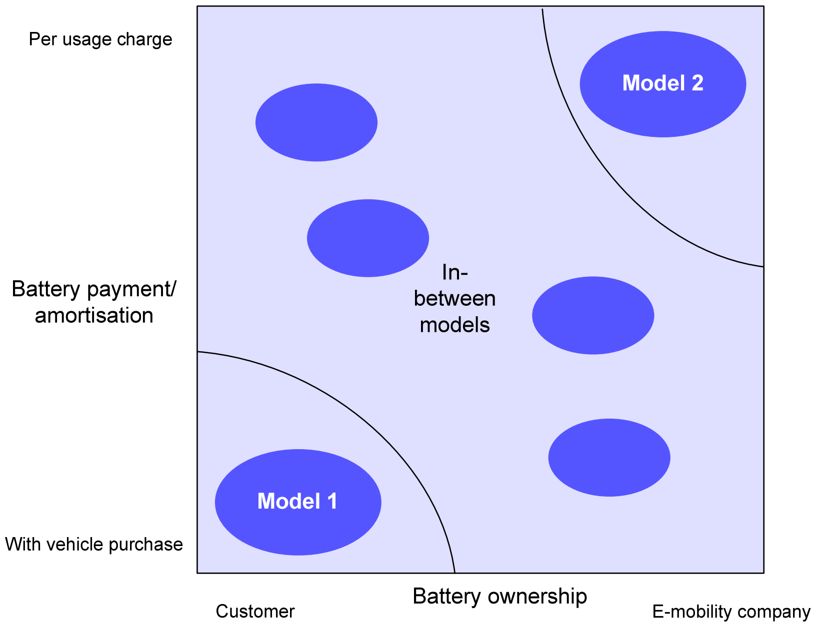
## 4.2 Possible business models for EVs

There is considerable uncertainty over what business models will evolve to help overcome the high cost, limited lifespan of vehicle batteries and the additional issues described above. Innovative business models are expected to develop in order to create a package that is attractive to customers. These are likely to vary depending on the specific support mechanisms and incentives available in any particular country.

Two distinct models of ownership are emerging as proposals along with a significant number of variations of 'in between' models. The models focus on different options for ownership of the battery. Model 1 is similar to the conventional vehicle ownership model and is based around the concept of customers purchasing the entire vehicle, including the battery. The vehicle is then charged at home or at a charging station using infrastructure established by an electricity company.

Model 2 involves an organisation that sells a mobility *service* rather than a *product*. The company owns the battery and sets up battery charging and battery exchange infrastructure and then charges the customer in order to cover the electricity consumption and battery amortisation.

**Figure 10 Potential ownership models**




Source: Ricardo, 2009.

Under Model 2, the customer sees a sale price that is competitive with that of an ICE vehicle. In addition, risk, or perceptions of risk, associated with the longevity of the batteries are overcome as the battery is considered separately to the rest of the vehicle, therefore removing some uncertainty from the second-hand car market.

The business model proposed by the organisation Better Place is a variation of Model 2. It is based around a model used in the mobile phone industry and involves the customer purchasing a vehicle at a subsidised price coupled with a subscription service that covers battery replacement, charging, and all running costs. A number of other 'in-between' models are likely to emerge that have elements of the two models. Specific products will likely develop and vary as a result of specific support measures and costs of vehicle and battery production. They are likely to vary on extent of ownership and level of service included in the per usage charge.

As well as the models of battery ownership described above, a move towards de-privatisation of mobility has already begun with internal combustion engine vehicles through car-club business models. Car-club models are generally based around an annual membership fee followed by hourly leasing charges that include fuel. This approach is growing in popularity particularly in urban areas and can help make Electric Vehicles attractive to customers by tackling the issues associated with battery cost and lifespan. A variation on this theme has been proposed by a UK consortium, Riversimple, which is currently developing a hydrogen fuel-cell based vehicle. This uses a mobility service-based business model whereby the whole vehicle, including tax, maintenance, insurance and all fuel is included in a service package that is covered by a fixed monthly and per-mile charge. The company's stated objective is to drive forward the development of technology that demonstrates longevity and low running costs rather than obsolescence and high running costs.

In summary, the exact nature of future EV ownership and usage models is uncertain. Successful models are likely to vary depending on the specific incentives available in a particular country. In the short-medium term at least, they are likely to focus around variations of Model 2, where batteries are excluded from the up-front cost of the vehicle and incorporated into an on-going usage-related service charge.

# 5 The future uptake of EVs from an economic perspective

## 5.1 Total cost of ownership comparison crucial to market uptake

The economics of the EVs will not be the only parameter that determines market uptake of these vehicles, but it is expected to be the main driver for EV sales.

The current vehicle market illustrates that the economics (purchase cost and TCO) is important for car buyers to base their purchase decision on. However, quite a number of other issues play a role as well, and consumers do not always opt for the most cost-efficient vehicle: vehicle appearance and status, performance characteristics such as engine power and acceleration, perceived risk/confidence in a brand, advice from and relationship with a specific dealer, size of the boot, comfort and appearance of the interior, etc. play an often important role as well.

Environmental characteristics of a vehicle are typically not very important factors to car buyers, unless there are financial incentives associated with these impacts (see, for example, the ADAC review of the $CO_2$ labelling of passenger cars that concluded that the impact was very low, and compare this to the significant impact of tax incentives for low-$CO_2$ cars on the sales of these vehicles in, for example the UK and NL[4]).

From a consumer/car buyer point of view, market uptake of EVs will therefore depend on quite a number of issues, such as purchase cost and total cost of ownership, car performance and comfort, driving range, charging time and charging infrastructure, etc. In addition, vehicle availability (i.e., how many EVs are on the market), information and communication (e.g., are EVs promoted by car dealers and can they provide sufficient information), vehicle attractiveness and perceived risk of the new technology will affect vehicle sales as well. The impact of environmental benefits can be expected to be limited.

Comparing the short-term non-financial features of EVs with that of comparable ICEs, one can conclude that there seem to be only few non-financial reasons for consumers to choose an EV:
- The performance of current FEVs (speed, acceleration) is, on average, comparable or less than that of ICEs.
- This driving range of FEVs is still much lower than that of ICEs.
- FEVs are typically small, as costs increase significantly with vehicle weight due to the increasing battery demand.
- There is not yet much data on the performance of PHEVs, but if may be assumed that the driving characteristics and design of the PHEVs are comparable to that of the conventional hybrid cars, they will be quite comparable to ICEs of the same size.

4 ADAC, Study on the effectiveness of Directive 1999/94/EC relating to the availability of consumer information on fuel economy and CO2 emissions in respect of the marketing of new passenger cars, March 2005

- There is even less data on EREVs, but it seems reasonable to assume that their characteristics are rather comparable to that of EVs, except for the driving range.
- The environmental impact of all types of EVs is less than that of ICEs, as direct vehicle emissions and noise are zero. The well-to-wheel greenhouse gas emissions depend on the energy source, but are on average significantly lower than that of ICEs, and may be (close to) zero in case renewable electricity is used.

This implies that at least in the short term, the performance, appearance, size, etc. of EVs will be comparable or less than that of their ICE counterparts. Only consumers that are attracted by the new technology and environmental benefits will be likely EV buyers as long as the TCO are higher than that of ICEs. The consumer group that is willing to accept higher cost for environmental benefits and innovation is typically relatively small[5].

It is therefore expected that competitive TCOs are a prerequisite for an increasing market share of these vehicles. Only if the TCO of one or more types of EV, in one or more parts of the market, becomes close to or reduces below that of comparable ICEs, the large bulk of car buyers in these markets will consider the investment.

**Cost and market uptake are closely linked – in two ways**

The EV market share depends strongly on the TCO: sales will only increase significantly once the TCO is comparable to that of ICEs.

However, vice versa is just as true: the cost of the EVs is expected to reduce once sales volumes increase. This is due to both economy of scale and the learning curve that is being followed.

This may lead to a potential stalemate - quite a common situation for any new technology - which may be resolved by government policies, as discussed in Chapter 3. Financial policies may (temporarily) reduce the TCO of the EVs, to ensure a market share increase. Over time, the financial incentive may then be reduced as the cost of the new technology reduces. Alternatively, regulation may demand from the market to produce and sell an increasing number of the new vehicle types. This can also be expected to lead to the cost reductions needed in the longer term.
A more detailed assessment of policy options will be provided in WP 7 of this project.

## 5.2 Potential market uptake

What does this mean for the future market uptake of EVs?

From the consumer point of view, the following can be concluded.
- Firstly, the market of PHEVs, EREVs and FEVs will remain very limited unless the TCO of the vehicles approaches that of ICEs. Until then, the market will be limited to a small group of innovators that are interested in the new technology, to local or regional (subsidised) pilot projects and perhaps government procurement projects.
  Government policies are needed to increase the (economic) attractiveness of EVs for larger groups of consumers. Based on the data we used in this

5 See, for example, the relatively low share of organic products in the overall sales of foodstuff, or the low share of aviation passengers that chooses to pay extra to offset their climate impact of their flight (only 7%, according to a recent survey in the UK).

report, the policies required are relatively limited for PHEVs, but more significant for FEVs and EREVs. These policies may be financial (subsidies, differentiated taxes, etc.) or non-financial (e.g., regulations)[6].
- Once the sales increase, costs of EVs are expected to reduce. Government incentives may then be reduced. More potential car buyers will be interested in these vehicles, as more vehicles are being developed, experience is gained and charging issues are being resolved.
  However, as long as the performance of EVs does not exceed that of ICEs, a significant market share can only be achieved if the TCO of EVs are comparable or lower than that of ICEs.
- Apart from cost, a large driving range, in combination with sufficient charging points and reasonable charging times, is expected to be the next important factor that determines the market uptake. If the range is limited and charging times are long, they will be attractive alternatives to ICE for only a relatively limited part of the potential market (city cars, second or third cars in a household). This criterion is mainly relevant for FEVs and, to a lesser extent, for EREVs.
- Car and battery manufacturers need to develop business models that make EVs attractive for consumers. This holds especially for FEVs and perhaps also for EREVs, as their batteries represent a relatively large value.

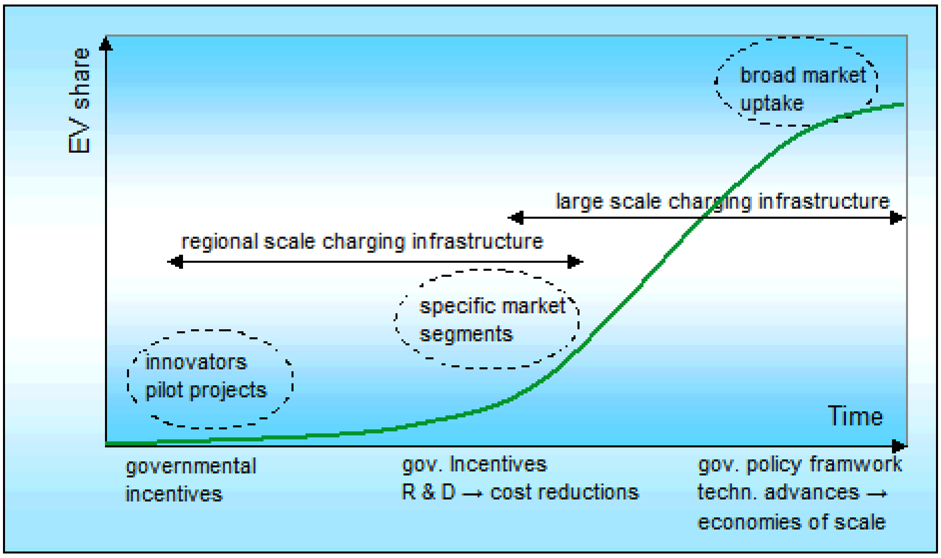
To achieve the larger market shares, both the car industry and the electricity sector are likely to play a major role. For example:
- The car industry needs to invest in (battery) R&D and EV production, develop new, profitable business models for the industry, and ensure an increasing, attractive supply of EVs for various parts of the market. These activities should result in cost reductions and increased performance of EVs.
- Together with other parties, such as the transmission grid operators, local governments, etc., the electricity sector needs to invest in charging infrastructure and develop a strategy on how to profitably integrate EVs in the future grid.

These developments can also be promoted by government policy.

These developments towards an increasing EV market share are shown in a road map in Figure 11.

[6] Note that a more detailed analysis is required to determine the actual incentives needed. The analysis here is for illustrational purposes only.

**Figure 11** **A schematic road map that illustrates how an increasing EV market share can be achieved**




In WP 6 of this project, the market uptake of the various types of EVs is assessed in more detail and quantitatively, using various scenarios.

# Annex A Assumptions for the calculations in this report

## A.1 Data needed for the calculations

Calculations of, for example, total cost of ownership of various vehicle types require quite a large amount of input data. In WP 6, a number of scenarios will be developed where these data are varied. In this report, we have included some results of calculations to illustrate

- The typical cost differences between the various vehicle types.
- Cost developments that might be expected in the coming years, and their impact on TCO.
- Sensitivity of the TCO to variations and uncertainties in various parameters.

For the various vehicle types, the following data are required for TCO calculations:

- Vehicle purchase cost: catalogue price, vehicle registration tax, VAT, in some cases minus EV purchase subsidies.
- Vehicle registration tax.
- Vehicle lifetime or residual value after x years.
- In case the batteries of Electric Vehicles have lower lifetime than the rest of the car (i.e., will need to be replaced after some years): battery cost and lifetime.
- Kilometres per vehicle, per year.
- Average fuel use and/or electricity use per kilometre.
- This depends on urban or non-urban use of the car.
- Electricity price.
- Fuel price.
- Annual insurance and maintenance cost.

To assess market uptake, other, non-financial performance data are also relevant. Especially range, and perhaps also acceleration, will also play a role in the choice of consumers to buy a specific vehicle type.

The uncertainty regarding the future development of these parameters is quite significant, as earlier reports show (WP 1 and WP 2). In addition, the variation between individual vehicles and owners can be expected to be large. This makes generic and representative calculations quite difficult.

In order to still provide some feeling for costs, sensitivities and trends, we have decided on a set of (realistic) input data for the calculations in this report, as shown in the following table. Please note that the results may be quite different if other parameters are assumed, as shown in the illustrative sensitivity analysis in section 2.2.

## A.2 Input data

Cost data can be found in Table 1, other vehicle and user data are depicted in Table 2. We have assumed no vehicle taxes or subsidies in this report, except VAT, and where explicitly stated.

**Table 1 Cost-related input data**

| | Type | Size | Fuel | 2010 | 2015 | 2020 | 2025 | 2030 | Based on |
|---|---|---|---|---|---|---|---|---|---|
| **Catalogue price (€)** | ICE | Small | Petrol | 9,000 | 9,450 | 9,923 | 10,419 | 10,940 | Assumptions, based on EU car prices report 2010 and 5% increase/5 years) |
| | ICE | Medium | Petrol | 13,000 | 13,650 | 14,333 | 15,049 | 15,802 | Assumptions, based on EU car prices report 2010 and 5% increase/5 years) |
| | ICE | Large | Petrol | 19,000 | 19,950 | 20,948 | 21,995 | 23,095 | Assumptions, based on EU car prices report 2010 and 5% increase/5 years) |
| | ICE | Small | Diesel | 9,000 | 9,450 | 9,923 | 10,419 | 10,940 | Assumptions, based on EU car prices report 2010 and 5% increase/5 years) |
| | ICE | Medium | Diesel | 13,000 | 13,650 | 14,333 | 15,049 | 15,802 | Assumptions, based on EU car prices report 2010 and 5% increase/5 years) |
| | ICE | Large | Diesel | 19,000 | 19,950 | 20,948 | 21,995 | 23,095 | Assumptions, based on EU car prices report 2010 and 5% increase/5 years) |
| | PHEV | Small | Petrol | 22,000 | 20,900 | 19,855 | 18,862 | 17,919 | Own estimates 2010, -5% every 5 years |
| | PHEV | Medium | Petrol | 26,000 | 24,700 | 23,465 | 22,292 | 21,177 | Own estimates 2010, -5% every 5 years |
| | PHEV | Large | Petrol | 38,000 | 36,100 | 34,295 | 32,580 | 30,951 | Own estimates 2010, -5% every 5 years |
| | PHEV | Small | Diesel | 22,000 | 20,900 | 19,855 | 18,862 | 17,919 | Own estimates 2010, -5% every 5 years |
| | PHEV | Medium | Diesel | 26,000 | 24,700 | 23,465 | 22,292 | 21,177 | Own estimates 2010, -5% every 5 years |
| | PHEV | Large | Diesel | 38,000 | 36,100 | 34,295 | 32,580 | 30,951 | Own estimates 2010, -5% every 5 years |
| | EREV | Small | Petrol | 26,000 | 24,700 | 23,465 | 22,292 | 21,177 | Own estimates 2010, -5% every 5 years |
| | EREV | Medium | Petrol | 35,000 | 33,250 | 31,588 | 30,008 | 28,508 | Own estimates 2010, -5% every 5 years |
| | EREV | Large | Petrol | 50,000 | 47,500 | 45,125 | 42,869 | 40,725 | Own estimates 2010, -5% every 5 years |
| | EREV | Small | Diesel | 26,000 | 24,700 | 23,465 | 22,292 | 21,177 | Own estimates 2010, -5% every 5 years |
| | EREV | Medium | Diesel | 35,000 | 33,250 | 31,588 | 30,008 | 28,508 | Own estimates 2010, -5% every 5 years |
| | EREV | Large | Diesel | 50,000 | 47,500 | 45,125 | 42,869 | 40,725 | Own estimates 2010, -5% every 5 years |
| | EV | Small | Electra | 28,000 | 26,600 | 25,270 | 24,007 | 22,806 | Own estimates 2010, -5% every 5 years |
| | EV | Medium | Electra | 35,000 | 33,250 | 31,588 | 30,008 | 28,508 | Own estimates 2010, -5% every 5 years |
| | EV | Large | Electra | 50,000 | 47,500 | 45,125 | 42,869 | 40,725 | Own estimates 2010, -5% every 5 years |
| **Residual value (€)** | All vehicles | | | 0 | | | | | 0 |
| **Fuel price petrol (€/l)** | | | | 1.35 | 1.52 | 1.70 | 1.87 | 2.05 | EU oil bulletin, July 2010, EU average incl. taxes, following oil price increase as predicted in EU Energy Trends to 2030 |
| **Fuel price diesel (€/l)** | | | | 1.18 | 1.33 | 1.49 | 1.64 | 1.79 | EU oil bulletin, July 2010, EU average incl. taxes, following oil price increase as predicted in EU Energy Trends to 2030 |
| **Electricty price (€/kWh)** | | | | 0,16 | 0,18 | 0,20 | 0,22 | 0,24 | Eurostat data 2010, following electricity price increase as predicted in EU Energy Trends to 2030 |

| | Type | Size | Fuel | 2010 | 2015 | 2020 | 2025 | 2030 | Based on |
|---|---|---|---|---|---|---|---|---|---|
| **Maintenance costs (€/year)** | ICE | Small | | 457 | 504,56 | 557,08 | 615,06 | 679,08 | CE Delft data |
| | ICE | Medium | | 914 | 1009,13 | 1114,16 | 1230,12 | 1358,16 | CE Delft data |
| | ICE | Large | | 1396 | 1541,30 | 1701,72 | 1878,83 | 2074,38 | CE Delft data |
| | PHEV | Small | | 209 | 230,75 | 254,77 | 281,29 | 310,56 | Based on ICEs, differentiated to size/cost ratio |
| | PHEV | Medium | | 418 | 461,51 | 509,54 | 562,57 | 621,13 | Based on ICEs, differentiated to size/cost ratio |
| | PHEV | Large | | 628 | 693,36 | 765,53 | 845,21 | 933,17 | Based on ICEs, differentiated to size/cost ratio |
| | EREV | Small | | 209 | 230,75 | 254,77 | 281,29 | 310,56 | Based on ICEs, differentiated to size/cost ratio |
| | EREV | Medium | | 418 | 461,51 | 509,54 | 562,57 | 621,13 | Based on ICEs, differentiated to size/cost ratio |
| | EREV | Large | | 628 | 693,36 | 765,53 | 845,21 | 933,17 | Based on ICEs, differentiated to size/cost ratio |
| | EV | Small | | 209 | 230,75 | 254,77 | 281,29 | 310,56 | Based on ICEs, differentiated to size/cost ratio |
| | EV | Medium | | 418 | 461,51 | 509,54 | 562,57 | 621,13 | Based on ICEs, differentiated to size/cost ratio |
| | EV | Large | | 628 | 693,36 | 765,53 | 845,21 | 933,17 | Based on ICEs, differentiated to size/cost ratio |
| **Insurance costs (€/year)** | ICE | Small | | 620 | 685 | 756 | 834 | 921 | CE Delft data |
| | ICE | Medium | | 1,240 | 1,369 | 1,512 | 1,669 | 1,843 | CE Delft data |
| | ICE | Large | | 1,958 | 2,162 | 2,387 | 2,635 | 2,909 | CE Delft data |
| | PHEV | Small | | 975 | 1,076 | 1,189 | 1,312 | 1,449 | Based on ICEs, differentiated to size/cost ratio |
| | PHEV | Medium | | 1,949 | 2,152 | 2,376 | 2,623 | 2,896 | Based on ICEs, differentiated to size/cost ratio |
| | PHEV | Large | | 2,924 | 3,228 | 3,564 | 3,935 | 4,345 | Based on ICEs, differentiated to size/cost ratio |
| | EREV | Small | | 975 | 1,076 | 1,189 | 1,312 | 1,449 | Based on ICEs, differentiated to size/cost ratio |
| | EREV | Medium | | 1,949 | 2,152 | 2,376 | 2,623 | 2,896 | Based on ICEs, differentiated to size/cost ratio |
| | EREV | Large | | 2,924 | 3,228 | 3,564 | 3,935 | 4,345 | Based on ICEs, differentiated to size/cost ratio |
| | EV | Small | | 975 | 1,076 | 1,189 | 1,312 | 1,449 | Based on ICEs, differentiated to size/cost ratio |
| | EV | Medium | | 1,949 | 2,152 | 2,376 | 2,623 | 2,896 | Based on ICEs, differentiated to size/cost ratio |
| | EV | Large | | 2,924 | 3,228 | 3,564 | 3,935 | 4,345 | Based on ICEs, differentiated to size/cost ratio |

**Table 2 Other input data**

| | Type | Size | Fuel | 2010 | 2015 | 2020 | 2025 | 2030 | Based on |
|---|---|---|---|---|---|---|---|---|---|
| **Vehicle lifetime (years)** | All vehicles | | | 14 | 14 | 14 | 14 | 14 | Own estimate |
| **Battery lifetime (years)** | PHEV | | | 10 | 11 | 12 | 13 | 14 | Own estimate, based on WP2 |
| | EREV | | | 10 | 11 | 12 | 13 | 14 | Own estimate, based on WP 2 |
| | FEV | | | 10 | 11 | 12 | 13 | 14 | Own estimate, based on WP 2 |
| **Vehicle kilometers (km/year)** | ICE | Small | Petrol | 8,245 | 8,050 | 7,854 | 7,926 | 7,998 | TREMOVE |
| | ICE | Medium | Petrol | 10,525 | 10,487 | 10,449 | 10,589 | 10,728 | TREMOVE |
| | ICE | Large | Petrol | 12,204 | 12,116 | 12,027 | 12,186 | 12,344 | TREMOVE |
| | ICE | Small | Diesel | 20,623 | 19,835 | 19,047 | 19,253 | 19,458 | TREMOVE |
| | ICE | Medium | Diesel | 20,749 | 20,120 | 19,491 | 19,549 | 19,607 | TREMOVE |
| | ICE | Large | Diesel | 22,484 | 22,006 | 21,528 | 21,630 | 21,731 | TREMOVE |
| | PHEV | Small | Petrol | 7,421 | 7,245 | 7,069 | 7,133 | 7,198 | 0.9 * ICE value |
| | PHEV | Medium | Petrol | 9,473 | 9,438 | 9,404 | 9,530 | 9,655 | 0.9 * ICE value |
| | PHEV | Large | Petrol | 10,984 | 10,904 | 10,824 | 10,967 | 11,110 | 0.9 * ICE value |
| | PHEV | Small | Diesel | 18,561 | 17,852 | 17,142 | 17,327 | 17,512 | 0.9 * ICE value |
| | PHEV | Medium | Diesel | 18,674 | 18,108 | 17,542 | 17,594 | 17,646 | 0.9 * ICE value |
| | PHEV | Large | Diesel | 20,236 | 19,805 | 19,375 | 19,467 | 19,558 | 0.9 * ICE value |
| | EREV | Small | Petrol | 7,008 | 6,842 | 6,676 | 6,737 | 6,798 | 0.85 * ICE value |
| | EREV | Medium | Petrol | 8,946 | 8,914 | 8,882 | 9,000 | 9,119 | 0.85 * ICE value |
| | EREV | Large | Petrol | 10,373 | 10,298 | 10,223 | 10,358 | 10,492 | 0.85 * ICE value |
| | EREV | Small | Diesel | 17,530 | 16,860 | 16,190 | 16,365 | 16,539 | 0.85 * ICE value |
| | EREV | Medium | Diesel | 17,637 | 17,102 | 16,567 | 16,617 | 16,666 | 0.85 * ICE value |
| | EREV | Large | Diesel | 19,111 | 18,705 | 18,299 | 18,385 | 18,471 | 0.85 * ICE value |
| | FEV | Small | Electra | 6,596 | 6,440 | 6,283 | 6,341 | 6,398 | 0.8 * ICE petrol value |
| | FEV | Medium | Electra | 8,420 | 8,390 | 8,359 | 8,471 | 8,582 | 0.8 * ICE petrol value |
| | FEV | Large | Electra | 9,763 | 9,692 | 9,622 | 9,748 | 9,875 | 0.8 * ICE petrol value |

| | Type | Size | Fuel | 2010 | 2015 | 2020 | 2025 | 2030 | Based on |
|---|---|---|---|---|---|---|---|---|---|
| **Fuel use (litre/100 km)** | ICE | Small | Petrol | 8.0 | 7.5 | 6.1 | 5.8 | 5.5 | 2010 data, 2010-2020 efficiency improvement somewhat above CO2 regulation, post 2020 improvement 5% every 5 years |
| | ICE | Medium | Petrol | 9.6 | 8.9 | 7.3 | 6.9 | 6.6 | " |
| | ICE | Large | Petrol | 12.0 | 11.2 | 9.2 | 8.7 | 8.3 | " |
| | ICE | Small | Diesel | 5.1 | 4.8 | 3.9 | 3.7 | 3.5 | " |
| | ICE | Medium | Diesel | 6.7 | 6.2 | 5.1 | 4.9 | 4.6 | " |
| | ICE | Large | Diesel | 9.2 | 8.6 | 7.0 | 6.7 | 6.3 | " |
| | PHEV | Small | Petrol | 3.2 | 3.0 | 2.4 | 1.7 | 1.7 | Assumption: 2010-2020: 0,4 * fuel use ICE; 2025-2030: 0,3 * fuel use ICE |
| | PHEV | Medium | Petrol | 3.8 | 3.6 | 2.9 | 2.1 | 2.0 | " |
| | PHEV | Large | Petrol | 4.8 | 4.5 | 3.7 | 2.6 | 2.5 | " |
| | PHEV | Small | Diesel | 2.1 | 1.9 | 1.6 | 1.1 | 1.1 | " |
| | PHEV | Medium | Diesel | 2.7 | 2.5 | 2.0 | 1.5 | 1.4 | " |
| | PHEV | Large | Diesel | 3.7 | 3.4 | 2.8 | 2.0 | 1.9 | " |
| | EREV | Small | Petrol | 2.4 | 2.2 | 1.8 | 1.2 | 1.1 | Assumption: 2010-2020: 0,3 * fuel use ICE; 2025-2030: 0,2 * fuel use ICE |
| | EREV | Medium | Petrol | 2.9 | 2.7 | 2.2 | 1.4 | 1.3 | " |
| | EREV | Large | Petrol | 3.6 | 3.4 | 2.8 | 1.7 | 1.7 | " |
| | EREV | Small | Diesel | 1.5 | 1.4 | 1.2 | 0.7 | 0.7 | " |
| | EREV | Medium | Diesel | 2.0 | 1.9 | 1.5 | 1.0 | 0.9 | " |
| | EREV | Large | Diesel | 2.8 | 2.6 | 2.1 | 1.3 | 1.3 | " |
| | FEV | All | | 0 | 0 | 0 | 0 | 0 | No fuel use |

| | Type | Size | Fuel | 2010 | 2015 | 2020 | 2025 | 2030 | Based on |
|---|---|---|---|---|---|---|---|---|---|
| Electricity use (kWh/100 km) | **ICE** | **All** | | **0** | **0** | **0** | **0** | **0** | **No electricity use** |
| | PHEV | Small | | 15.0 | 14.3 | 13.5 | 15.0 | 14.3 | Assumption: 2010-2020: 0,6 * electricity use_EV; 2025-2030: 0,7 |
| | PHEV | Medium | | 17.4 | 16.5 | 15.7 | 17.4 | 16.5 | “ |
| | PHEV | Large | | 19.8 | 18.8 | 17.9 | 19.8 | 18.8 | “ |
| | EREV | Small | | 17.5 | 16.6 | 15.8 | 17.1 | 16.3 | Assumption: 2010-2020: 0,7 * electricity use_EV; 2025-2030: 0,8 |
| | EREV | Medium | | 20.3 | 19.3 | 18.3 | 19.9 | 18.9 | Assumption: 2010-2020: 0,7 * electricity use_EV; 2025-2030: 0,8 |
| | EREV | Large | | 23.1 | 21.9 | 20.8 | 22.6 | 21.5 | Assumption: 2010-2020: 0,7 * electricity use_EV; 2025-2030: 0,8 |
| | FEV | Small | | 25.0 | 23.8 | 22.6 | 21.4 | 20.4 | Own estimate, 5% improvement every 5 years |
| | FEV | Medium | | 29.0 | 27.6 | 26.2 | 24.9 | 23.6 | Own estimate, 5% improvement every 5 years |
| | FEV | Large | | 33.0 | 31.4 | 29.8 | 28.3 | 26.9 | Own estimate, 5% improvement every 5 years |
| **Range (km)** | ICE | All | | 600 | 600 | 600 | 600 | 600 | 2020-2030: Ricardo/TNO, 2010-2020: own assumption |
| | PHEV | All | | 450 | 500 | 550 | 600 | 600 | 2020-2030: Ricardo/TNO, 2010-2020: own assumption |
| | EREV | All | | 450 | 450 | 450 | 450 | 450 | 2020-2030: Ricardo/TNO, 2010-2020: own assumption |
| | FEV | Small | | 120 | 120 | 150 | 200 | 250 | 2020-2030: Ricardo/TNO, 2010-2020: own assumption |
| | FEV | Medium | | 150 | 150 | 175 | 238 | 300 | 2020-2030: Ricardo/TNO, 2010-2020: own assumption |
| | FEV | Large | | 175 | 175 | 200 | 275 | 350 | 2020-2030: Ricardo/TNO, 2010-2020: own assumption |