TØI report 1421/2015

Nils Fearnley
Paul Pfaffenbichler
Erik Figenbaum
Reinhard Jellinek

COMPETT

Electromobility+

Institute of Transport Economics
Norwegian Centre for Transport Research

Vejdirektoratet
Danish Road Directorate

AUSTRIAN ENERGY AGENCY

# E-vehicle policies and incentives - assessment and recommendations

TØI Report
1421/2015

# E-vehicle policies and incentives - assessment and recommendations

Nils Fearnley, Paul Pfaffenbichler, Erik Figenbaum and Reinhard Jellinek



ISSN 0808-1190
ISBN 978-82-480-1644-1 Electronic version

Oslo, august 2015

**Title:** E-vehicle policies and incentives - assessment and recommendations

**Tittel:** Elbilinsentiver – evaluering og anbefalinger

**Author(s):** Nils Fearnley, Paul Pfaffenbichler, Erik Figenbaum, Reinhard Jellinek

**Forfattere:** Nils Fearnley, Paul Pfaffenbichler, Erik Figenbaum, Reinhard Jellinek

| | | | |
|---|---|---|---|
| **Date:** | 08.2015 | **Dato:** | 08.2015 |
| **TØI report:** | 1421/2015 | **TØI rapport:** | 1421/2015 |
| **Pages** | 109 | **Sider** | 109 |
| **ISBN Electronic:** | 978-82-480-1644-1 | **ISBN Elektronisk:** | 978-82-480-1644-1 |
| **ISSN** | 0808-1190 | **ISSN** | 0808-1190 |
| **Financed by:** | EU 7th FP (Electromobility+)<br>The Research Council of Norway<br>Transnova | **Finansieringskilde:** | EU 7th FP (Electromobility+)<br>Norges forskningsråd<br>Transnova |
| **Project:** | 3826 - Compett | **Prosjekt:** | 3826 - Compett |
| **Project manager:** | Erik Figenbaum | **Prosjektleder:** | Erik Figenbaum |
| **Quality manager:** | Frode Longva | **Kvalitetsansvarlig:** | Frode Longva |
| **Key words:** | Benefits<br>Cost<br>Electromobility<br>Incentives | **Emneord:** | Nytte<br>Kostnader<br>Elbil<br>Insentiv |

**Summary:**

The report describes incentives for electromobility across Europe. A dynamic car fleet and propulsion technology model, SERAPIS, is built and used as basis for economic assessments of different e-vehicle incentives in Norway and Austria. A scenario analysis illustrates the importance of the supply side and technological development.

**Sammendrag:**

Rapporten beskriver insentiver for elektromobilitet i Europa. En dynamisk modell for bilhold og fremdriftsteknologi, SERAPIS, er videreutviklet og benyttes som grunnlag for å analysere elbilinsentiver og deres konsekvenser for elbilandeler, offentlige inntekter, miljø, mv. for Norge og Østerrike. En scenarioanalyse understreker betydningen av tilbudssiden og teknologiutvikling.

Language of report: English

*This report is available only in electronic version.*

*Rapporten utgis kun i elektronisk utgave.*

*Institute of Transport Economics*
*Gaustadalleen 21, 0349 Oslo, Norway*
*Telefon 22 57 38 00 - www.toi.no*

*Transportøkonomisk Institutt*
*Gaustadalleen 21, 0349 Oslo*
*Telefon 22 57 38 00 - www.toi.no*

# Preface

This report is deliverable 5 of the COMPETT project (Competitive Electric Town Transport), financed jointly by the EU's 7th FP (Electromobility+ programme), Transnova, the Research Council of Norway (RCN), the Austrian Research Promotion Agency (FFG) of Austria and the Ministry of Science, Innovation and Higher Education in Denmark.

COMPETT is a co-operation between the Institute of Transport Economics (TØI) in Norway, The Austrian Energy Agency (AEA), the University College Buskerud and Vestfold in Norway, Kongsberg Innovation in Norway and the Danish Road Directorate (DRD).

The objective of COMPETT is to promote the use of electric vehicles, particularly with focus on private passenger cars. The main question to be answered is: "How can electric vehicles come in to use to a greater degree?" More information about the project and all project results are presented on the website www.compett.org.

This deliverable is the result of COMPETT's Work Package 5 "Economic assessment of incentives for e-vehicles and implementation". This Work Package has built a dynamic car fleet and propulsion technology model, which has formed the basis to carry out economic assessments of different e-vehicle incentives.

Work Package leader Nils Fearnley has been the overall responsible for this deliverable. The Serapis model is developed by Paul Pfaffenbichler, who also took care of the Austrian data and analyses. Erik Figenbaum and Reinhard Jellinek have contributed with data and inputs to the analyses and to planning and interpretations of analyses. Following COMPETT's quality assurance guidelines, COMPETT partners G. Maarten Bonnema and Lykke Møller Iversen have reviewed the report. Formal Quality Assurance has been performed by Robin Krutak of the Austrian Energy Agency.

Oslo, August 2015
Institute of Transport Economics

| | |
|---|---|
| *Gunnar Lindberg*<br>*Managing director* | *Frode Longva*<br>*Research director* |

# Table of Contents:

**Acronyms and terminology**

| | |
|---|---|
| BEV | Battery electric vehicle – pure battery electric vehicle |
| BRN | Norwegian model base run – a theoretical situation with no EV incentives |
| BRA | Austrian model base run – a theoretical situation with no EV incentives |
| EREV | Extended range electric vehicles |
| EV | Electric vehicle – any kind of recharge electric vehicle |
| HEV | Hybrid electric vehicle – vehicle having both a common combustion engine and an electric motor |
| ICE | Internal combustion engine vehicle – vehicle using petrol or diesel fuel |
| NOK | Norwegian currency, “krone”. As of 25 June 2015, NOK 1 = € 0.11 and €1=NOK 8.74 |
| OEM | Original Equipment Manufacturer |
| OLS | Ordinary least squares regression |
| PHEV | Plug-in hybrid electric vehicle – hybrid vehicle which can be charged from the grid and use that electricity for propulsion in pure electric mode |
| VAT | Value added tax |

Institute of Transport Economics
Norwegian Centre for Transport Research

Executive summary:

# E-vehicle policies and incentives - assessment and recommendations

*TØI Report 1421/2015*
*Author(s): Nils Fearnley, Paul Pfaffenbichler, Erik Figenbaum and Reinhard Jellinek*
*Oslo 2015, 109 pages Norwegian language*

*This report documents state and regional electromobility incentives across Europe with strong emphasis on 1) battery electric vehicle (BEV) incentives and 2) the two countries Austria and Norway. We find that electromobility incentives can be effective in growing e-vehicle markets, but a substantial growth comes only at a high budget cost for the government. Only the Norwegian bus lane access for BEVs stands out as a low cost incentive (ignoring congestion costs to bus operators and their passengers). Free BEV parking is found to be the least cost effective policy. It has no significant impact on BEV sales and is costly. A scenario analysis emphasises the importance of the supply side, or technology improvements, for a thriving e-vehicle market.*

The report identifies a strong and clear relationship between the amount and intensity–i.e. money used–of incentives on the one side, and market penetration of BEVs on the other side. Figure S.1 illustrates how the user value of local benefits bus lane access, free ferries, free parking, and toll road exemptions are associated with BEV market penetration in Norway.

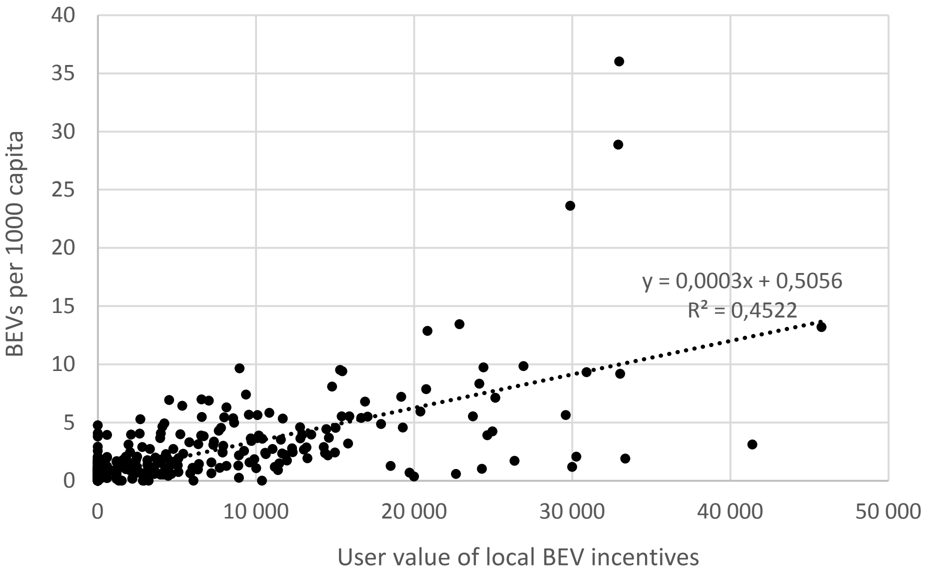



*Figure S.1: BEVs per 1,000 capita in Norwegian municipalities, compared with the annual value (NOK) of local benefits. Values are based on annual money and time savings as reported by BEV owners. NOK 1 = EUR 0.12 at time of survey.*

In addition to these local incentives, come the national incentives of VAT and registration tax exemption and reduced annual tax. Incentives that directly reduce the purchase price of an EV are particularly effective in growing the BEV market. In Norway, also bus lane access contributes considerably to BEV sales.

National BEV incentives appear to out-perform local and regional incentives and are, usually, appreciated by the market as more stable and predictable. The fact that Norwegian policies enjoy state backing and apply to all parts of the country has probably reduced the perceived risk for market players, like car importers. However, the great benefit of local incentives lie in the way they can be tailored to local circumstance: access to bus lanes can have huge effects on BEV sales in some areas; in other places, free ferry rides have large effect. This fact highlights an important aspect of the Norwegian success. Since the users have different needs, national and local stakeholders and the industry should use a broad package of incentives in marketing this new technology in order to speed up its diffusion. In total, the package of incentives sums to a forceful and reinforcing combination market stimuli.

Compared with Norway, Austria has followed a path which relies less on market mechanisms and which is more top-down in the sense that much responsibility and initiative lies with the e-mobility regions rather than general incentives in the market. So far, this strategy has not resulted in any significant market expansion of EVs.

Figure S.2 illustrates the modelled individual and combined contributions of BEV incentives in Norway in 2020. On the x-axis, incentives increase the Norwegian BEV stock and on the y-axis, they contribute to government net revenue losses. Budget costs are the net effect on fuel and electricity taxes, VAT, registration tax, annual tax, road charging, and parking fees. In terms of fiscal cost effectiveness, access to bus lanes generates most BEVs per public budget cost. However, the effect is limited to just under 20,000 vehicles. Larger market penetration requires additional (and less cost effective) incentives. Free parking is the least cost effective policy.

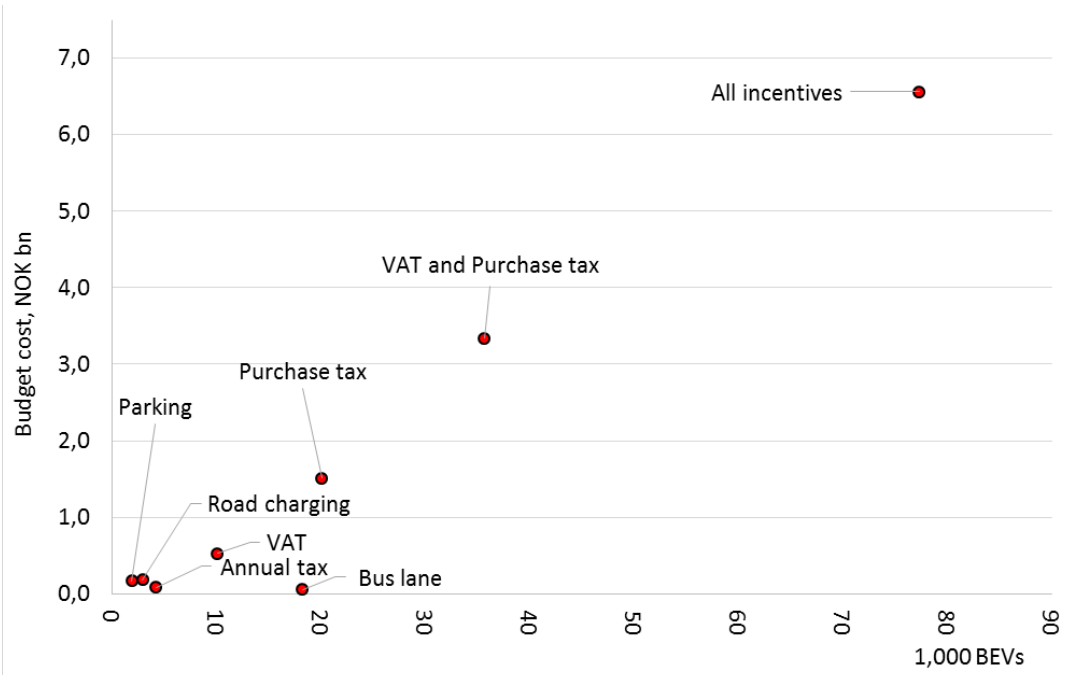



*Figure S.2: Effects in 2020 of individual BEV incentives: Budget cost (in NOK) and effect in terms of BEV stock generated (in thousands), and a linear trend.*

In terms of $CO_2$ emission reductions, the government budget cost per tonne of $CO_2$ follows the same pattern: bus lane access is the most cost effective policy, whereas free BEV parking is the least cost effective policy.

The fact that BEV incentives strongly affect government revenues, suggests that an effective package of BEV incentives will be perceived as costly for the government. However, it is possible to recoup these revenues by relatively modest adjustments to the car taxation regime. The following adjustments to a likely future base scenario make the BEV incentives revenue-neutral: An annual real increase in the annual tax of 2.5 percent; about one percent higher fuel tax increases per year; and a gradual steepening of the car registration tax. Together, these adjustments secure a stable stream of government revenues despite the presence of strong and costly BEV incentives.

*In this way, substantial domestic $CO_2$ reductions can be achieved at no government cost.* However, the package of BEV carrots and conventionally fuelled car sticks cause considerable transfers from fuel car owners to BEV owners.

A scenario assessment identifies two main dimensions that affect the BEV market: 1) technology and supply-side factors, and 2) policy factors. In Norway as well as in Austria, the role of supply side developments is particularly important. The main contribution of favourable BEV policies is to support and speed up technological development. This fact suggests free rider problems: Countries with generous policies bear a high cost, while any country can reap the benefits of technological advances.

# 1 Introduction

The 2011 EU White Paper on Transport sets ambitious goals for phasing out conventionally fuelled cars in cities. Take-up and expansion of electric vehicles (e-vehicles, or electromobility) are one way to achieve this, as proposed by, e.g., the European Green Cars Initiative, the EU Action Plan on Urban Mobility, and the European alternative fuels strategy. The EU regulation 449/2009 specifies the average $CO_2$-emission of new vehicles to go below 130 g/km in 2015 and 95 g/km before 2021. Vehicles emitting less than 50 g/km will count as more than one vehicle, called supercredits. The EU is currently considering to tighten the limit after 2021. Although several countries have set sales and stock targets for electrification as part of their climate policy, the number of such vehicles in use is very limited in most countries. A report from the Electric Vehicles Initiative (2013) shows that their 15 member states have an electric vehicle stock of 0.02 percent while the target is 2 percent. This discrepancy is part of the background for ERA-net's Electromobility+ programme, which funds 20 European projects on this topic. COMPETT, "Competitive Electric Town Transport", is one of these projects. A key reference for this report is Figenbaum et al. (2015, forthcoming).

In this report, the term electric vehicle (EV) comprises battery electric vehicles (BEV) that are only powered by electricity, extended range electric vehicles (EREV), hybrid electrical vehicles (HEV), and plug-in hybrid vehicles (PHEV). The most widely used alternative is the ordinary internal combustion engine (ICE) vehicle, which usually runs on conventional fuels like petrol and diesel.

The recent years have seen substantial developments in the EV markets globally. The price of EVs has gone significantly down in real prices. Figure 1.1 illustrates how net prices have fallen steadily during the period 2009-14 for two typical BEV classes, mini vehicles as represented by the Think City/Mitsubishi i-Miev, which are of relatively equivalent category, and the compact Nissan Leaf. This development in price reflects a real development in prices of relevance, since BEVs have been exempted from Norwegian VAT and registration tax throughout this period. At the same time, the new models are better equipped and enjoy better warranties and dealer coverage. Further, a large variation of vehicles is now available. Back in 2009, there was only one real battery passenger car alternative in the Norwegian market, the "Think". The Tesla Roadster was also available but only a few were sold.

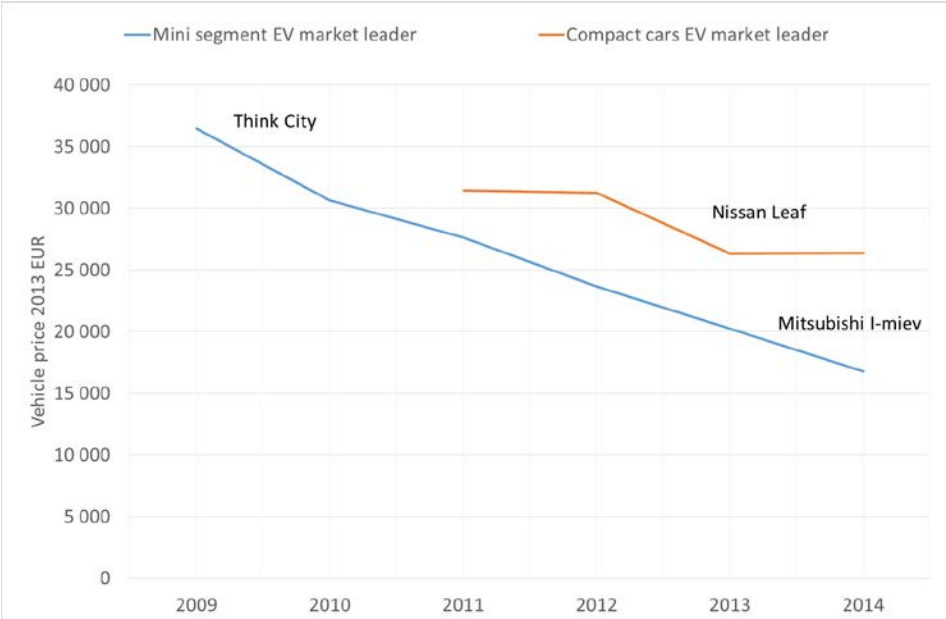



*Figure 1.1: Typical price development of EVs in the Norwegian market. Net costs, fixed 2013 prices. (NOK 1 = €0.12 at time of writing)*

The introduction of a new technology and departure from ICEs could require large subsidies and investments as well as a political commitment (Ramjerdi and Fearnley, 2014), a situation more generally found for environmental technology (Jacobsen and Bergek, 2011; van den Bergh et al., 2011).

This report is concerned with incentives for the take-up and use of passenger e-vehicles (registration class M1) that are in place in different European countries and to what extent they affect market shares of vehicle sales and vehicle fleets. A focus is placed on the user value of individual incentives, their effect on BEV sales, their impact on public budgets and their cost effectiveness (defined in chapter 4.4 as number of BEVs generated per unit of public spending). It is outside of this report's scope to consider the consequences on the total level of traffic, nor to present a full economic welfare assessment of EV policies.

Norway currently stands out as the world's largest e-vehicle market as measured per capita. Therefore, Norwegian policies and their impact are of particular interest for this report. The analysis includes socio-economic factors as well as convenience and time savings due to e-vehicle policies. On the government side, the fiscal effects of e-vehicle incentives are significant. The cost of lifting a new technology into the market is considerable. Therefore, this report also highlights the need for a strategy for a phase-out of EV policies once the market has taken off.

In this report, we investigate policy options for increasing the share of BEVs. We concentrate particularly on the Norwegian situation as well as on Austria.

This report brings in, and combines, analyses of two web surveys among e-vehicle owners and non-e-vehicle owners, respectively, and an analysis of socio-economic factors, including convenience and time savings due to e-vehicle incentives, and how they affect EV uptake. It also builds on work within the COMPETT project to further develop a dynamic car fleet and propulsion technology model called Serapis (Pfaffenbichler et al. 2009; Renner et al. 2010; Frey et al. 2011; Pfaffenbichler et al. 2012). Serapis produces time series data about the number of vehicles by propulsion technology as a result of policy interventions like EV incentives, and calculates environmental and economic indicators for the evaluation of these policies.

This report is organised as follows. Chapter 2 gives an overview of European incentives and market shares. Chapter 3 introduces the Serapis model including its procedures for calibration and estimation. In chapter 4, we look at effectiveness and budget cost effectiveness of various EV incentives from a government budget point of view, which also acknowledges the need for governments to maintain fiscal revenues. Electromobility scenarios are developed and assessed in chapter 5. Chapter 6 addresses implementation of EV incentives and, importantly because of their high cost, the need for a strategy for phase-out of incentives before chapter 7 wraps up the report with summary, conclusions and policy recommendations.

# 2 European EV incentives

## 2.1 European status: market shares and incentives in place

The market for EVs has increased between 2010 and 2014 in most countries, but most profoundly in Norway, which currently is the European leader in EV adoption both in absolute numbers and in market share (figure 2.1 for BEVs and table 2.1 for all EVs). The market share of sales in the first half of 2014 was close to 13 percent in Norway, with the Netherlands and Estonia as the next countries, relatively far behind with market shares around 1 percent.

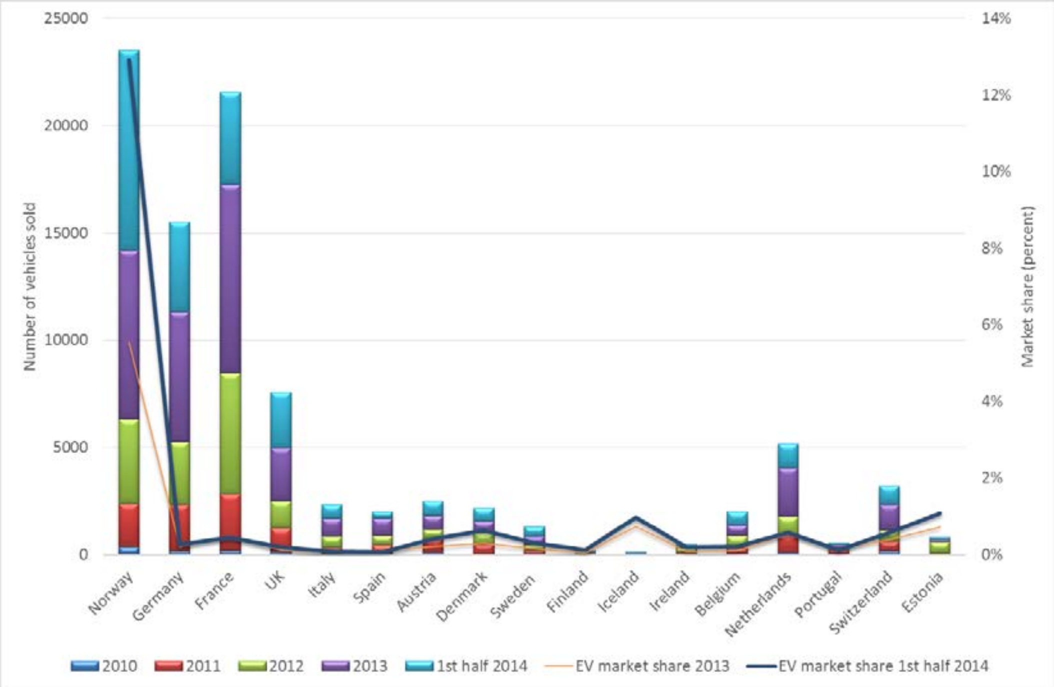



*Figure 2.1: 2010-2013 BEV total sales (bars; left axis) and share of total sales (lines; right axis) in different countries. Sources: ACEA, local statistical services, internet fora, and industry monitors.*

Table 2.1 also presents the various EV incentives that are in place in a selection of European countries. The table is an approximation and a snapshot only, because several subsidies come and go, are only in place in certain regions or cities, are limited in time and value, and so on. The most widely used incentives in this selection of European countries are registration tax exemption, annual vehicle tax exemption and purchase subsidy/grant. In some countries, these are rebates rather than exemptions. It is worth noting that the highest market shares, especially in Norway and Iceland, are associated with non-financial incentives as well, like bus lane access, and non-tax incentives like free street parking. This observation supports the findings of Moch and Yang (2014) who compare incentives and market share in different countries and show that there are limits to what can be obtained by fiscal incentives alone.

There is a clear tendency in table 2.1 that more incentives are associated with higher EV market shares. Norway, in particular, stands out with the highest market share and the widest array of incentives. These are presented and discussed in greater detail below.

*Table 2.1: EV market shares and incentives in a selection of countries. Sources: European Union (2013), Wikipedia (2014), Shahan (2014) and ACEA (2014)*[1]

| Country | EV market share 2013 | Purchase grant/ subsidy | Registration tax exemption | Annual tax rebate/ exemption | Free street parking | Free toll roads | Bus lane access | VAT exemption | Other incentives |
|---|---|---|---|---|---|---|---|---|---|
| Norway | 6,10 | | x | x | x | x | x | x | |
| Netherlands | 5,55 | | x | x | (x) | | | | |
| Iceland | 0,94 | | | | x | | | x | |
| France | 0,83 | x | | | | | | | x |
| Estonia | 0,73 | | x | | | | | | x |
| Sweden | 0,71 | x | x | x | | | | | x |
| Switzerland | 0,44 | | x | x | | | | | |
| Denmark | 0,29 | | x | | (x) | | | | |
| Austria | 0,26 | x | x | x | (x) | | | | |
| Germany | 0,23 | | | x | | | | | |
| Portugal | 0,21 | x | x | x | | | | | |
| Spain | 0,18 | x | | | | | | | |
| Belgium | 0,17 | | x | (x) | | | | | x |
| Finland | 0,17 | | x | | | | | | |
| United Kingdom | 0,17 | x | | | | London CC | | | |
| Italy | 0,11 | | | x | | | | | |
| Ireland | 0,08 | x | | | | | | | |
| Czech Republic | N/A | | | x | | | | | |
| Greece | N/A | | x | x | | | | | x |
| Latvia | N/A | | x | | | | | | |
| Luxembourg | N/A | x | | | | | | | |
| Hungary | N/A | | x | x | | | | | |
| Romania | N/A | x | x | | | | | | |

## 2.2 Norwegian incentives and market shares

### 2.2.1 Incentives and status

Norway has the worldwide largest number of EVs per capita. The policy basis leading to this achievement has evolved over the years. In the early 1990s, the target of the policies was to make it possible to test and evaluate environmental technology by removing the vehicle purchase tax (Ministry of Finance, 1989). Cities soon wanted faster market development and the exemption from toll roads (in the beginning around Oslo) was introduced in 1997 and free parking in 1999 (Asphjell et al., 2013). In the period around the turn of the century the focus shifted towards supporting the emerging national electric vehicle industry, such as Think, which was acquired by Ford in 1999 (Hoogma et al., 2002). The exemption from VAT was introduced in order to help boost the home market (Budget agreement, 2001). In 2003, EVs gained access to the bus lanes around Oslo. The Norwegian Public Roads Administration wanted to remove private minibuses from the bus lane, thereby opening up a

[1] For some countries, these sources are in conflict. The table may have errors.

window of opportunity for EV lobbyists (Figenbaum et al., 2013). However, Think was unable to produce EVs, as Ford had sold the company. PureMobility, another Norwegian company, produced a small hand-built EV. Second-hand EVs were imported from countries that had abandoned their EV activities, such as France and the US, to meet the demand from bus lane users in the Oslo area (Figenbaum et al., 2013). Towards 2010, the EV policy focus also shifted towards reducing greenhouse gas emissions. Think was reborn and a support program for charging infrastructure and reduced rates on ferries was introduced in 2009. The aftermath of the financial crisis in 2009 led to a downfall of the Norwegian EV industry. Original Equipment Manufacturers (OEMs) launching their EVs from late 2010, could exploit two decades of efforts to establish EV incentives. The sharp increase in the fleet after 2010 is due to the launch of more and more OEM EVs into the market. The prices of EVs were at the same time going down, cf. figure 1.1. The developments in incentives, supply side and market penetration are combined in figure 2.2.

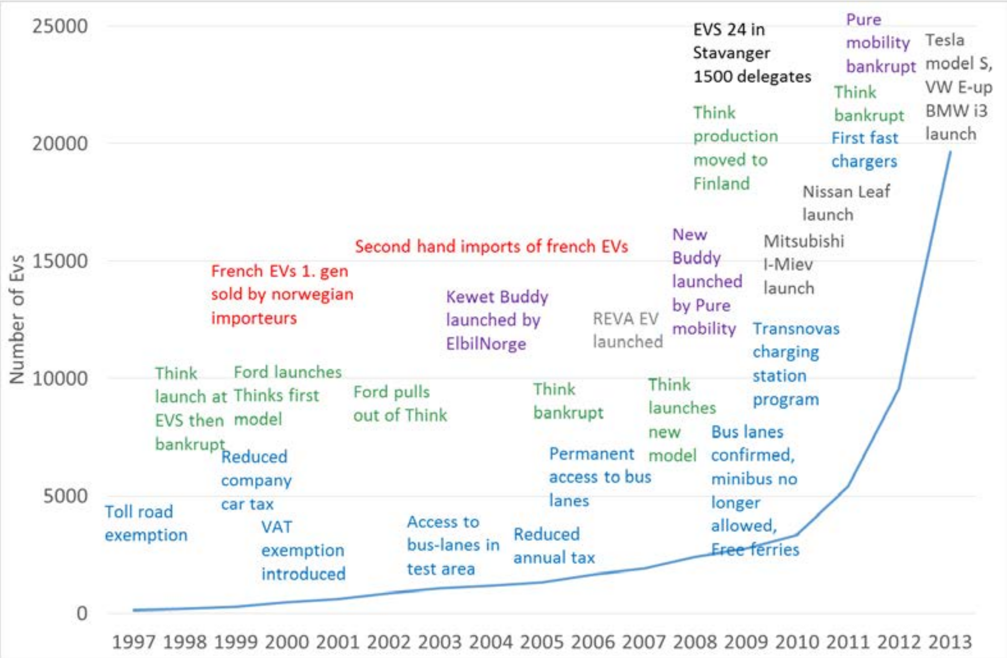



*Figure 2.2: Developments of the EV fleet and in EV policies in Norway 1997-2013.*

When looking at the different Norwegian EV incentives, Figenbaum et al. (2014) used a division into three different categories of incentives: 1) fiscal; 2) direct; and 3) incentives giving relative advantages to compensate for drawbacks. This again is based on Figenbaum and Kolbenstvedt (2013). Parts of their elaboration is reproduced in table 2.2.

*Table 2.2: Figenbaum et al. (2014)'s evaluation of EV Norwegian incentives*

| Incentives | Introduced | Importance for uptake |
|---|---|---|
| Fiscal incentives - reduce purchase price/yearly cost | | |
| Exemption from registration tax | 1990/1996 | + |
| VAT exemption | 2001 | ++ |
| Reduced annual vehicle license fee | 1996/2004 | + |
| Reduced taxable benefit on company cars | 2000 | 0 |
| Direct subsidies to users – reduce usage costs and range challenges | | |
| Free toll roads | 1997 | ++ |
| Reduced rates on ferries | 2009 | 0 |
| Financial support for charging stations | 2009 | + |
| Fast charge stations | 2011 | + |
| Reduction of time costs and giving relative advantages | | |
| Access to bus lanes | 2003/2005 | ++ |
| Free parking | 1999 | + |

++ Crucial factor in explaining the EV market development,

\+ Less important factor or only important in some market niches

0 Factor which up to 2013 was not considered important

Norway is in many ways unique. It is wealthy, distances are long, it is mountainous, and winters are cold. While the former might promote EV usage, the latter three limit their application. Expansion outside of the major urban areas and commuting distances necessitates a suitable charging infrastructure. This is under (rapid) development led by both a nationally funded organisation (Transnova, a government body, which provides financial support to the establishment of public charging facilities; in 2015 Transnova merged with ENOVA) and local and private initiatives. As of June 2015, there are about 1,700 charging stations with 6,500 charging points of which 5,600 are public (nobil.no) across Norway. Special attention has been paid to developing fast chargers along the main transnational routes. This means that, despite the long distances, a cross-Norway drive is a possibility for most EVs, albeit requiring frequent charging stops.

### 2.2.2 Value of Norwegian local incentives

As part of the COMPETT project (WP4; Figenbaum et al., 2014), Norwegian EV owners were asked to identify the various *local user benefits* they enjoy when using their EVs. From this, Figenbaum et al (2015) calculated the annual average economic value of the incentives for the average EV driver. In table 2.3, the results have been scaled up to the size of the EV fleet as of April 2014, 25 000 vehicles. The economic value is €1,900 per vehicle and €48m for the total fleet that year. The result rests on the following assumptions:

- Based on the National Value of Time study, the value of time saved in queue due to the access to bus lanes on rush hour trips to work is NOK 280 per hour. The time saved per average user is based on the users assessment of the time saving.

- The value of the toll-road exemption is estimated by combining respondents' information about usage of toll-road, and the cost of the toll-road that they could be using, given maximum available rebates (which daily commuters will be entitled to). This approach is associated with some uncertainties. The average reflects the fact that not all EV owners pass toll roads. The regional differences are very large.
- The value of free parking is calculated via a weighted average of EV owners' stated weekly saving. This total figure corresponds well with findings of another study of this incentive (Fearnley, 2014)
- The reduced ferry price is a very crude estimate based on the ferry rate savings in the municipality the owner belongs to and how they responded in the questionnaire about this incentive's importance

*Table 2.3: Calculated average values per year of different local incentives per car and for total fleet in Norway Total fleet in Norway = 25 000 EV's in April 2014. Euros/year. Source: Figenbaum et al 2014.*

| Incentive | Value per car Euros/year | Value for EV fleet million Euros/year |
|---|---|---|
| Bus lane | 940 | 24 |
| Toll-road | 434 | 11 |
| Free parking | 398 | 10 |
| Free ferries | 145 | 4 |
| Total | 1 928 | 48 |

There are large regional differences in the advantages the users report from the various incentives. Bus lane access is emphasised in the Oslo-region, where resulting time savings are large (up to 30 minutes). Reduced ferry rates are more important in the coastal regions. The share of EV owners using both free toll road and access to bus lane more than twice a week when driving to work is only 33 percent. In addition, 26 percent uses toll roads only and 6% bus lanes only. EV owners seem to live and work in areas where they can use these facilities to a larger extent than the average car owner. However, the EV market is spreading into smaller towns and even in areas where no local incentives are at work. This fact suggests that incentives are not the only factor influencing the EV-buyer's choice, but are efficient in raising awareness and getting the market started.

Bus lane access will be a benefit to society as long as spare capacity is used without delaying buses. The toll-road incentive leads to lower income for the toll-road company. This company has a loan that is used to build roads and to support public transport in different ways. When income is reduced because of BEV exemptions, either the rate per paying vehicle must be increased, or the period of payment prolonged. In both cases there is a cross subsidy between payers and non-payers. If fewer pay, the rate per paying vehicle is increased or the subsidy from the province or government must increase. Free ferries for BEVs are different from free toll-roads in that the *drivers* still have to pay even if the vehicle is exempted. Free parking means that municipal income per parking space is reduced, that fewer parking spaces are available to other paying users, and reduced circulation. The cost of the free parking incentive for municipalities may therefore exceed the value of the incentive for EV owners.

In figure 2.3, each of the 428 Norwegian local municipalities is recorded with BEV market penetration (BEVs per 1000 capita; y-axis) and a calculation of the value of local EV incentives (x-axis), which every BEV owner enjoys. Some municipalities enjoy zero or hardly any local incentives (no bus lanes or toll roads, parking is already free, and so on.). In others, the local value can be substantial, due to, e.g., large travel time savings from bus lane access, toll road exemptions and ferry rebates. The outliers with very high market penetration are wealthy areas with especially high benefit from access to bus lanes, or small islands with costly toll road connections to the mainland. In the other end of the spectrum, the outliers with relatively low market shares despite high value of incentives are rural areas where access to the nearest city (Trondheim) is costly. Assumingly, BEV incentives cannot compensate for the troublesome distances and ferry crossing there. The linear trend line has a fairly good level of fit only from this bivariate relationship, which suggests that BEV market shares depend strongly on local incentives. Note that general incentives of purchase tax and VAT exemption come in addition. If the outliers are excluded then the slope and $R^2$ of the trend line remain relatively unchanged.

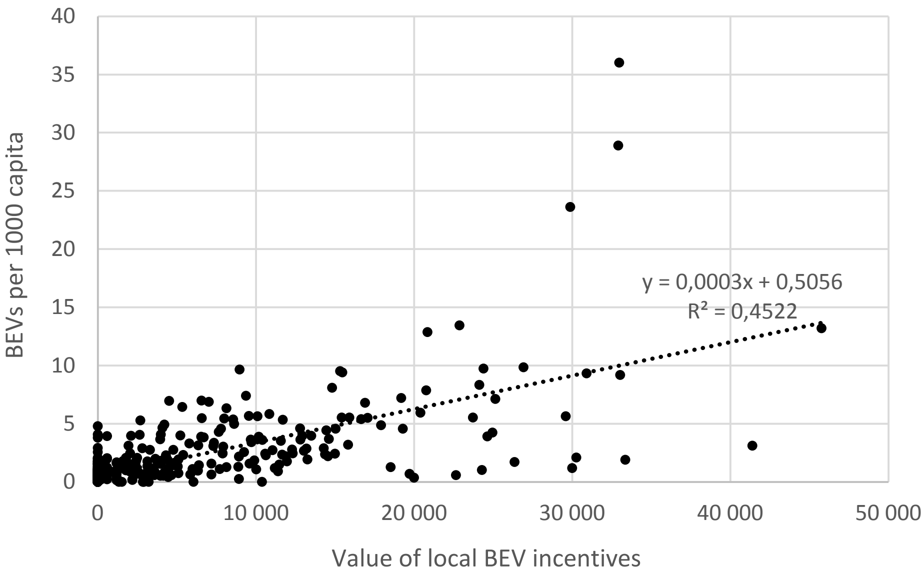
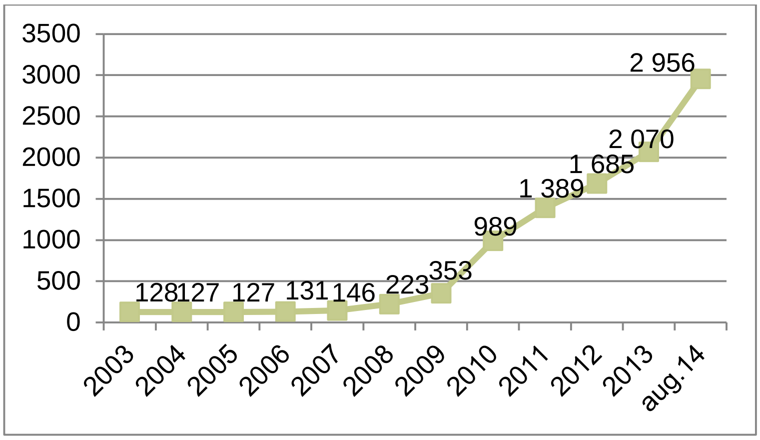



*Figure 2.3: BEVs per 1,000 capita in Norwegian municipalities, compared with the annual value (NOK) of local benefits. NOK 1 = EUR 0.12 at time of survey.*

## 2.3 Austrian incentives and market shares

The number of e-vehicles in the stock is rising rapidly (see figure 2.4), but of course still not comparable with that of Norway. The share of e-vehicles compared to the total stock (about 4.7 million cars) was in the range of about 0.06 percent in August 2014.




Source: Statistic Austria, registration statistics.

*Figure 2.4: EV development in Austria from 2003 to August 2014.*

### 2.3.1 Incentives for e-mobility

In Austria, battery electric vehicles are generally exempted from purchase tax and annual motor vehicle tax, resulting in about 4,000 EUR savings over five years. Also, some insurance companies offer discounts from 10 to 20 percent for e-vehicles on their monthly rates. Some cities offer free parking for e-vehicles (but not e.g. the Austrian capital of Vienna).

Some of the nine Austrian federal states have offered or are offering financial incentives for private e-vehicle users. The schemes differ a lot but can offer direct subsidies of up to 3,000 EUR per e-vehicle.

Financial incentives for companies and communities are offered within the national climate change programme "klima**aktiv** mobil"[2]. The rates are staggered according to the type of vehicle introduced, the level of $CO_2$ reduction achieved and the amount of renewable energy used for new cars with alternative propulsion systems:

- Up to 4,000 EUR are granted for purchasing EVs if powered with renewable energy, otherwise only 2,000 EUR. Utility vehicles over 2,5 t gross vehicle weight and electric mini-buses are subsidised with 20,000 EUR if powered with renewable energy, otherwise 10,000 EUR. Electric buses over 5 t gross vehicle weight receive a subsidy of 40,000 EUR with renewable energy, otherwise 20,000 EUR.
- Since 2013, also PHEVs and EREVs are eligible within the new funding regime and receive subsidies of between 500 – 3,000 EUR, depending on the level of $CO_2$ reduction and amount of renewable energy used. HEV are granted 400 EUR and, if powered with at least 50% biofuel, even 800 EUR.
- Pedelecs are granted with 200 resp. 400 EUR (when powered with green electricity). E-scooters receive subsidies of 250 – 500 EUR.

Within "klima**aktiv** mobil" 11,900 e-vehicles (primarily e-bikes/e-scooters and light-weight community e-vehicles) were supported with an overall volume of €13 m.

[2] The program "klima**aktiv** mobil" is only open for fleets and not for private persons.

### 2.3.2 Pilot regions for E-mobility

The Austrian Climate and Energy Fund promotes the introduction of e-mobility by funding R&D projects and so called pilot regions for e-mobility. These regions focus on electric vehicles powered by renewable energy sources and the integration of "vehicle use schemes" in combination with public transport. Users within a pilot region pay a monthly "mobility rate" which includes not only the electric vehicle, but also the use of public transport.

To date, seven pilot regions have been established (figure 2.5):

(1) Vorarlberg/Rhine valley region (VLOTTE Project) with 360 e-cars/LDVs and 120 charging stations; mobility services contracts including leasing of e-cars, railway/public transport pass, car sharing and free charging; provision of 20m$^2$ photovoltaic power for each e-car;

(2) Greater Salzburg Area with 100 e-cars and 750 e-bikes; ElectroDrive „e-mobility with the public transport pass": leasing/purchasing concept for e-bikes, e-scooters, Segways and e-cars; free charging with „green electricity" (photovoltaic; hydro-power);

(3) Urban agglomeration of Graz: e-mobility Graz; goal 500 e-cars, 1200 e-bikes, 140 public charging points; e-mobility services packages for large fleet operators (vehicles, public transport, charging stations);

(4) Vienna metropolitan area; e-mobility on demand; goal of 500 cars, 100 charging points; multi-modal mobility and public transport pass with focus on commuters and fleet operators; renewable energy for 2000 e-cars;

(5) e-mobility in Lower Austria: 49 municipalities, use of electric vehicles by commuters, promising last mile solutions;

(6) The Austrian Post e-mobility delivery services in Vienna metropolitan and 12 regional distribution centres: 200 electric utility vehicles for postal mail delivery

(7) e-log in the City of Klagenfurt; promising e-logistics solutions with 200 electric vehicles (goal) with focus on SMEs.

About 3.5 million people or 40 percent of the Austrian population live in these regions. Model regions are the major drivers for the establishment of charging infrastructure in Austria.

As a next step, particular attention will be given to linking the different pilot regions by facilitating interoperability of electric vehicles and charging stations. For all the pilot regions particular attention is given to integrate e-mobility and public transport, facilitate multi-modal solutions and interlink the different pilot regions to facilitate interoperability of electric vehicles and the charging infrastructure.

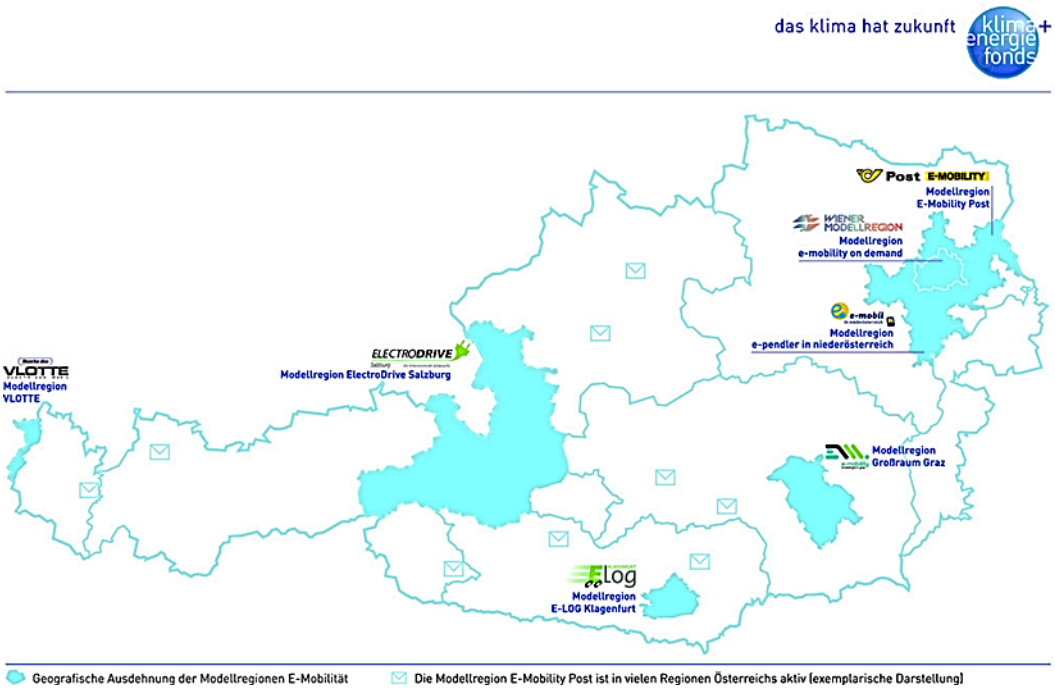



*Figure 2.5: Austrian pilot regions for E-mobility. Source: www.e-connected.at*

So far, due to users and testers in pilot regions, the lessons learned can be pointed out as follows:

- 120-150 km range of e-vehicles is sufficient for daily journeys (50 percent of car trips <5km); combined mobility services provide solutions for long distance.
- Environmental advantages of e-vehicles are important
- Preferential charging with green electricity from 100 percent renewable energy sources (photovoltaic, wind and water power, biomass)
- 80 to 90 percent slow charge at home/office with ordinary power plugs (2,3 kW power). Re-charging of batteries is only needed every third day
- Public charging stations are psychologically important (limited e-vehicle range), but little used, except for fast, high power (50kW) charging stations
- Higher purchase prices of e-cars require some financial support at present

# 3 Serapis – a model for evaluating EV incentives

This chapter introduces the main tool used behind this report, namely the SERAPIS model. A more detailed manual for installation and use is provided in Appendix 1.

## 3.1 The quantitative model

### 3.1.1 Background

The model SERAPIS (Simulating the Emergence of Relevant Alternative Propulsion technologies in the car and motorcycle fleet Including energy Supply) forms the basis to carry out an economic assessment of the implementation of different incentives for e-vehicles in COMPETT. SERAPIS is a dynamic car fleet and propulsion technology model and utilises the methods and principles of System Dynamics. The development of SERAPIS started in 2009 (Pfaffenbichler, et al. 2009). Later on, SERAPIS was adapted for and used in several other projects (Frey, et al. 2011, Frey, et al. 2012, Pfaffenbichler, et al. 2012, Pfaffenbichler, et al. 2011, Renner, et al. 2010). The original version of SERAPIS models included:

- the development of the fleet of motorised individual vehicles (cars, 2-wheelers[3]),
- the share of alternative propulsion technologies (internal combustion engine, hybrid and battery electric) and
- the utilities needed to provide ultra low carbon electric energy for the emerging e-vehicle fleet.

While the case study area was modelled as only one zone in the original version, later versions facilitate the subdivision into a discrete number of zones. A more detailed description of the original version of SERAPIS is given in (Pfaffenbichler, et al. 2011).

A radical revamp of the original SERAPIS model (named version 1.0) has been carried out based on the requirements for COMPETT in general and the Oslo case study in particular. The result of this revamp is the actual SERAPIS version 2.0. The major changes are as follows. The definition of the propulsion technology HEV (hybrid electric vehicles) was rather vague in version 1.0. The propulsion technologies taken into account are now explicitly defined as follows:

- ICE: internal combustion engine incl. non-plug in hybrids (e.g. the normal Prius)
- PHEV: plug in hybrids and range extender vehicles (e.g. Prius Plug In, Volt)
- BEV: battery electric vehicles

[3] SERAPIS does not model e-bicycles and pedelecs.

Furthermore, the car fleet is now differentiated into first and second (+) cars and the following three different car categories:

- Compact (everything from micro-cars up to cars like Renault Clio, Volkswagen Polo etc.)
- Family (everything from Volkswagen Golf, Ford Focus, etc. up to BMW 3, Mercedes C, etc.)
- Luxury (BMW 5 and 7, Audi A6, A7 and A8, Mercedes E and S, Ferrari, Lamborghini, BMW X series, Jeep Wrangler, etc.)

In version 2.0 a trade off in the utility/generalised costs from range and density of service (including electric charging) stations was implemented in the software, i.e. if range is higher the importance of the density of service stations declines and vice versa. Furthermore, utility/generalised costs from time savings due to exemptions for electric vehicles (use of bus lanes, dedicated parking, etc.) have been included in the utility function of the multinomial logit model.

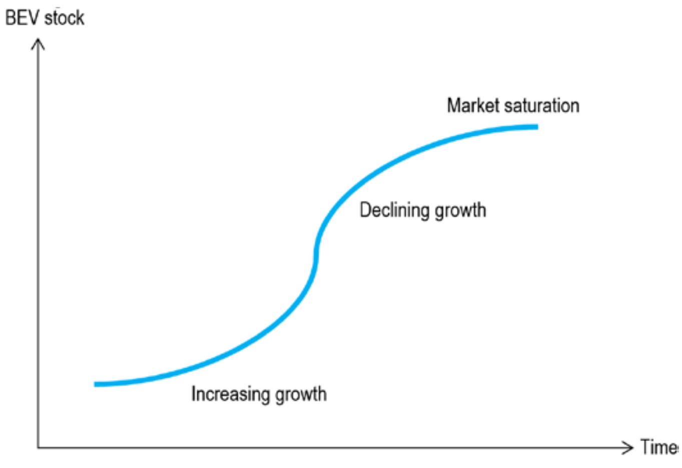
### 3.1.2 Mathematical description of the model

Multinomial logit models are standard practice in choice modelling. SERAPIS utilizes such a model to represent the choice of propulsion technology in each model year (Equation 1). The probability $P_{i,n,c}(t)$ that propulsion technology $i$ is chosen for a car of order $n$ (first or second+) in category $c$ (compact, family, luxury) is the exponential function of the utility $U_{i,n,c}(t)$ of the propulsion technology $i$ divided by the sum over the exponential functions of all alternatives. As mentioned above, SERAPIS v2.0 considers the propulsion technologies internal combustion engine including non-plug-in hybrids (ICE), plug in hybrids (PHEV) and battery electric (BEV).

$$\mathrm{P}_{\mathrm{i,n,c}}(t) = \frac{\mathrm{e}^{\mathrm{U}_{\mathrm{i,n,c}}(\mathrm{t})}}{\sum_{\mathrm{i}} \mathrm{e}^{\mathrm{U}_{\mathrm{i,n.c}}(\mathrm{t})}}$$

*Equation 1: Basic form of the multinomial logit model (MNL) in SERAPIS v2.0*

This functional form generates the well-known S-shaped curve, whose principles are illustrated below. After a period of increasing growth, the market reaches its inflection point, after which the growth rate slows down (but remains positive) as market reaches saturation levels.



In SERAPIS v2.0 the utility $U_i$ of a propulsion technology $i$ is a function of investment costs $I_i$, operating costs $O_i$, variety of makes and models $M_i$, density of service stations $D_i$, range with a single tank/battery content $R_i$ and time saved due to exemptions from traffic regulations $T_i$ (Equation 2). The current version does not yet consider entities such as image and comfort.

$$\mathrm{U_i = f(I_i, O_i, M_i, D, R_i, T_i)}$$

*Equation 2: General form utility of the choice of a propulsion technology*

The definition of utility as used in SERAPIS is to a large extent based on the model design as presented in (Greene 2001). The utility $U_i$ of propulsion technology $i$ equals the marginal utility price $\mu_P$ multiplied by the generalized costs $C_i$ of propulsion technology $I$ (Equation 3).

$$\mathrm{U_i} = \mu_\mathrm{P} * \mathrm{C_i}$$

*Equation 3: Utility and generalized costs*

The marginal utility price $\mu_P$ is calculated as the ratio of the price elasticity $\beta_P$ to the purchase price $P$ multiplied by one minus the market share $s$ (Equation 4).

$$\mu_\mathrm{P} = \frac{\beta_\mathrm{P}}{\mathrm{P} * (1 - \mathrm{s})}$$

*Equation 4: Marginal utility price*

The utility $U_i$ of choosing propulsion technology $i$ is the marginal utility price $\mu_P$ multiplied by the sum of the generalised costs $C_i^e$ of the entities $e$ taken into account[4] (Equation 5).

$$\mathrm{U_i} = \mu_P * \sum_\mathrm{e} \mathrm{C_i^e}$$

*Equation 5: Utility and generalised costs*

Generalised costs are calculated on the basis of discounted total costs per lifespan of a car. Generalized costs from investments $C_i^I$ are calculated as a weighting parameter $a_I^v$ multiplied by the vehicle investment costs $I_i^v$ plus a weighting parameter $a_I^{ch}$ multiplied by the investment costs for a private home charging station $I_i^{ch}$ (Equation 6).

$$\mathrm{C_i^I} = \alpha_I^v * I_i^v + \alpha_I^{ch} * I_i^{ch}$$

*Equation 6: Generalised costs from investment costs*

Generalised costs from operating costs $C_i^O$ are calculated as the weighted sum of discounted costs for fuel $f$, road charges $r$, parking charges $p$ and annual vehicle tax $a$ (Equation 7), where $a_O$ are the weights of the different cost components, $r$ is the discount rate, $t$ future years and $\Theta$ the lifespan of the vehicle.

[4] Here investment costs, operating costs, variety of makes and models, range and density of public charging stations, time savings due to exemptions from regulations.

$$\mathrm{C_i^O} = \alpha_O^f * \sum_{t=1}^{\theta} \frac{o_i^f(t)}{(1+r)^t} + \alpha_O^r * \sum_{t=1}^{\theta} \frac{o_i^r(t)}{(1+r)^t} + \alpha_p^f * \sum_{t=1}^{\theta} \frac{o_i^p(t)}{(1+r)^t} + \alpha_O^a * \sum_{t=1}^{\theta} \frac{o_i^a(t)}{(1+r)^t}$$

*Equation 7: Generalised costs from operating costs*

Generalized costs for the variety of makes and models $C_i^M$ are calculated as the ratio of a weighting parameter $a_M$ divided by the coefficient for the marginal utility price $\mu_P$ multiplied by the natural logarithm of the ratio of the number of makes and models $n_i$ for propulsion technology $i$ to the total number of makes and models $N$ available on the market (Equation 8).

$$\mathrm{C_i^M} = \frac{\alpha_M}{\mu_P} * ln\left(\frac{n_i}{N}\right)$$

*Equation 8: Generalised costs variety of makes and models*

Generalised costs of range and density of public charging stations $C_i^{R,D}$ are calculated as the willingness to pay for range/density equal to the maximum available on the market $C_{r,i}$, $C_{d,i}$ multiplied by the exponential function of an elasticity parameter $b_{r,i}$, $b_{d,i}$ multiplied by the ratio of range/density of charging stations of a propulsion technology $r_i$, $d_i$ to maximum range/density of charging stations $r_{max}$, $d_{max}$ (Equation 9), where $a_{R,D}$ is a weighting factor.

$$\mathrm{C_i^{R,D}} = \alpha_{R,D} * \left[C_{r,i} * e^{\left(b_{r,i} * \frac{r_i}{r_{max}}\right)} + C_{d,i} * e^{\left(b_{r,i} * \frac{d_i}{d_{max}}\right)}\right]$$

*Equation 9: Generalised costs range and density of public charging stations*

Generalised costs from time savings due to exemptions from regulations $C_i^T$ are calculated as the discounted monetized time savings (Equation 10), where $a_T$ is a weighting factor, $VOT$ is the value of time, $\Delta t_i(t)$ are the time savings in year $t$, $r$ is the discount rate and $\Theta$ the lifespan of the vehicle.

$$\mathrm{C_i^T} = \alpha_T * \sum_{t=1}^{\theta} \frac{VOT * \Delta t_i(t)}{(1+r)^t}$$

*Equation 10: Generalised costs from time savings due to exemptions from regulations*

## 3.2 Data input and sources

Data needed to run SERAPIS can be subdivided into two different types:

- data for the base year and
- scenario data representing changes between two consecutive years.

If the case study area is subdivided into zones then some data sets have to be defined zone specific while others have no spatial dimension.

### 3.2.1 Base year data

Table 3.1 gives an overview of the base year data needed to run SERAPIS.

*Table 3.1: List of base year data needed to run SERAPIS*

| Description | Unit |
|---|---|
| Number of cars by zone, first and second+ car and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | - |
| Average number of years until car is disposed by zone and first and second+ car | years |
| Net investment costs per vehicle by vehicle type (compact, family, luxury) and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | Euro, NOK |
| Purchase tax by vehicle type (compact, family, luxury) and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | % |
| Value added tax | % |
| Net investment costs for private charging infrastructure by zone | Euro, NOK |
| Average yearly vehicle mileage by first and second+ car and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | km/a |
| Consumption liquid fuels by vehicle type (compact, family, luxury) and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | l/100 km |
| Consumption electricity by vehicle type (compact, family, luxury) and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | kWh/100 km |
| Average fuel costs at the pump by zone | Euro/l, NOK/l |
| Average electricity costs for the customer by zone | Euro/kWh, NOK/kWh |
| Discount rate | % |
| Average yearly parking charges by zone and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | Euro/a, NOK/a |
| Average yearly road charges by zone and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | Euro/a, NOK/a |
| Number of available makes and models by vehicle type (compact, family, luxury) and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | - |
| Average travel speed by zone | km/h |
| Estimate of the relative time savings due to exemptions for electric vehicles (use of bus lanes, dedicated parking places, etc.) for n=1 e-car by zone | % |
| Average range of a car with one tank refill/recharge by vehicle type (compact, family, luxury) and propulsion technology (internal combustion engine, plug in hybrid electric vehicle, battery electric vehicle) | km |
| Density of public charging stations relative to internal combustion engine cars by zone (petrol/diesel = 100%) | % |

### 3.2.2 Scenario data

Table 3.2 gives overview of the scenario data which are needed to run SERAPIS.

*Table 3.2: Overview scenario data needed to run SERAPIS*

| Description | Unit |
|---|---|
| Yearly rate of change in numbers of first cars by zone | %/a |
| Yearly rate of change in numbers of second cars by zone | %/a |
| Yearly rate of change life span of first cars by zone | %/a |
| Yearly rate of change life span of second cars by zone | %/a |
| Share of compact cars in the fleet of first cars by year and zone | % |
| Share of family cars in the fleet of first cars by year and zone | % |
| Share of compact cars in the fleet of second+ cars by year and zone | % |
| Share of family cars in the fleet of second+ cars by year and zone | % |
| Yearly rate of change net purchase price by car type and propulsion technology | %/a |
| Purchase tax as percentage of net purchase price by car type and propulsion technology | % |
| Value added tax by year | % |
| Direct subsidies for battery electric vehicles by zone and year | Euro, NOK |
| Direct subsidies for plug in hybrid electric vehicles by zone and year | Euro, NOK |
| Yearly rate of change in net investment costs for private charging infrastructure by zone | %/a |
| Direct subsidies for private charging infrastructure by zone and year | Euro, NOK |
| Yearly rate of change vehicle mileage first car propulsion technology ICE by zone | %/a |
| Yearly rate of change vehicle mileage first car propulsion technology PHEV by zone | %/a |
| Yearly rate of change vehicle mileage first car propulsion technology BEV by zone | %/a |
| Yearly rate of change vehicle mileage second+ car propulsion technology ICE by zone | %/a |
| Yearly rate of change vehicle mileage second+ car propulsion technology PHEV by zone | %/a |
| Yearly rate of change vehicle mileage second+ car propulsion technology BEV by zone | %/a |
| Yearly rate of change specific consumption liquid fuels by car type and propulsion technology | %/a |
| Yearly rate of change specific consumption electricity by car type and propulsion technology | %/a |
| Yearly rate of change costs for liquid fuels by zone | %/a |
| Yearly rate of change costs for electricity by zone | %/a |
| Average parking charges by zone propulsion technology and year | Euro/a, NOK/a |
| Average road charges by zone propulsion technology and year | Euro/a, NOK/a |
| Yearly change in the number of makes and models by car type and propulsion technology | - |
| Yearly rate of change average speed by zone | %/a |
| Relative time savings due to exemptions for electric vehicles (use of bus lanes, dedicated parking places, etc.) for n=1 e-car by zone | % |
| Yearly rate of change value of time by zone | %/a |
| Average range by car type, propulsion technology and year | km |
| Relative density public charging station (petrol/diesel = 100%) by zone and year | % |

## 3.3 Calibration

### 3.3.1 Principles

*Calibration is the estimation of certain model parameters to fit the model results to a set of observed data* (Pfaffenbichler 2003 p. 134). The year 2005 was chosen as the base year for both the Austrian and the Norwegian model. The scenario data have been defined in a way to represent the observed historical developments of vehicle price, fuel price, subsidies, other benefits etc. of the period 2005 and 2014. Both models were then calibrated to fit the observed developments from car registration statistics as good as possible.

*Table 3.3: List of parameters used in the model calibration*

| Parameter | Description | See |
|---|---|---|
| $\beta_P$ | price elasticity for the calculation of the marginal utility price | Equation 4 |
| $\alpha_I^v$ | weighting parameter vehicle investment costs | Equation 6 |
| $\alpha_I^{ch}$ | weighting parameter investment costs private charging point | Equation 6 |
| $\alpha_O^f$ | weighting parameter discounted lifetime fuel costs | Equation 7 |
| $\alpha_O^r$ | weighting parameter discounted lifetime road charge | Equation 7 |
| $\alpha_O^p$ | weighting parameter discounted lifetime parking charge | Equation 7 |
| $\alpha_O^a$ | weighting parameter discounted lifetime annual vehicle tax | Equation 7 |
| $\alpha_M$ | weighting parameter variety of makes and models | Equation 8 |
| $\alpha_{R,D}$ | weighting parameter range and density of public charging stations | Equation 9 |
| $\alpha_T$ | weighting parameter time savings due to exemptions from regulations | Equation 10 |
| $C_{r,i}$ | willingness to pay for range equal to the maximum available on the market | Equation 9 |
| $C_{d,i}$ | willingness to pay for density of charging stations equal to the maximum available on the market | Equation 9 |
| $b_{r,i}$ | elasticity parameter range | Equation 9 |
| $b_{d,i}$ | elasticity parameter density of charging stations | Equation 9 |

### 3.3.2 Results

*Table 3.4: Parameter values calibrated models (currencies: NOK for Norway and € for Austria)*

| Parameter | | | Norway | | | Austria | | |
|---|---|---|---|---|---|---|---|---|
| | | | Compact | Family | Luxury | Compact | Family | Luxury |
| $\beta_P$ | | | -2.04 | -1.97 | -1.98 | -2.34 | -1.83 | -1.50 |
| $\alpha_I^V$ | | 1st car | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | | 2nd+ car | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| $\alpha_I^{ch}$ | | 1st car | 1.00 | 0.25 | 0.25 | 1.50 | 0.50 | 1.50 |
| | | 2nd+ car | 0.25 | 5.00 | 1.00 | 1.50 | 0.50 | 0.50 |
| $\alpha_O^f$ | | 1st car | 1.00 | 5.00 | 5.00 | 1.11 | 0.60 | 0.50 |
| | | 2nd+ car | 4.57 | 0.25 | 1.00 | 0.50 | 0.50 | 0.50 |
| $\alpha_O^r$ | | 1st car | 1.00 | 0.25 | 2.13 | 1.00 | 1.00 | 1.00 |
| | | 2nd+ car | 0.36 | 0.25 | 1.00 | 1.00 | 1.00 | 1.00 |
| $\alpha_O^p$ | | 1st car | 1.00 | 0.45 | 1.65 | 0.50 | 0.50 | 0.50 |
| | | 2nd+ car | 0.25 | 0.25 | 1.00 | 0.50 | 0.50 | 0.50 |
| $\alpha_O^a$ | | 1st car | 1.00 | 3.98 | 5.00 | 1.38 | 1.50 | 0.50 |
| | | 2nd+ car | 0.48 | 0.25 | 1.00 | 0.50 | 1.18 | 0.50 |
| $\alpha_M$ | | 1st car | 1.00 | 2.81 | 1.66 | 1.01 | 1.14 | 0.70 |
| | | 2nd+ car | 2.05 | 0.79 | 3.74 | 1.50 | 1.39 | 0.53 |
| $\alpha_{R,D}$ | | 1st car | 3.00 | 5.00 | 5.00 | 0.88 | 0.50 | 0.50 |
| | | 2nd+ car | 5.00 | 5.00 | 3.00 | 2.50 | 1.22 | 2.22 |
| $\alpha_T$ | | 1st car | 1.00 | 5.00 | 0.29 | n.a. | n.a. | n.a. |
| | | 2nd+ car | 0.40 | 0.25 | 1.00 | n.a. | n.a. | n.a. |
| $C_{r,i}$ | | 1st car | 50,000 | 50,000 | 150,000 | 5,000 | 7,500 | 10,000 |
| | | 2nd+ car | 10,000 | 10,000 | 33,333 | 1,667 | 2,500 | 3,333 |
| $C_{d,i}$ | BEV | 1st car | 25,000 | 53,734 | 38,906 | 2,500 | 3,750 | 7,500 |
| | | 2nd+ car | 12,342 | 86,887 | 23,333 | 833 | 1,250 | 2,500 |
| | PHEV | 1st car | 5,000 | 2,000 | 2,000 | 0 | 0 | 0 |
| | | 2nd+ car | 2,500 | 2,000 | 8,966 | 0 | 0 | 0 |
| $b_{r,i}$ | | 1st car | -8.00 | -8.44 | -5.08 | -8.00 | -8.00 | -8.00 |
| | | 2nd+ car | -7.07 | -5.00 | -10.00 | -10.00 | -10.00 | -10.00 |
| $b_{d,i}$ | BEV | 1st car | -5.00 | -15.00 | -15.00 | -5.00 | -5.00 | -5.00 |
| | | 2nd+ car | -15.00 | -15.00 | -7.34 | -8.00 | -8.00 | -8.00 |
| | PHEV | 1st car | -5.00 | -5.25 | -15.00 | -5.00 | -5.00 | -5.00 |
| | | 2nd+ car | -8.00 | -15.00 | -7.34 | -8.00 | -8.00 | -8.00 |

Figure 3.1 shows a comparison between the number of BEVs and PHEVS registered in Austria 2010 to 2014 and the model results. Due to the poor performance of

replicating Norwegian PHEVs, the remainder of this report will focus solely on the BEV market.

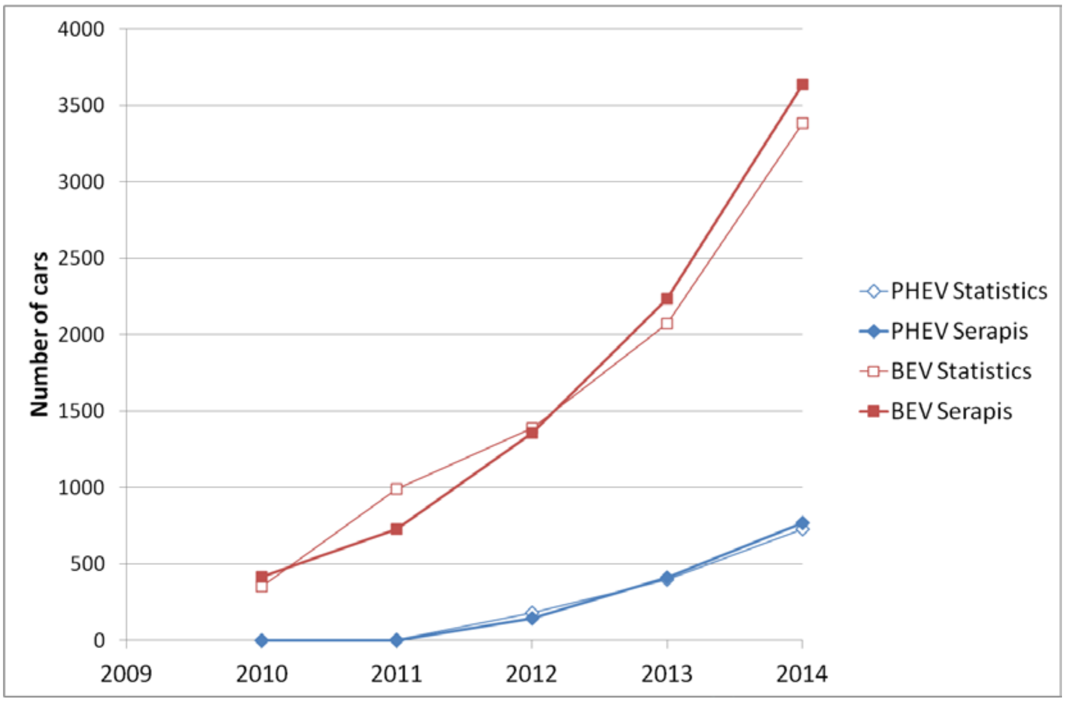



*Figure 3.1: Comparison Austrian registration statistics – SERAPIS results 2010-2014. Source: Statistik Austria Registration Statistics 2010-2014.*

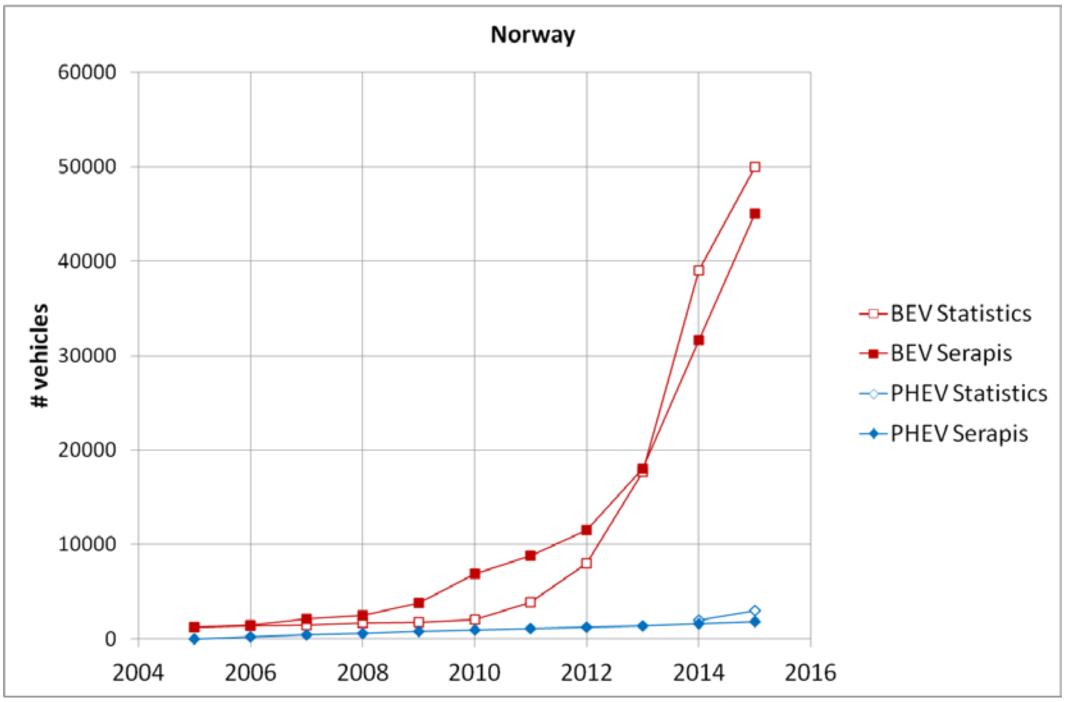



*Figure 3.2: Comparison Norwegian registration statistics – SERAPIS results 2005-2015 Source: Norwegian Registration Statistics 2005-2015.*

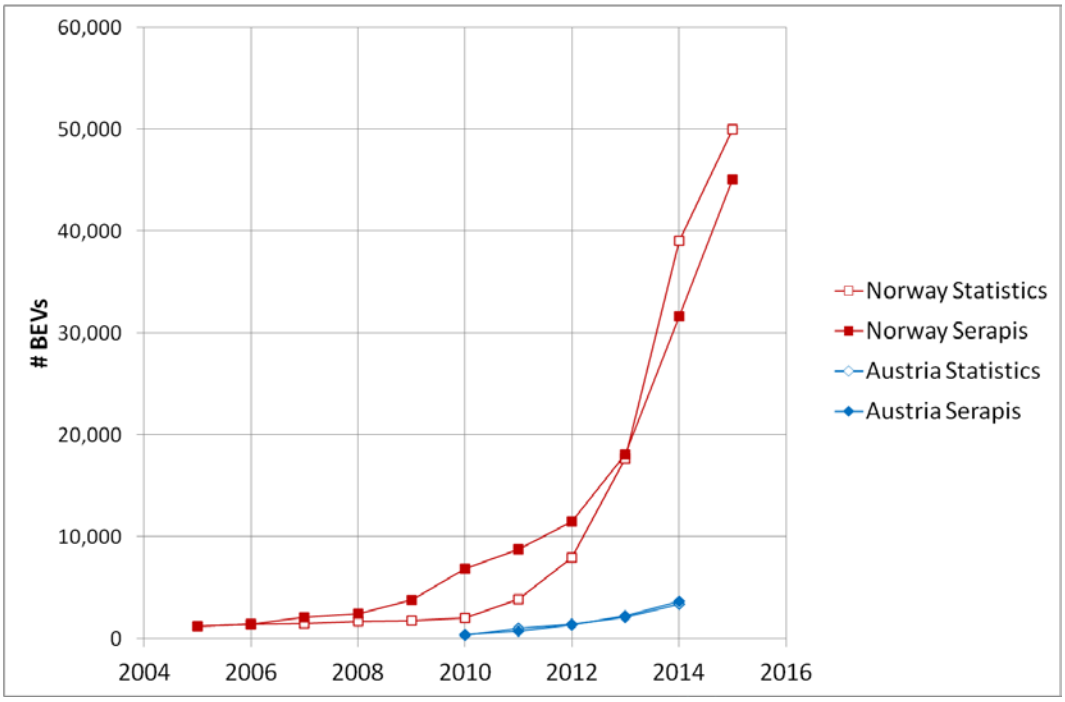



*Figure 3.3: Comparison of calibration results BEV in Austria and Norway Source: Austrian and Norwegian Registration Statistics 2005-2015.*

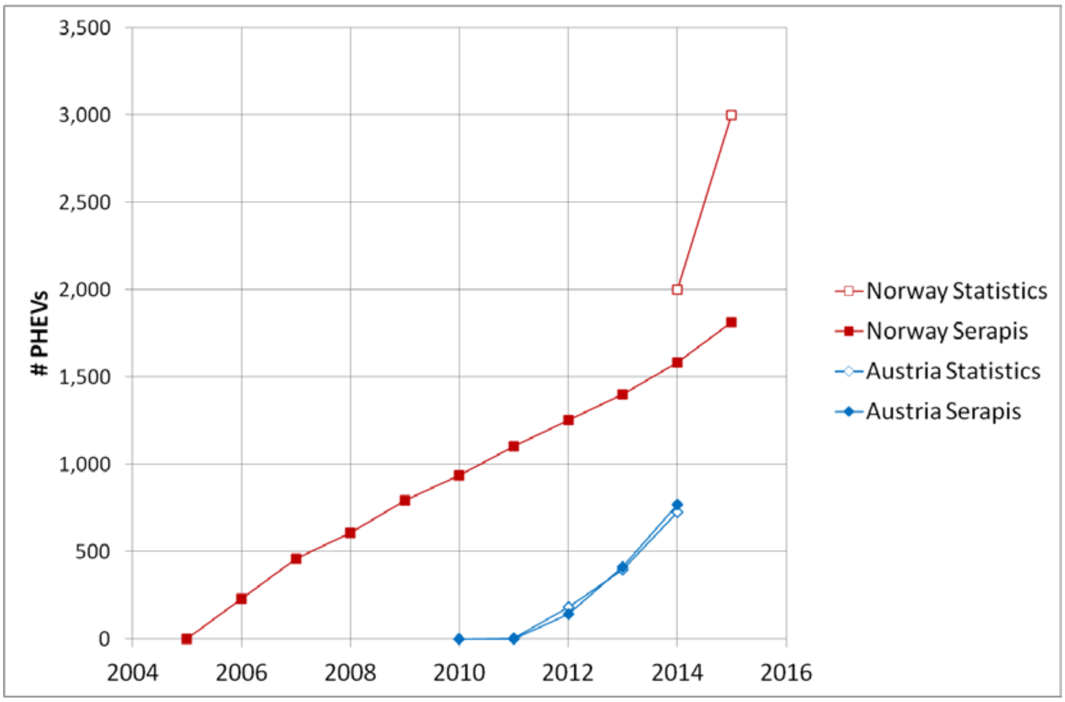



*Figure 3.4: Comparison of calibration results PHEV in Austria and Norway Source: Austrian and Norwegian Registration Statistics 2005-2015.*

## 3.4 Sensitivity testing and critical assumptions

For the purpose of assessing the performance of SERAPIS, numerous sensitivity tests have been performed. The sensitivity tests are performed in order to identify assumptions, parameters and input data that strongly affect model outcomes. This is done by comparing the Base scenario (see chapter 5) with model runs where various assumptions and parameters are changed. The tests are presented in Appendix 2.

Overall, SERAPIS results appear quite robust within what can be said to be realistic variations of input assumptions. One critical factor is the demand elasticity assumption for compact car and luxury car segments. They have large effect on the outcome but are not based on other empirical evidence than the input data on which SERAPIS is calibrated.

It is also evident that liquid fuel (gasoline and diesel) prices have considerable effect on BEV sales. This fact suggests not only that the model is sensitive to this assumptions, but also that the BEV market largely depends on ICE operating costs, which is plausible. The model suggests that BEV energy costs have a lesser effect on BEV sales, which is also reasonable keeping in mind that BEV energy costs are much smaller than ICE energy costs.

The discount rate assumption also affect results distinctively. It may be that a 3% discount rate results in over-estimation of the BEV market size.

Finally, it is apparent that the supply side is important and has visible effects on the model outcome. This appears to be plausible.

# 4 Effectiveness and fiscal cost effectiveness of EV incentives

This chapter evaluates various incentives with respect to their effectiveness and fiscal cost effectiveness. *Effectiveness*, or goal effectiveness, is a measure of the extent to which the incentives achieve their objectives. Here, this is understood as their contribution to market uptake of BEVs, i.e. in terms of numbers of registered BEVs and in terms of BEV market shares. Fiscal cost effectiveness, on the other hand, is a measure of the extent to which objectives are achieved at the lowest possible cost. It is clear that while a policy may be effective in introducing a large number of BEVs into the market, it can come at a prohibitively high cost. Given that governments face budget constraints, the aim would be to identify and implement policies that generate the largest number of BEVs per unit of government spending.

Government costs consist not only of the direct cost of the policy, for example the registration tax exemption. We also need to take into account the reduced revenues from ICE purchase and usage taxes and charges, including petrol taxes and parking revenue. Increased electricity tax revenue from BEV charging make up some of the lost revenues and is also accounted for.

## 4.1 Effectiveness of Norwegian BEV incentives

In this section, we assess the individual effects of Norwegian BEV incentives from two angles: SERAPIS model runs and a regression model based on observations from Norway's 428 municipalities.

### 4.1.1 SERAPIS modelling of incentives' effectiveness

We run SERAPIS in order to establish the individual contribution of each of the Norwegian BEV incentives[5]. To this end, a SERAPIS base run for Norway (BRN) is established in which all the Norwegian incentives are removed throughout the period till 2045. In BRN, BEVs pay the same taxes and charges as ICEs, and do not enjoy any preferential treatment[6]. While this is not a reasonable assumption about future EV policies, it provides a good basis for introducing BEV incentives one by one for a closer analysis of their partial effects.

[5] Except for ferry rebates, which are not modelled in SERAPIS.

[6] This means that, in the BR base run, BEVs pay the same registration tax as ICEs, which in Norway in fact is wrong because of the $CO_2$ emission and the combustion engine power components of registration tax. With the current Norwegian registration tax regime, BEVs would pay less registration tax even without preferential treatment because of this. It is believed, however, that BEV tax of the same size as the ICE tax is more generalizable and a sufficiently good approximation. The effect of setting BEV registration tax equal to ICE registration tax is to slightly exaggerate the effect on BEV sales and on public budgets.

So, from a hypothetical development where no BEV incentives are in place, individual SERAPIS runs are established in which one of the incentives are introduced in turn. In this way, the partial effect of, for example, the purchase tax exemption equals the difference between BEV take-up in the BRN and BEV take-up in the model run where purchase tax exemption is the only BEV incentive. Figure 4.1 shows SERAPIS results of the partial effects, as well as the BRN with no incentives. BRN generates a BEV fleet[7] of about 400,000 vehicles by the year 2045 (shaded area). These BEVs are generated by the model due to exogenous technology improvements, which are a result of, i.a., policies in other countries and by the policies that were in place up to 2015. Norway is a large part of the international BEV market. If we remove all incentives, the international development will be slower, although our model does not include such feedback.

We see from figure 4.1 that exemption from road charges and parking fees produce almost intangible effects on BEV sales. They have virtually no additional effect on BEV market shares. (However, all BEVS, including those that would be in circulation even without any incentives, will enjoy the benefit.) At the other end of the spectrum, bus lane access appears to have the most pronounced effect. Relative to BRN, the introduction of BEV bus lane access will increase the total BEV market to just over 500,000 – an increase of about 25 percent. The combined effect of purchase tax and VAT exemptions is also considerable, as is the combined effect of all incentives.

Continuation of all BEV incentives – although this is not a reasonable assumption about future EV policies – will generate a BEV fleet of just over 700,000 vehicles in 2045. The result is influenced by the assumptions on the number of makes and models available as seen in chapter 5.3.5. and figure 5.10.

[7] "Fleet" and "stock" are used interchangeably in this deliverable and refer to the total number of registered vehicles. Every year there is an inflow of new vehicles which adds to the stock, and an outflow of old vehicles with the opposite effect.

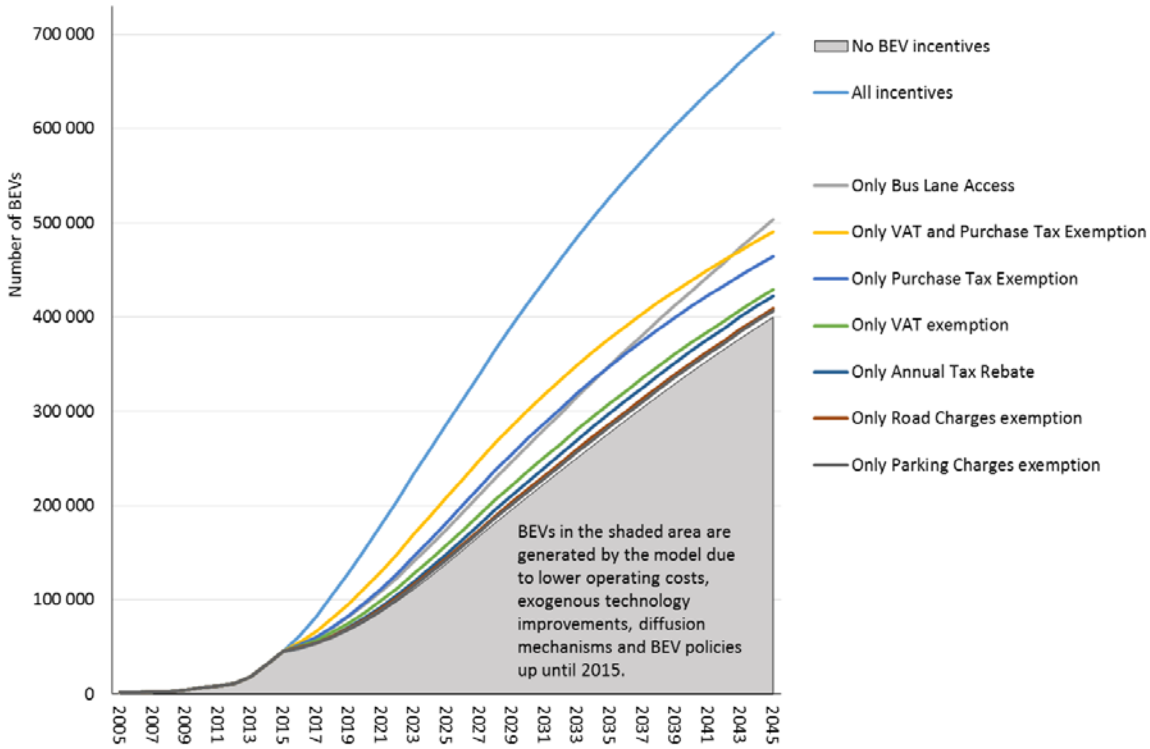



*Figure 4.1: Partial effects on BEV stock of removing individual Norwegian incentives.*

An important observation is the fact that the gains from all incentives (with an exception for bus lane access) level off relative to BRN after some 10-15 year. Relative to BRN, all incentives immediately produce increasing number of BEVs, whereafter the effect stabilises. This is shown in figure 4.2, below, where the results from figure 4.1, above, are translated into effects *relative* to the BRN (which is why some of the curves dip despite growth). Here, the important contributions of purchase tax and VAT exemptions during the earlier years up to the mid-2030s are quite prominent. However, their importance diminishes towards the end of the period and is overtaken by the noticeable bus lane access push[8]. Around that point of time, their effect reaches saturation levels, such that their effect relative to BRN diminishes (in BRN, BEV growth keeps continuing, slowly, due to supply side improvements) [9].

Fiscal incentives directed at the *use* of BEVs appear to have relatively less impact on BEV sales compared with the larger effect of incentives that are directed at reducing purchase costs. In between lies the annual circulation tax rebate, whose effect on BEV sales is significant and add just over 20,000 BEVs in 2045.

[8] In Norway, it is clear that bus lane access cannot exist for a long period of time. BEVs fill up bus lanes and cause severe problems for public transport operators. It is agreed that this incentive will be phased out in road links where this is particularly problematic. So, the model run is by no means a realistic forecast but rather a visualisation of the importance of bus lane access for BEV market uptake.

[9] When this happens during the mid-2030s, it is timely to consider gradual out-phasing of these incentives. This is dealt with in more detail in chapter 6.3

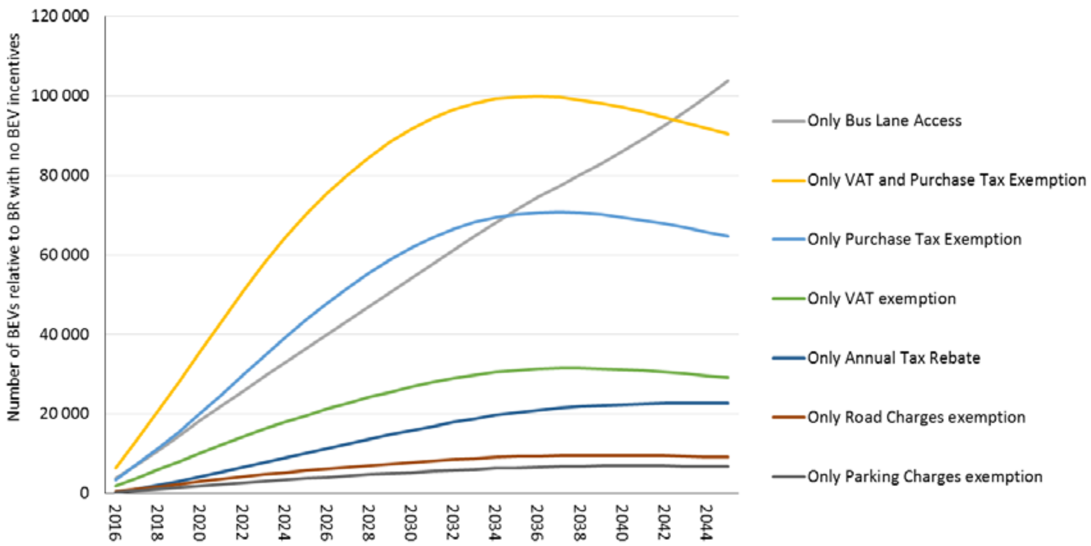



*Figure 4.2: Contribution of individual incentives on the stock of registered BEVs in the Norwegian passenger car fleet.*

### 4.1.2 A Tobit model approach of Norwegian local incentives

As part of the COMPETT project, Figenbaum et al. (2014) asked Norwegian EV owners to identify the various *local user benefits* they enjoy when using their EVs. This makes an excellent base for an analysis of how the various BEV incentives contribute to BEV sales and market shares. The details are described in section 2.2.2.

We have observed BEV market shares in 428 Norwegian municipalities (zones), and calculations of the annual value of each of the local incentives: free parking; no road charges; bus lane access; and reduced ferry fares. Table 4.1summarises the data.

*Table 4.1: Data overview, Norwegian municipalities. Annual figures, NOK.*

| | Inhabitants | No. of registered ICEs | No. of registered EVs | Saved parking cost | Road charges saved | Value of bus lane access | Ferry rebate | BEVs per 1000 capita | BEV share of private cars |
|---|---|---|---|---|---|---|---|---|---|
| Max | 634 463 | 259 202 | 3 392 | 26 400 | 30 000 | 23 333 | 26 000 | 36 | 8,1 % |
| Min | 211 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 0,0 % |
| Average | 11 937 | 5 790 | 41 | 977 | 1 221 | 1 059 | 831 | 2 | 0,4 % |
| % zero | 0 % | 0 % | 27 % | 69 % | 71 % | 82 % | 86 % | 27 % | 27 % |
| N | 428 | 428 | 428 | 428 | 428 | 427 | 428 | 428 | 428 |

An ordinary least squares (OLS) regression would help identify the relative importance of the local BEV incentives and the individual effect of the different local incentives. However, as we see from table 4.1, 27 percent of the zones (municipalities) had zero percent BEV market share. Therefore, OLS will produce inconsistent estimates since the observed BEV demand is only zero or above, i.e. a non-negative (so: limited) dependent variable. In order to handle this problem, a tobit model is more appropriate than OLS. The tobit model combines a probit model (Prob (y>0)) and a truncated regression (E(y>0)). We observe the actual market shares when they exceed zero. Otherwise, we observe a zero market share:

$$y = \begin{cases} y^* & if\ y^* > 0 \\ 0 & if\ y^* \leq 0 \end{cases},$$

where y* is the latent variable. This can also be expressed as y = max (*y**,0).

Tobit coefficients are interpreted much in the same way as OLS regression coefficients, but note that the model does not resemble the observed BEV market shares; instead, it estimates the latent censored behaviour, taking into account that we do not observe demand below zero[10]. The tobit model estimate is summarised in table 4.2, while the full model output is provided in Appendix 3.

The model explains the variation in BEV market shares relatively well. The pseudo $R^2$ is 0.536, all coefficients have the expected sign (i.e. positive) and, apart from saved parking cost, they are statistically significant.

*Table 4.2: Tobit analysis. Dependent variable: BEV market share in percent*

| Variable | ML estimates | t-value | p-value |
|---|---|---|---|
| Saved Parking Cost | 0.0000057 | 0.7202 | 0.47143 |
| Road charges saved | 0.0001458 | 14.9882 | 0.00000 |
| Value bus lane access | 0.0000487 | 5.5520 | 0.00000 |
| Ferry | 0.0000362 | 3.9274 | 0.00009 |
| Standard error of u | 0.5612094 | 24.4993 | 0.00000 |

Log likelihood: -3.3910E+002

Pseudo R^2: 0.53595

Sample size (n): 427

An interesting observation is that saved parking cost appears to have insignificant impact on BEV market shares. There is no statistical evidence in our data to suggest that free public parking affects BEV market shares. The remaining explanatory factors have significant impact on BEV market shares. Road charges saved has the highest impact.

We now use the estimated coefficients and look at four particular zones in the Oso-Kongsberg region. This is done in table 4.3 where we estimate the contribution of individual local incentives to the BEV market share. We look at the zones Bærum, Asker, Oslo and Kongsberg. In addition, we include an unweighted national average value of incentives (which are identical to the mean values in table 4.1, above, and are low due to many zero values). Bus lane access and exemption from road charges contribute the most to BEV market shares. The latter is contrary to the SERAPIS finding. Free parking has virtually zero effect. Ferry rebates are not relevant for the listed Oslo-Kongsberg zones. However, they contribute a small fraction to the Norwegian average.

---

[10] See McDonald and Moffitt (1980) for details and modifications to this statement, which according to them only holds true when the independent variable equals infinity. According to them (p 318), "*the total change in y can be disaggregated into two […] (1) the change in y of those above the limit, weighted by the probability of being above the limit; and (2) the change in the probability of being above the limit, weighted by the expected value of y if above.*" On this background, poisson models may be better suited for our analysis. However, this would require different (count) data that would not serve our purpose of analysing market shares sufficiently well, and would not gain the same insights from the many zero (0) observations in our data.

The individual effects do not sum up to the observed BEV market share. This is because the calculations are based on the tobit estimates with some of its limitations described above. BEV market shares are of course result of other factors than those included in our tobit analysis, most notably the national incentives such as the registration tax exemption. Income effects, psychological effects of toll roads, and the *keep up with the neighbour* effect are other examples of omitted explanatory variables which may explain the difference between estimate and observed market shares.

*Table 4.3: Contribution of individual incentives to BEV market share (%)*

| | Free parking | Road charges | Bus lane | Ferry rebate | Sum | Observed share (%) |
|---|---|---|---|---|---|---|
| Bærum | 0.02 | 0.74 | 0.37 | 0.0 | 1.12 | 1.4 |
| Asker | 0.02 | 0.77 | 1.01 | 0.0 | 1.80 | 4.9 |
| Oslo kommune | 0.02 | 0.64 | 0.22 | 0.0 | 0.87 | 1.3 |
| Kongsberg | 0.02 | 0.18 | 0.0 | 0.0 | 0.20 | 0.2 |
| Norway (mean of all zones) | 0.01 | 0.18 | 0.05 | 0.03 | 0.27 | 0.4 |

Overall, this tobit modelling exercise supports the general picture which is drawn from the SERAPIS model calibration and runs. The importance of bus lane access is confirmed, as is the negligible effect of free parking. However, while free toll roads have a relatively minor effect according to the SERAPIS runs, road charges come out as important in the tobit model. Note that the tobit model only considers local incentives and not national incentives such as registration tax, annual circulation tax, and VAT exemption. Therefore, the results are not directly comparable.

## 4.2 Effectiveness of BEV incentives in Austria

In this section, we assess the individual effects of BEV incentives in Austria using SERAPIS model runs. We run SERAPIS in order to establish the individual contribution of each of the BEV incentives used in Norway[11] (see previous chapter) plus the contribution of the incentive of direct subsidies on vehicle investment costs as in operation in some of the Austrian federal provinces. To this end, a SERAPIS base run for Austria (BRA) is established in which all incentives are removed from 2015 onwards until 2045. While this is not a reasonable assumption about future EV policies, it provides a good basis for introducing BEV incentives one by one for a closer analysis of their partial effects.

So, from a hypothetical development where no incentives are in place, individual SERAPIS runs are established in which one of the incentives is introduced in turn. In this way, the partial effect of, for example, the purchase tax exemption equals the difference between BEV take-up in the BRA and BEV take-up in the model run where purchase tax exemption is the only BEV incentive.

Additionally, we test three scenarios which are a combination of individual incentives, which are:

[11] Some Austrian provinces also supported the purchase of PHEVs. According to our knowledge, there are no plans to incentivise PHEVS in the near future.

- **baseline**: a likely forward projection of the incentives as currently in use in Austria,
- **all-Norwegian-incentives**: a combination of the incentives as currently given in Norway and
- **all-incentives**: a combination of the incentives as currently given in Norway plus a likely forward projection of direct subsidies given in some of the Austrian federal provinces.

Figure 4.3 shows SERAPIS results of the partial effects, as well as the BRA scenario with no incentives and the three combined scenarios. BRA generates a BEV fleet of about 150,000 vehicles by the year 2045 (blue line with blue diamonds). This number of BEVs is generated by the model mainly due to exogenous technology improvements, which are a result of, i.a., policies in other countries.

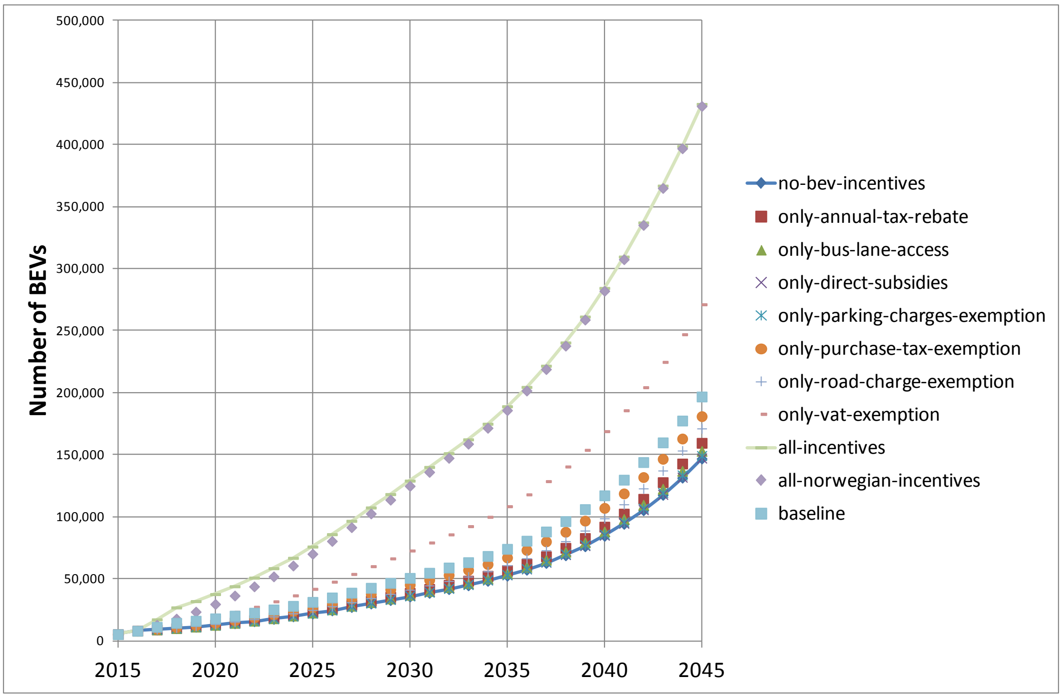



*Figure 4.3: Partial effects of adding individual incentives - Austria.*

We see from *Figure 4.3* that exemptions from parking fees produce almost intangible effects on BEV sales (<2% throughout the whole forecasting period). At the other end of the spectrum, a VAT exemption is the single incentive with the most pronounced effect. Relative to BRA, the introduction of a VAT exemption will increase the total BEV market to just over 430,000 in 2045 – an increase of about 85 percent. Concerning the combined scenarios, an implementation and continuation of all Norwegian BEV incentives plus a continuation of direct subsidies until 2017 will generate the largest BEV fleet. The number of BEVs is predicted to climb to about 433,000 vehicles in 2045 (light green line). The implementation and continuation of all Norwegian BEV incentives without direct subsidies results in a marginally lower fleet of about 431,000 vehicles. The likely forward projection of the incentives as currently in use in Austria (scenario "baseline") results in a BEV fleet of slightly less than 200,000 vehicles in 2045. No single incentive except the VAT exemption outperforms the likely forward projection of the incentives.

Unlike in Norway, the gains from the incentives do not level off relative to BRA after some 10-15 year. Direct subsidies, which are assumed to stop after the year 2017, are the only exception. The effects of all other incentives and their combinations are increasing over the whole evaluation period as Austria will not within this time frame reach the point on the S-curve (see chapter 3.1.2) where sales starts levelling off. This is shown in Figure 4., below, where the results from Figure 4.3, above, are translated into effects relative to the BRA.

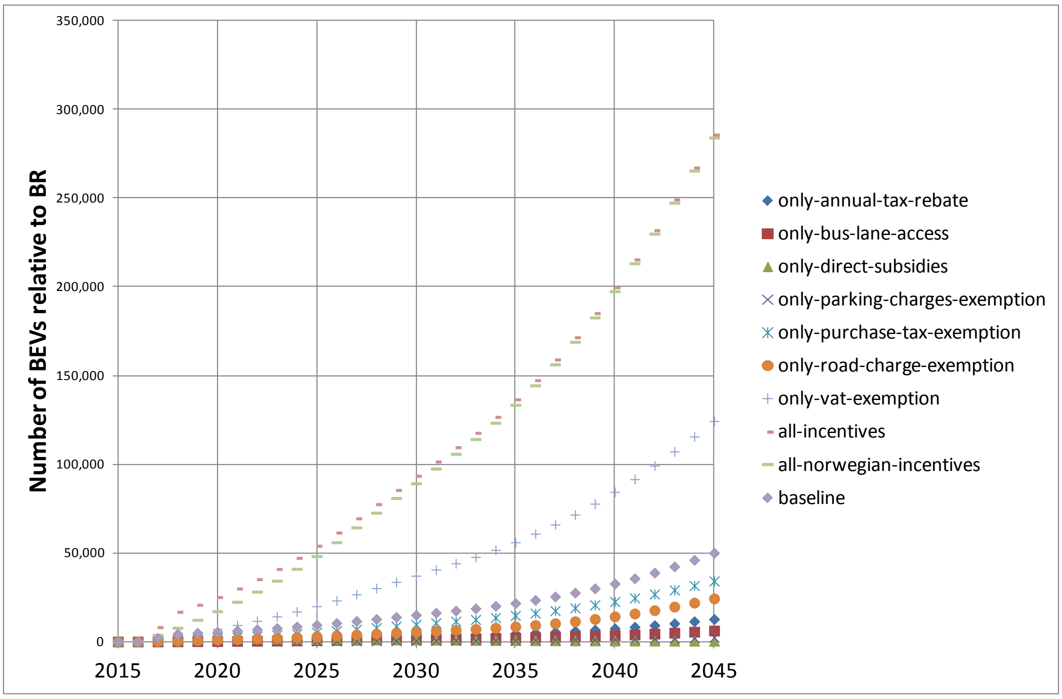



*Figure 4.4: Contribution of individual incentives on the number of registered BEVs in the Austrian passenger car fleet.*

## 4.3 Comparative observations Norway and Austria

This section provides a comparison of the effects of the different incentives in Norway and Austria. The total passenger vehicle fleet of Austria was about 4.7 million in 2014 and the Norwegian fleet was about 2.6 million.

Figure 4.5 shows a comparison of the number of registered BEVs in Norway and Austria if all incentives are removed in the years from 2015 onwards. Figure 4.6 shows the opposite extreme – that all incentives are in place. The difference between Austria and Norway can be explained to a large extent by the difference in gross investment and fuel costs for ICEs and BEVs. While in Norway differences in purchase costs are relatively small, there is still a large difference in Austria.

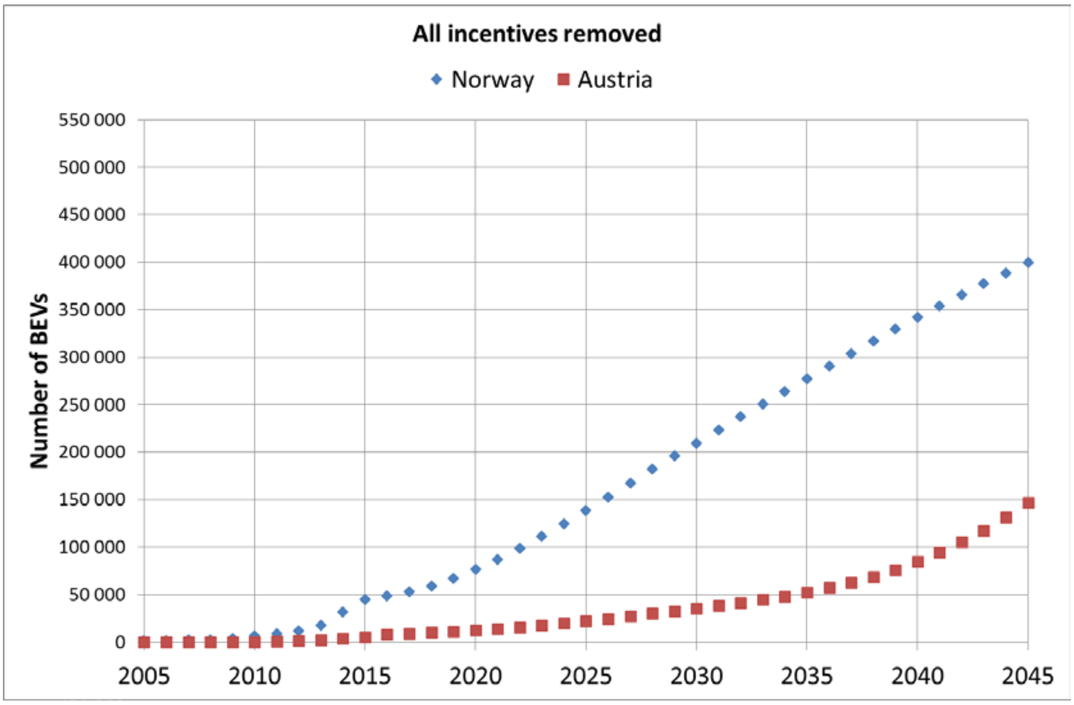



*Figure 4.5: Comparison of the number of registered BEVs in Norway and Austria – All incentives removed.*

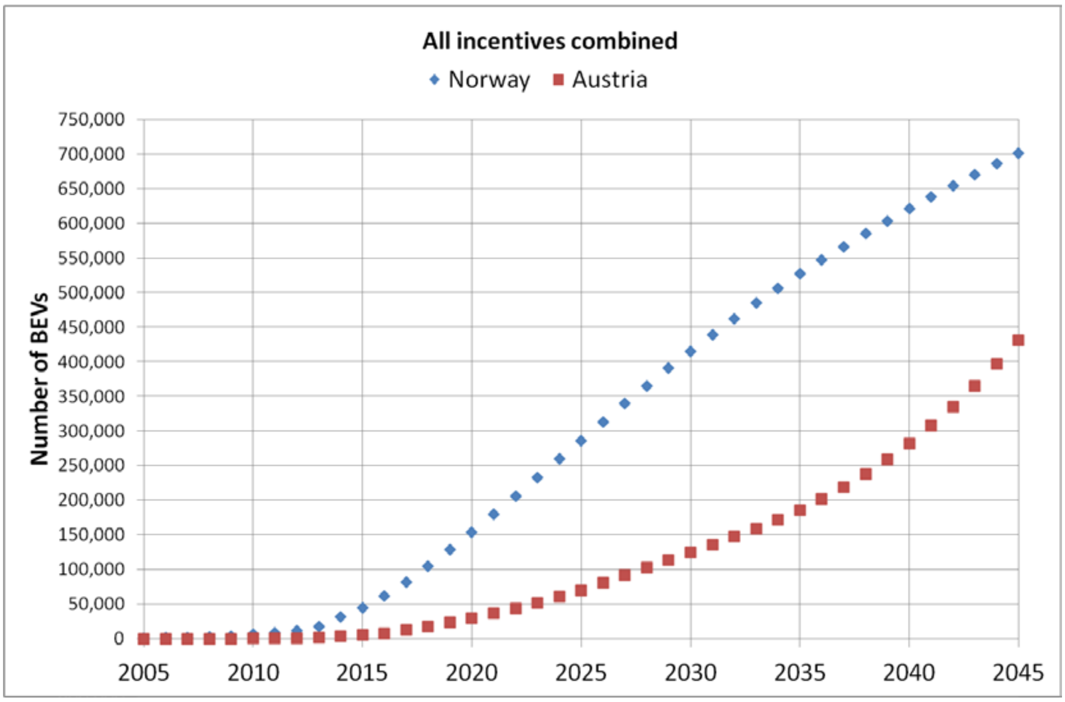



*Figure 4.6: Comparison of the number of registered BEVs in Norway and Austria – All incentives combined.*

With the S-shaped market penetration curve as described in section 3.1.2 in mind, it is evident that the Austrian BEV market will experience increased growth rated for a long period of time. The Norwegian BEV market, on the other hand, will reach its inflection point and experience growth rates that slow down because it approaches its saturation level.

Figure 4.7 compares the different effects in Norway and Austria of a thought situation where VAT exemption is the only BEV incentive in place. It is clear that this incentive has very different effect, especially in the later part of the period. In Norway, the partial effect of VAT exemption consolidates and levels off, whereas in Austria its effect continues to rise until the end of the time horizon of the prediction.

The next figures 4.8 – 4.9 also suggest that individual incentives have quite different effects in the two countries.

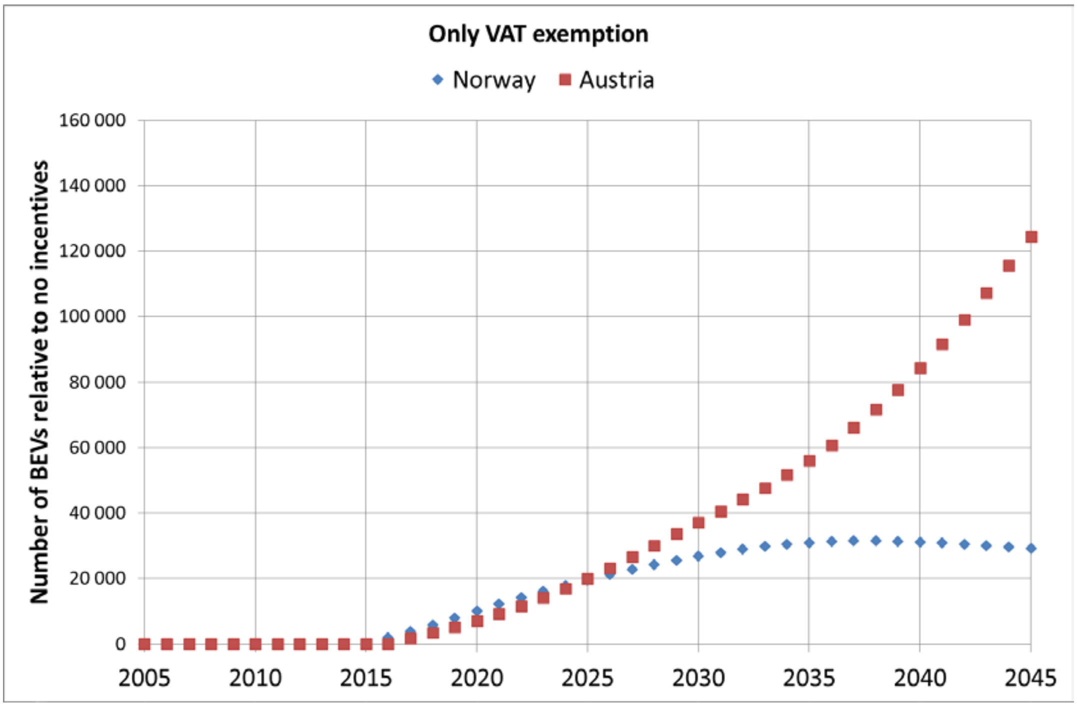



*Figure 4.7: Comparison of the number of registered BEVs in Norway and Austria – Only VAT exemption.*

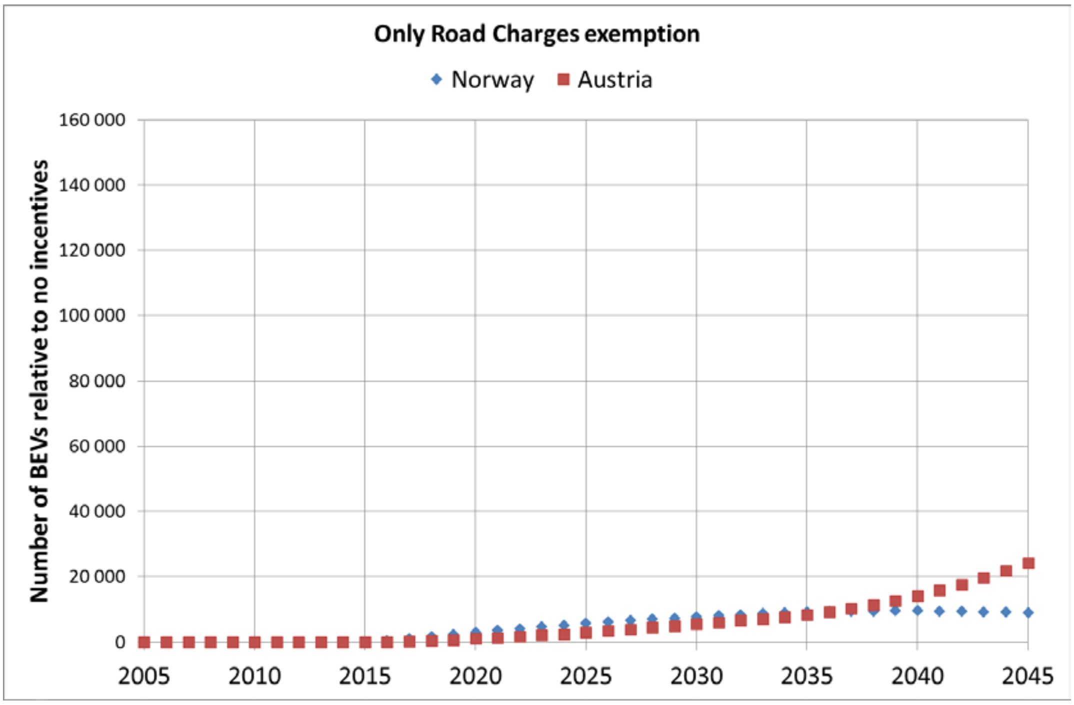



*Figure 4.8: Comparison of the number of registered BEVs in Norway and Austria – Only road charges exemption.*

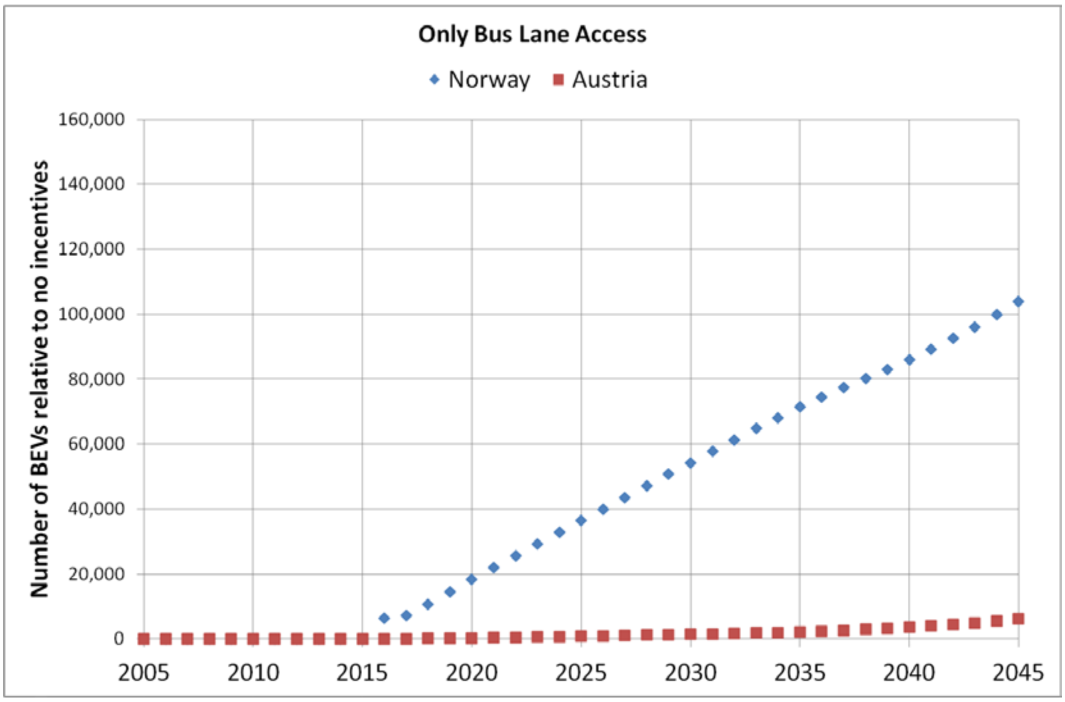



*Figure 4.9: Comparison of the number of registered BEVs in Norway and Austria – Only bus lane access.*

It is clear that the differences to some degree reflect the fact that the BEV markets in Norway and Austria have reached quite different levels of diffusion and saturation. This is evident from the next figures 4.10 and 4.11 which suggest that the Austrian BEV market is only about to take off, whereas in Norway it approaches saturation levels.

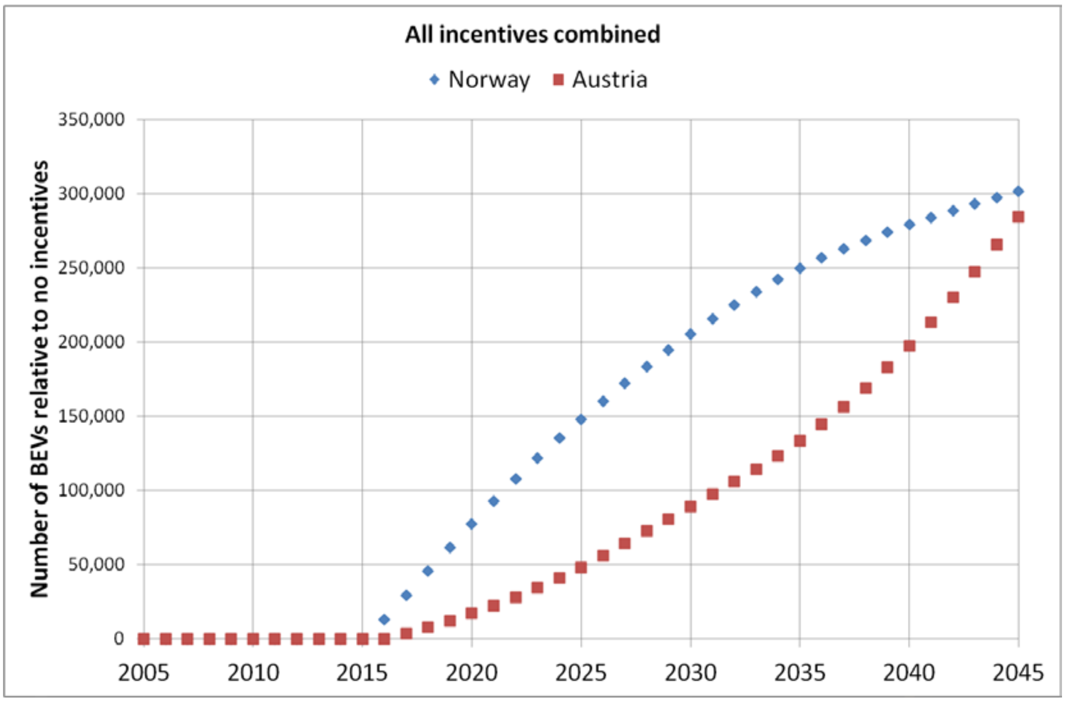



*Figure 4.10: Comparison of the difference in the number of registered BEVs in the scenarios: All incentives combined vs. No incentives - in Norway and Austria.*

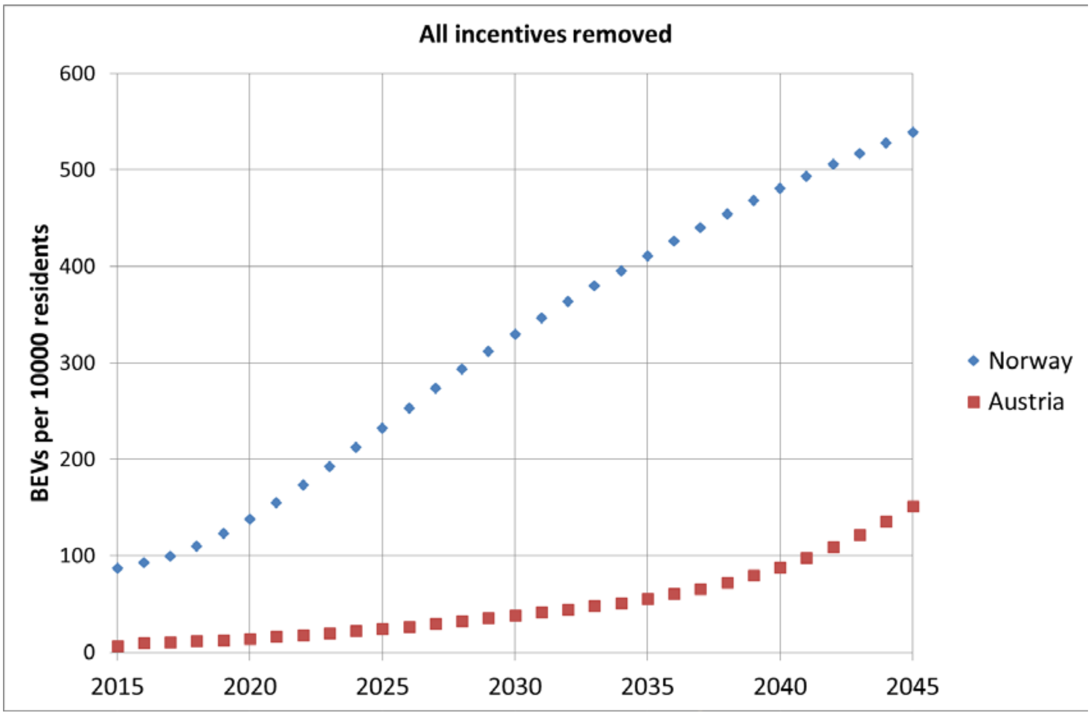



*Figure 4.11: Comparison of the number of registered BEVs per 10,000 residents in Norway and Austria – All incentives removed.*

## 4.4 Budget implications and fiscal cost effectiveness

### 4.4.1 Norwegian BEV incentives

When regarding fiscal cost effectiveness of BEV incentives, we look at their effectiveness (as studied in the previous sub-section) with regard to their impact on public budgets. The budget impacts can be direct, like for example the cost of a subsidy or of a tax exemption. The impact can also be indirect, like when lower ICE market shares reduce revenues from fuel taxes.

Within SERAPIS, electromobility affects the government's annual budget by changes in the following items[12]:

- Value added tax (VAT)
- Purchase tax
- Electricity and fuel tax
- Annual tax
- Road charges
- Parking charges

As explained above, all user incentives apply to all BEVs, even if they are not generated by the incentive in question. So, for example, free parking will apply to all BEVs and not only the relatively small number of BEVs that are generated by this incentive. Figure 4.3, below, is generated by the same SERAPIS model runs as in the previous sub chapter. We designed a Norwegian "base" run, BRN, where all Norwegian incentives are removed (other assumptions are the same as the base scenario described in chapter 5.1, below). From BRN, we introduce individual incentives and estimate the effects. Finally, we run a model where all current incentives remain in place all years, which would be the opposite extreme of removing all incentives. Neither of the extremes are realistic futures. However, the BRN is a convenient benchmark from which we analyse what happens when incentives are introduced one by one. Even without any particular BEV incentives, BRN is associated with government deficits relative to 2015 levels of revenues from car taxes and charges. SERAPIS estimates current (2015) revenue levels from these sources to lie around NOK 53bn. These revenues will fall to about NOK 48bn per year in 2045 if all BEV incentives are removed in 2015. We see that a discrete introduction of either bus lane access, road charges exemption, parking charges exemption, annual tax rebate, or VAT exemption is associated with relatively small revenue losses relative to BRN. Revenue losses from the introduction of bus lane access, for example, are only indirect, via petrol taxes. It should be noted that those that are allowed to use the bus lane will enjoy the benefit of reduced time cost. Purchase tax exemption, on the other hand, is associated with relatively large revenue losses. Introduction of this incentive, alone, is associated with a revenue loss of around NOK 6bn. If all current incentives remain in place throughout the period, the revenue loss is huge. This loss is due to reduced revenues from all sources of government revenues that are listed above.

---

[12] We allocate all revenues to 'the government' as a representative of public budgets which in fact also include local governments (parking charges) and toll road companies (road charges).

The very visible break point in government revenues around year 2025 is because fuel tax is set to increase a little every year between 2014 and 2025 but then stabilises. Revenues from fuel tax will fall, as electromobility increases and as ICE engines become more fuel-efficient.

It is evident that in 2045, government automobile-related revenues lie below their 2015 levels even without any electromobility incentives in place. However, annual revenues are app. NOK 15bn higher than in the BRN benchmark with full BEV incentives.

Chapter 6 presents strategies to maintain government revenues such that electromobility is compatible with the need for fiscal balance.

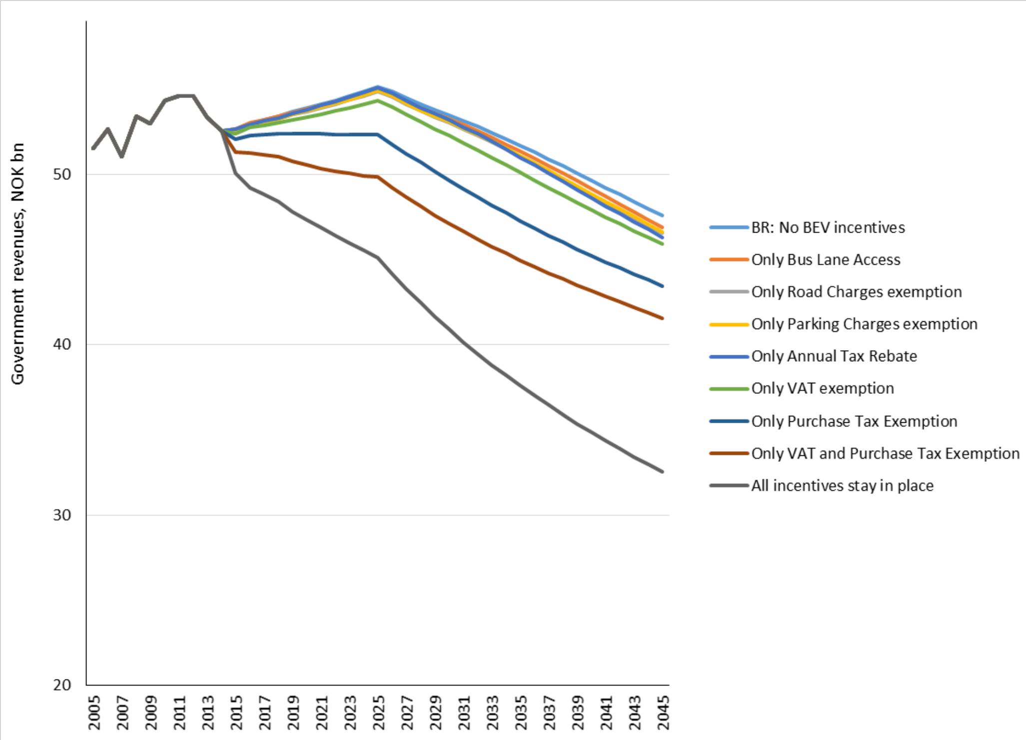



*Figure 4.12: Government net revenues per year in NOK bn. Effect of different incentives relative to a* base run *where no BEV incentives exist after 2015.*

Figure 4.13, below, gives a year 2020 snapshot of the effects of the different Norwegian BEV incentives as produced by the SERAPIS model runs. The figure shows, for example, that the effect of VAT exemption is, *ceteris paribus*, to add some 10,000 additional BEVs in the Norwegian market at a cost of around NOK 0.5bn. This comes in addition to the roughly 75,000 BEVs that would be on the road even if all incentives were withdrawn from 2015 (of which about 45,000 had already been sold up to that year). A linear trend line is added in order to visualise the relationship. It shows a clear positive relationship between effects and costs. This underlines the fact that market introduction of e-vehicles inevitably comes at a considerable cost. The most budget cost effective policies are to be found below the trend line and would contribute to the most BEV sales per budget cost unit. Again, we see that bus lane access is associated with a small burden on public budgets compared with its impact on BEV take-up. Therefore, it is the most cost effective policy among those studied in the figure. However, the impact of bus lane access is limited to around 18,000 BEVs in 2020. Expansion beyond this number of BEVs requires additional incentives. The rational choice would be to add more of the most cost effective policies because they add most BEVs at the least cost. However, it is clear from the figure that a substantial impact on BEV sales can only be achieved with the additional inclusion of less cost effective policies.

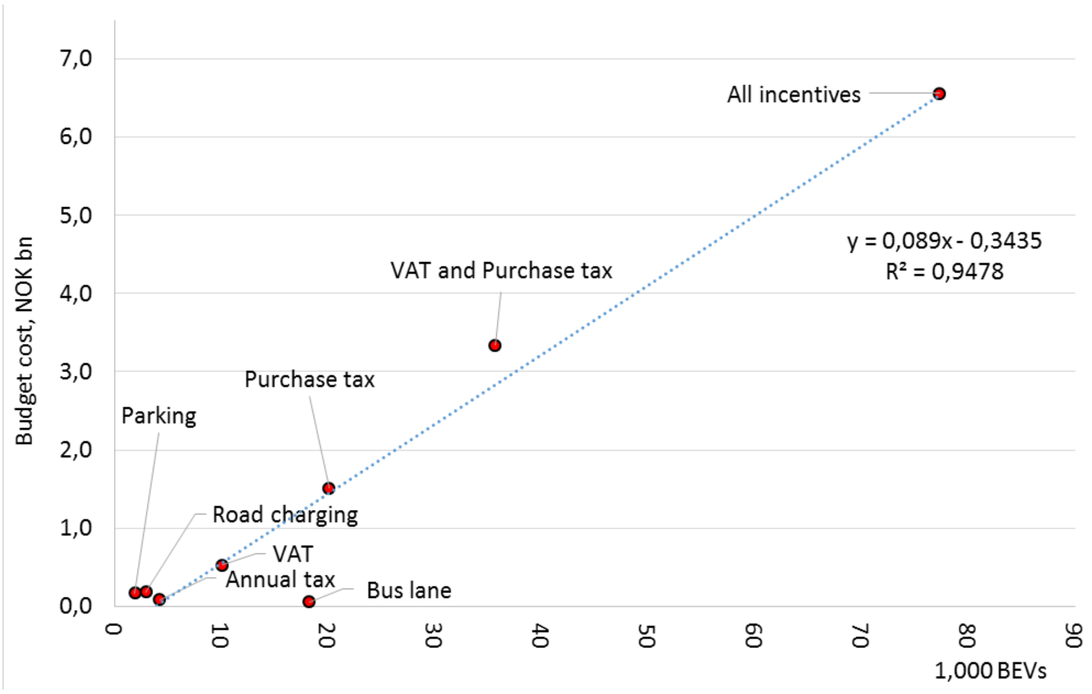



*Figure 4.13: Effects in 2020 of individual BEV incentives: Budget cost (in NOK) and effect in terms of BEV stock generated (in thousands), and a linear trend.*

Table 4.5 below summarises the findings of figure 4.13, above, and calculates government budget cost per BEV as an indicator of cost effectiveness. Bus lane access, the most cost effective policy, is associated with about NOK 3k governmental revenue loss per BEV generated to the market. Free BEV parking is the least cost effective single policy and, as shown above, is also among the least effective policies. The combination of VAT exemption and purchase tax exemption is also a costly way to introduce electromobility, although it generates a large demand for BEVs.

Synergies are not apparent. The total package of all incentives has a high cost per BEV generated to the 2020 car fleet.

*Table 4.5: Government cost, market impact and cost per BEV of incentives in 2020. NOK and number of BEVs.*

| BEV policy | Effect, number of BEVs | Budget effect ("cost"), NOK millions | Cost per BEV ('Cost effectiveness'), NOK |
|---|---|---|---|
| VAT exemption only | 10 102 | 527 | 52 143 |
| Road charges only | 2 949 | 186 | 63 021 |
| Free Parking only | 1 882 | 171 | 90 719 |
| Annual Tax only | 4 240 | 82 | 19 305 |
| Purchase Tax only | 20 101 | 1 514 | 75 332 |
| VAT and Purchase Tax | 35 700 | 3 340 | 93 546 |
| Bus Lane Access only | 18 255 | 55 | 3 025 |
| All incentives combined | 77 335 | 6 563 | 84 861 |

### 4.4.2 Austrian BEV incentives

Figure 4.14 shows the development of Austrian government net revenues per year in million Euros. The difference between the scenarios no BEV incentives, only annual tax rebate, only bus lane exemption, only direct subsidies and only parking charges exemption are relatively small. Revenues peak close to the year 2040. The revenues from the scenarios all incentives and all Norwegian incentives peak in 2024 and revenues of the final year 2045 are about 5% lower than in 2015.

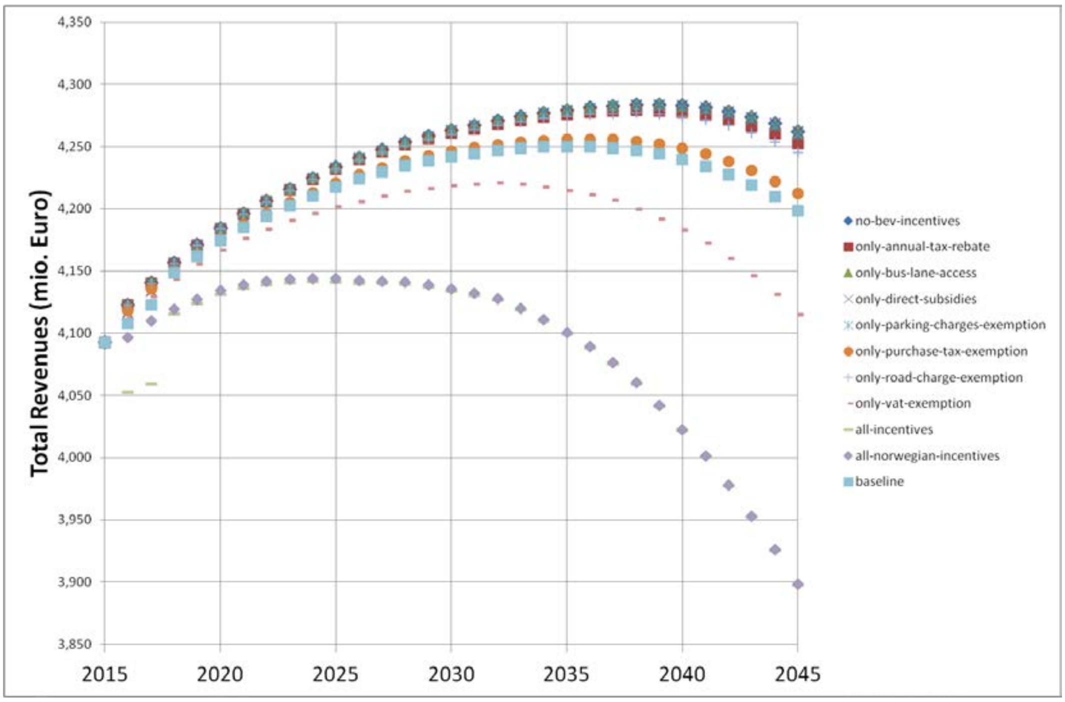



*Figure 4.14: Government net revenues per year in million Euros for different incentives and scenarios.*

Figure 4.15 shows the difference between the revenues in the scenarios with incentives and the scenario with no incentives. The scenarios only annual tax rebate, only direct subsidies and only parking charges exemption result in small relative losses. The scenario only bus lane exemption even results in a small cumulated gain of 6 million Euros. The scenario all incentives results in a cumulated loss of about 4,800 million Euros.

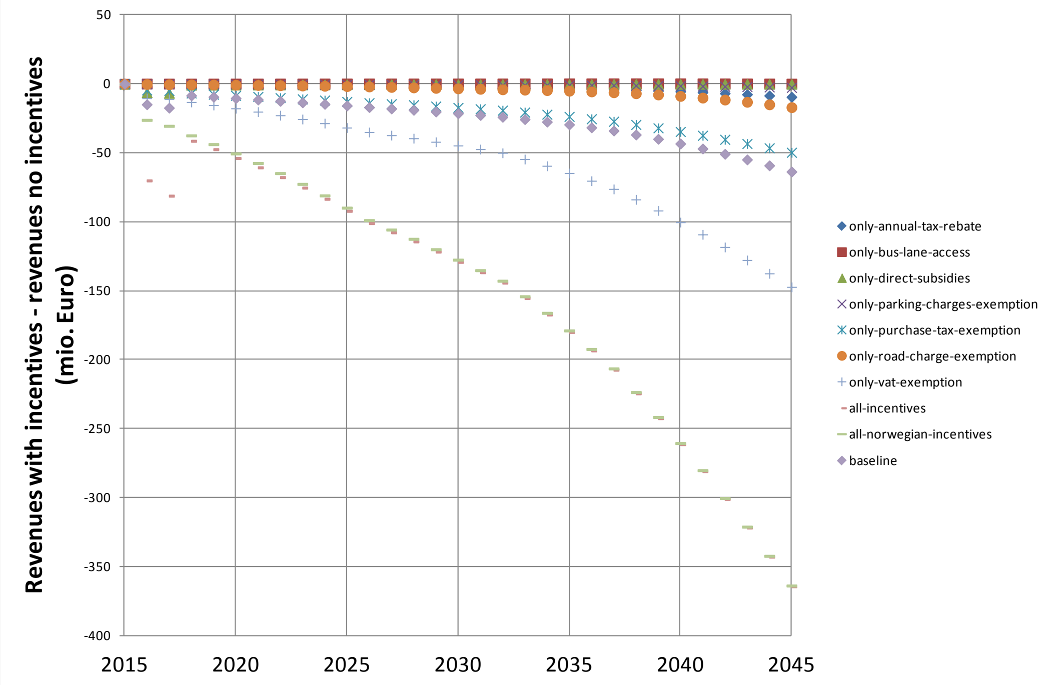



*Figure 4.15: Government net revenues per year in million Euros for different incentives and scenarios. Effect of different incentives relative to a base run where no BEV incentives exist after 2015.*

*Table 4.6: Government cost, market impact and cost per BEV of incentives in 2020. Euro and number of BEVs.*

| BEV policy | Effect, number of BEVs | Budget effect ("cost"), Euro millions | Cost per BEV ('Cost effectiveness'), Euro |
|---|---|---|---|
| VAT exemption only | 7,140 | 17.76 | 2,487 |
| Road charges only | 1,029 | 0.75 | 725 |
| Free Parking only | 103 | 0.21 | 2,007 |
| Annual Tax only | 456 | 0.54 | 1,183 |
| Purchase Tax only | 1,903 | 8.40 | 4,412 |
| Direct subsidies[1)] | 1,160 | 6.66 | 5,743 |
| All incentives combined | 25,063 | 53.88 | 2,150 |

[1)] Year 2017, subsidies phased out in 2018

## 4.5 Environmental impacts of EVs incentives

BEV policies and their impact on BEV market shares will affect total energy use and the mix of energy sources (liquid fuels and electricity). SERAPIS calculates this on the basis of assumptions regarding fuel consumption and electricity consumption per kilometre. This output is used to calculate effects of BEV policies on $CO_2$ emissions. $CO_2$ emissions from electricity production vary greatly across Europe. However, COMPETTs $CO_2$-emission calculation is based on the assumption that the EU

Emission Trading Scheme (EU ETS) is in operation and functions as intended: That means that the cap on $CO_2$ emission is constant independently of increases in the usage of electricity for transport. Any short term effects of accumulated emission credits that potentially cause the system to be less effective, are not taken into account. The result of replacing an ICE vehicle with a BEV driving equally many kilometres per year, will thus be to eliminate the ICE vehicle emission while keeping the emission within the EU ETS unchanged, i.e. a 100% reduction of $CO_2$ emissions. Even without EU ETS, this assumption still resembles the Norwegian electricity mix quite well, since it almost entirely produced by means of hydropower. The effect on the emissions of the various incentives is shown in figure 4.15.

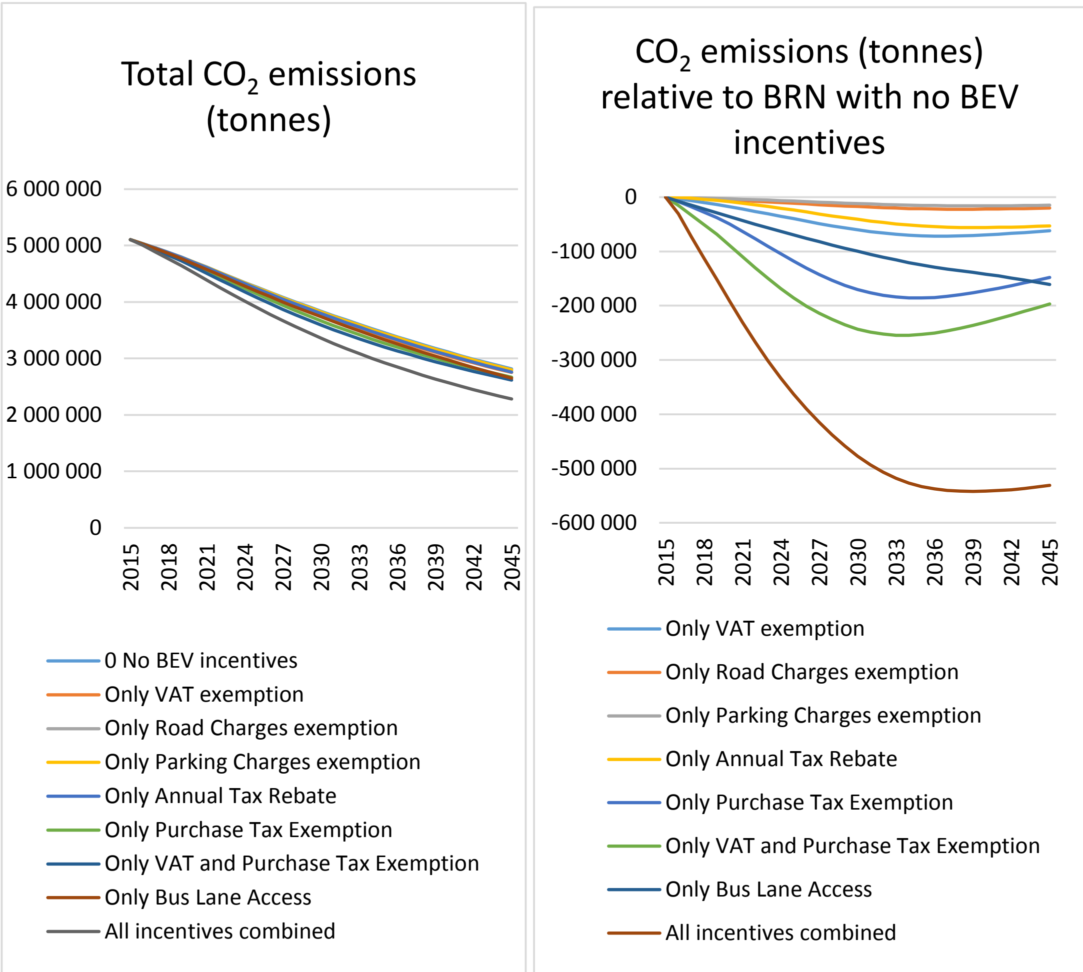



*Figure 4.15: Partial effects of various BEV incentives on tonnes of $CO_2$ emissions.*

Figure 4.16 shows the budget cost per tonne of $CO_2$.[13] The cost per tonne is so high because the cost is calculated from the entire BEV fleet. In figure 4.1, it was shown that the Base Run Norway (BRN) also generates a substantial number of BEVs that

[13] We here focus on the effect on public budgets, whose main effect is to transfer money to and from public budgets. This is different from resource cost effects, as used in Fridstrøm and Østli (2014). They identify long term resource costs per tonne of $CO_2$ which over time fall to levels below those identified here. They also assume shifts in motoring taxation that generate increased public revenues.

also receive incentives, adding to the cost in the numerator but not the number of vehicles in the denominator.

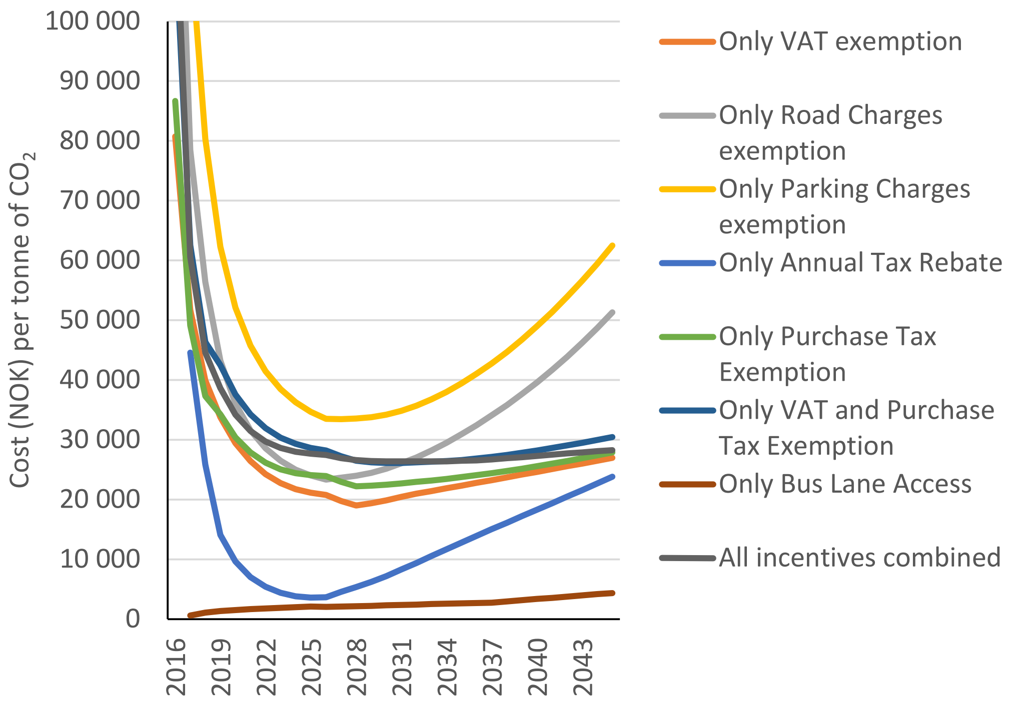



*Figure 4.16: Figure shows the budget cost per tonne of $CO_2$.*

Figure 4.17 presents the year 2020 costs from the previous figure. Bus lane access is by far the least costly policy for government budgets given the assumption of spare capacity in bus lanes. Most remaining BEV policies remove $CO_2$ at a budget cost of around NOK 30-40,000 per tonne.

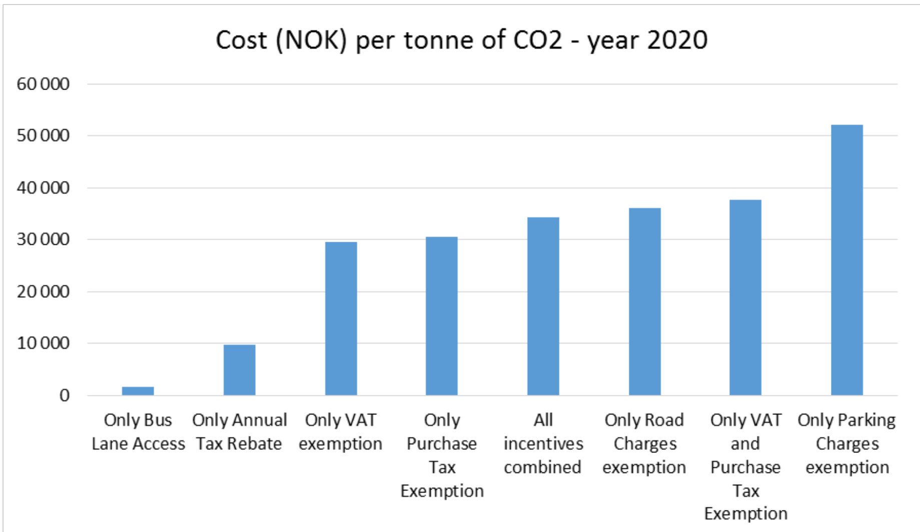



*Figure 4.17: Year 2020 net public budget cost (including lost government revenues) per tonne of $CO_2$ removed, relative to BRN. NOK.*

# 5 Scenario assessment

The purpose of a scenario exercise is to support and inform policymaking (Stead and Banister, 2003). While scenarios are not about producing exact forecasts, they are still relevant because they point to ways in which different policy options affect and create different possible futures. In this way they are a tool for strategic policy analysis.

Rather than predicting the future based on extrapolation of past trends, scenarios present and analyse *possible* futures. The scenario approach acknowledges uncertainty and, importantly, take account of the possibility for rapid change and trend breaks.

Scenario assessment is no exact method. In fact, a large diversity of approaches are reported (van Notten et al., 2003). Banister and Hickman (2013) develop a typology of scenario approaches. For the purpose of our task, three main approaches are particularly relevant:

1. "Forecast based" scenarios are a mix of probable as well as possible futures. The horizon is often short-term, the approach quantitatively oriented and is expert-led.
    - The COMPETT approach lies somewhere between short and long term, and the SERAPIS model exercise is essentially quantitative. However, SERAPIS modelling is not intended for forecasting, but rather to analyse alternative futures
2. Explorative approaches, (as opposed to trend extrapolation) which often focus on relevant external factors, i.e. those factors that make a difference for the outcome. The intention is to describe a plausible future state. Expert panels can inform the scenario designs. The perspective is long term.
    - The COMPETT approach is primarily inspired by this way of establishing scenarios.
3. Backcasting: This is a normative approach where a desirable future is designed. Then the exercise identifies possible trajectories between today and this image of the future.
    - While this kind of scenario building does not form a part of the scenario assessment in this chapter, this principle can be applied in order to identify the kind of policy measures that are necessary, and their intensity, to reach certain goals

## 5.1 Definition of a base scenario and alternative scenarios

A first step of the scenario assessment is to define a base scenario. The base scenario includes historical data from 2005 to 2013/14 and projections till 2045. Ideally, this represents a realistic future given our current knowledge and known future policies. The base scenario for Norway was defined during an internal expert workshop on the 17th of March 2015. For elements with an international or even worldwide dimension, the Austrian base scenario adopts the same assumptions as the Norwegian base scenario. National attributes are based on expert judgement. The base scenarios are characterised as follows:

- **Net prices and range**:
  → Battery technology improves rapidly. Given the characteristics of the market, it is expected that most of this gain translate into improved range rather than lower prices – at least in the near future. We anticipate a major improvement of 75 percent in battery range in the compact and family segments with second generation EVs with Li-Ion batteries coming to dealers in 2017. This is followed by a modest 3.5% annual improvement thence. The luxury BEV market will experience a smaller improvement of 37.5 percent in 2019 (as it already offers range up to 500 km) and thereafter improve gradually like the other segments.
  → Range is cut off at a real world range of 350 km, 450 km and 650 km for compact, family and luxury BEVs, respectively. After these ranges have been achieved, the annual 3.5 percent improvement translates into annual price reductions of 2.5% rather than further range. This leads compact and family BEV prices to fall approximately to the levels of ICE cars by 2045. Luxury BEVs will still be more expensive than ICEs in 2045.
  → The prices of luxury BEV segment is expected to increase in Norway in 2015 due to large changes to the currency rates.
  Figure 5.1 illustrates the way range and net price assumptions interact.

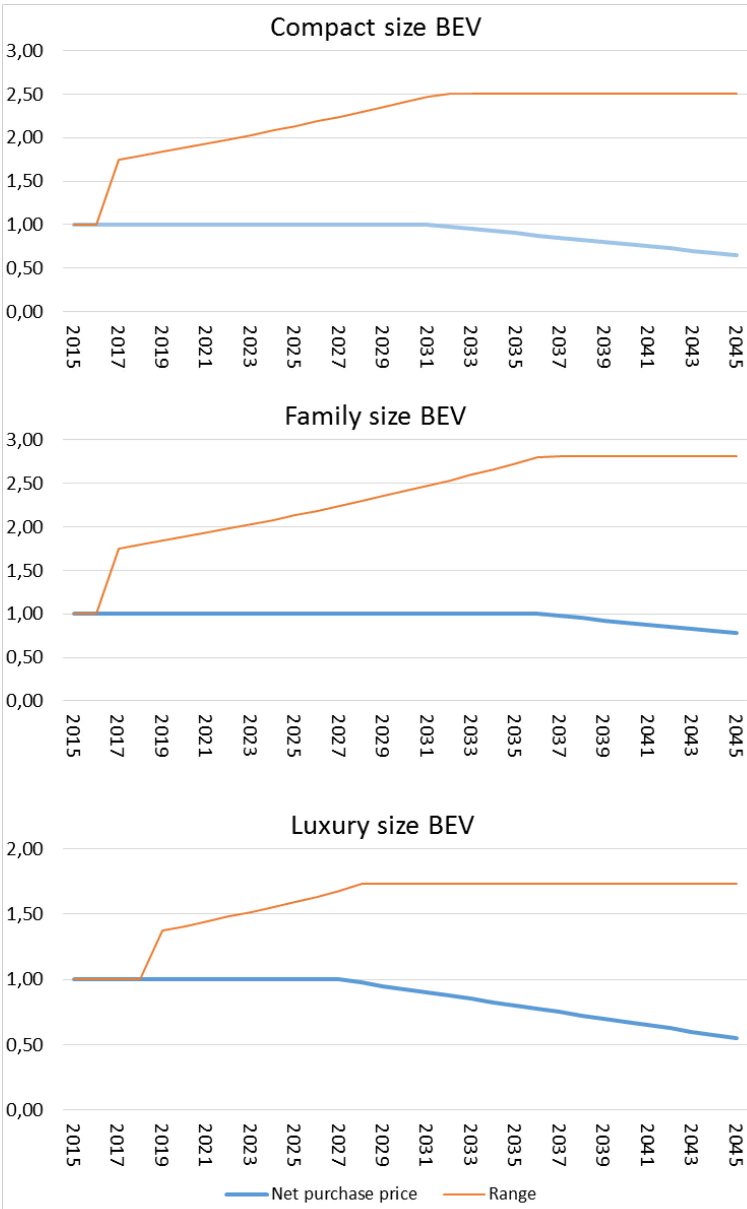



*Figure 5.1: Assumptions regarding developments in net purchase price and range 2015-45. Range increases up to where a threshold is reached, whereafter technology improvements result in lower net purchase prices. Index 2015 = 1.00.*

- **Incentives**: While in Norway BEVs currently enjoy free **toll roads**, the base scenario assumes that BEVs will pay half the ICE rate from 2017. In zones without road charges this will not change anything, whereas it can be a sharp increase in the most heavily tolled areas. BEV **parking** will remain free. In Austria BEVs do not enjoy free toll roads nor free parking. It is assumed that this will not change in the base scenario. **Annual circulation tax** will, according to the Government's 2015 declaration, increase to 50% of ICE tax in 2018 and 100% of ICE annual tax in 2020. In Austria BEVs enjoy an exemption from the annual circulation tax while PHEVs enjoy a rebate of about 25%. It is assumed that this will not change in the base scenario.
- **VAT:** In Norway, VAT is gradually introduced on BEVs from 2018, starting at 8 %, and increases to 13 % in 2023 and again to 25 % from 2028, which is the

same level as for ICEs. There is no VAT exemption in Austria. It is assumed that this will not change in the base scenario.

- **Purchase tax**: In Norway, purchase tax on compact and family sized BEVs is set at zero throughout the period. In the luxury segment, purchase tax will increase gradually from 0% to 20 % over the period 2017-2021. While Norwegian PHEV prices increased in 2014, they fell again in 2015 due to a purchase tax revision. Purchase taxes on compact and family PHEVs are relatively low and are expected to fall further – to zero for compact PHEVs from the current level of 4 percent (and 36% on compact ICEs); and to 0 percent from the current level of 4 percent for family PHEVs (it is 59% for ICEs throughout the period). The luxury PHEV segment tax is expected to remain stable at 34 percent, compared with 71 percent for ICEs. In Austria BEVs enjoy an exemption from the purchase tax. PHEVs enjoy a rebate of about 30% to 50% depending on vehicle size. It is assumed that this will not change in the base scenario.
- **ICE fuel consumption** is expected to fall by about 1.4 percent per annum up to 2020 due to the Norwegian Government's goal of 85 gram of $CO_2$ per km on average for new cars (includes EVs and PHEVs) by 2020. (EU's goal is 95 grams of $CO_2$.). The trend continues to 2045 but slows down after 2020.
- The **cost of liquid fuels** will increase by 3.2 percent per year up to 2025, which is the average real price increase 2005-13. From 2026, fuel cost will increase at the same rate as fuel consumption decreases, to keep fuel costs per car constant in Norway.
- **Makes and models**: While the ICE market is assumed mature and stable (at a total of 4,000 makes and models and variants), it is expected that the number of makes, models and specifications of BEVs and PHEVs will continue to increase as more car manufacturers enter the market and the existing ones launch new EV models. Due to lack of information, we assume a modest increase of 2 additional models per year per segment (compact/family/luxury) of BEVs and 2 per year for family and luxury PHEVs.
- The Norwegian **user value of BEV advantages**, like easier parking and bus lane access, are expected to diminish to zero by 2030. There are no such advantages in Austria.
- **Direct subsidies**: There are no direct subsidies for the purchase of BEVs in Norway. In some Austrian federal provinces, the purchase of BEVs is directly subsidised. In one federal provinces, also the purchase of PHEVs is subsidised. It is assumed that these subsidies will stop in 2018.

Apart from these assumptions, all other factors are assumed to be constant or to change by a historically relatively constant rate. For example, car life span is expected to increase 0.4 percent per year throughout the period, which is in line with observed historical development and expectations; while the share of compact cars in the market is assumed to remain stable at today's level and VAT levels on ICEs, PHEVs and BEVs (VAT gradually introduced in Norway) will remain as they are today.

## 5.2 Scenario definitions

During an expert workshop on the 20th of March 2015 the COMPETT project identified two key dimensions of change which are deemed relevant for the evolution of the electromobility market. These are: technological innovation, and intensity of supporting policies.

*Technological innovation* is in principle a question of battery technology. Innovations are expected to contribute to either longer battery range or lower production costs, or a mix of lower price and better range. Innovation will also cause more electromobility vehicles makes and models to enter the market and thereby offer more choice to the consumer. Other improvements to vehicles such as reduced aerodynamic drag, lower weight and more energy efficient subsystems will also contribute to increasing range and to reduce range variability.

*Intensity of supporting policies* is the degree to which local, regional and central governments make use of various policy instruments to support electromobility. The instruments may either be fiscal (e.g. tax rebates, subsidies, or taxation of alternatives to EV) or regulatory (e.g. EV access to bus lanes or dedicated parking). Policies may also support electromobility in a number of other ways, like enablement of car sharing schemes, R&D, public procurement, and standardisation of battery charging equipment.

Based on these dimensions, four scenarios are designed. They are illustrated in figure 5.2, and explained in more detail below. The scenario assessment compares these scenarios with the outcomes of the base scenario.

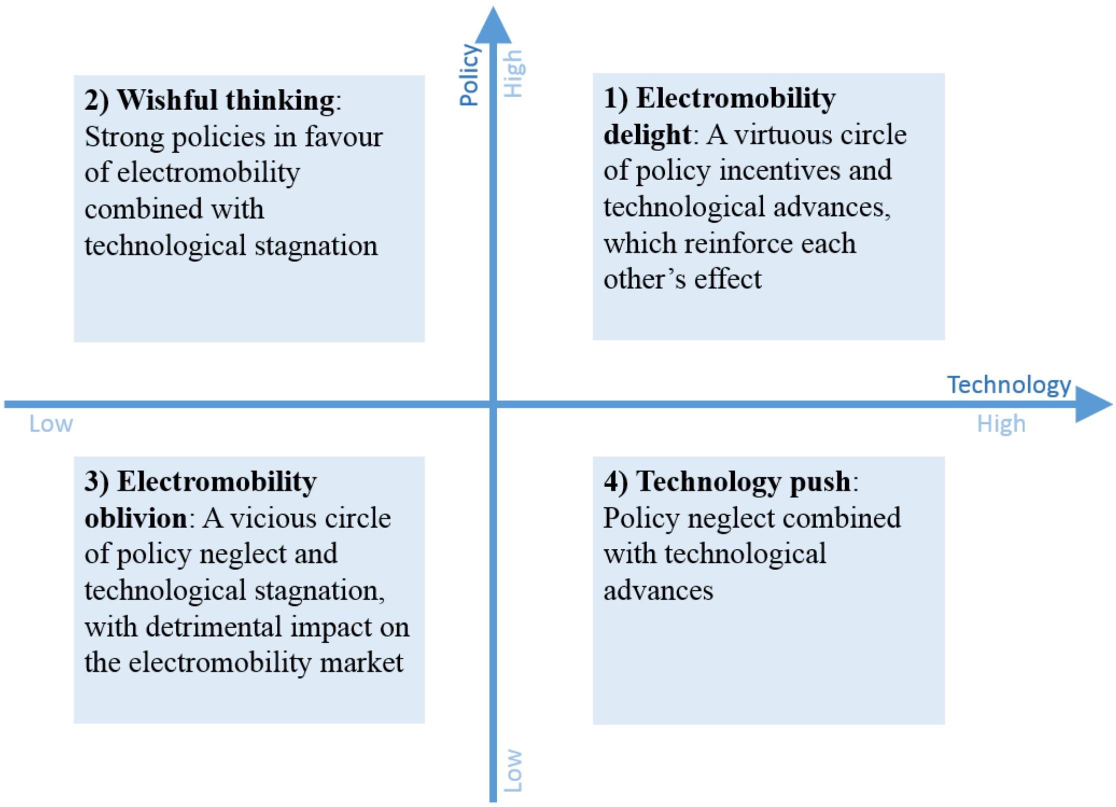



*Figure 5.2: Four Norwegian electromobility scenarios.*

### 5.2.1 Norway

The tables below explain key assumptions for the four scenarios, relative to the base scenario. Table 5.1 describes technology and supply factors, and table 5.2 describes policy factors.

*Table 5.1: Key characteristics of the four scenarios and base scenario. Technology and supply factors*

| | Base scenario | 1) Electromobility delight: | 2) Wishful thinking | 3) Electromobility oblivion: | 4) Technology push |
|---|---|---|---|---|---|
| EV net prices | Stable until battery technology (range) improves. Then 2.5% annual reduction | 2.5% price reduction per year from 2018 and until prices are equivalent to ICEs | Half the reductions of the base scenario | Half the reductions of the base scenario | 2.5% price reduction per year from 2018 and until prices are equivalent to ICEs |
| Range | Major improvements before 2020 followed by an annual 3.5% improvement up to cut-off levels | Same as base. (Improvements translate into faster cost reductions) | 1% improvement rather than the 2.5% in the base scenario (from same years) | 1% improvement rather than the 2.5% in the base scenario (from same years) | Same as base. (Improvements translate into faster cost reductions) |
| Makes and models | Increase of 2 per year per segment of BEVs and 2 per year for family and luxury PHEVs | 10 new makes/models each year for both BEVs and PHEVs | Same as base scenario | Stabilises at 2017 levels | 10 new makes/models each year for both BEVs and PHEVs |
| ICE fuel consumption and vehicle cost | Annual reduction of about 1.4 percent per annum up to 2020 followed by slower reduction | Same as base scenario | Same as base scenario | Same as base scenario | Same as base scenario |

*Table 5.2: Key characteristics of the four scenarios and base scenario. Policy factors*

| | Base scenario | 1) Electromobility delight: | 2) Wishful thinking | 3) Electromobility oblivion: | 4) Technology push |
|---|---|---|---|---|---|
| VAT exemption | 0% 2005-17<br>8% 2018-22<br>13% 2023-27<br>25% 2028→ | Base scenario developments postponed 5 years | Same as 1 Electromobility delight scenario | 0% 2005-17<br>8% 2018-19<br>13% 2020-21<br>25% 2022→ | 0% 2005-17<br>8% 2018-19<br>13% 2020-21<br>25% 2022→ |
| Purchase tax | • Luxury BEV: from 0 to 20% 2017-21.<br>• Other BEVs: 0%<br>• Compact and family PHEVs fall to zero<br>• Luxury PHEV 34% | Same as base but luxury BEV tax is kept at 0% | Same as 1 Electromobility delight scenario | BEV and PHEV tax set to ½ that of ICEs of same car segment. Phased in over five years starting in 2020[14] | BEV and PHEV tax set to ½ that of ICEs. Phased in over five years starting in 2020 |
| Toll Road | Free 2005-2016, then ½ ICE rates | Base scenario development postponed 5 years | Same as 1 Electromobility delight scenario | Full payment from 2017 | Full payment from 2017 |
| Parking fees | Free | Free | Free | Full fees from 2020 | Full fees from 2020 |
| Petrol tax and cost of liquid fuels | 3.2% increase 2014-2025. After 2026 price will increase inversely of reduced car fuel consumption.<br>Petrol tax increases at same percentage as petrol price. | Annual increase of 3.2% in petrol price (pump price) throughout the period to 2045 due to petrol tax and oil price increases. Petrol tax increases at same percentage as petrol price. | Same as 1 Electromobility delight scenario | Same as base scenario | Same as base scenario |
| User value of estimated time savings of EV bus lane access and dedicated parking | Gradually reduction to zero in 2030 | Twice as fast reduction as in base scenario, due to congested bus lanes and parkings | Same as base scenario | Twice as fast reduction as in base scenario, due to unfavourable policy | Twice as fast reduction as in base scenario, due to unfavourable policy |

## 5.2.2 Austria

The table below explains key assumptions for the four scenarios, relative to the base scenario. Technology and supply factors are the same as in the Norwegian case study. Table 5.3 describes the Austria-specific policy factors.

[14] Cf. The Norwegian Climate Policy settlement, which states that EVs and low-emission vehicles shall fare well in the tax system.

*Table 5.3: Key characteristics of the four scenarios and base scenario. Policy factors*

| | Base scenario | 1) Electromobility delight: | 2) Wishful thinking | 3) Electromobility oblivion | 4) Technology push |
|---|---|---|---|---|---|
| VAT exemption | no exemption | no exemption | no exemption | no exemption | no exemption |
| Purchase tax | • 0% for all types of BEVs<br>• 2.8% instead of 6.1% Compact PHEV<br>• 5.0% instead of 7.3% Compact PHEV<br>• 9.5% instead of 14.0% Compact PHEV | Same as base | Same as base | BEV and PHEV tax set to ½ that of ICEs of same car segment. Phased in over five years starting in 2020 | Same as 3) Electromobility oblivion |
| Toll Road | BEV and PHEV same as ICE | Free 2015-2020, then ½ ICE rates | Same as 1) Electromobility delight scenario | Same as base | Same as base |
| Parking fees | No exemption | No exemption | No exemption | No exemption | No exemption |
| Petrol tax and cost of liquid fuels | 3.2% increase 2014-2025. After 2026 price will increase inversely of reduced car fuel consumption.<br>Petrol tax increases at same percentage as petrol price. | Annual increase of 3.2% in petrol price (pump price) throughout the period to 2045 due to petrol tax and oil price increases. Petrol tax increases at same percentage as petrol price. | Same as 1 Electromobility delight scenario | Same as base scenario | Same as base scenario |
| User value of estimated time savings of EV bus lane access and dedicated parking | No time savings | No time savings | No time savings | No time savings | No time savings |
| Direct subsidies | Subsidies stop in 2018 | Phase out is postponed by 5 years | Same as base | Subsidies stop in 2016 | Same as 3) Electromobility oblivion |

## 5.3 Scenario analysis and assessment

### 5.3.1 BEV uptake

The four scenarios combine different levels of policy intensity and supply side developments. Figure 5.3 illustrates the overall SERAPIS results with respect to the number of BEVs they generate in the market. In the baseline scenario, BEV market shares increase throughout the period but the growth rate starts to level off around year 2017 in Norway. By 2045, the estimated BEV fleet is around 482,000 in the Norwegian baseline scenario.

It is evident that technology and the supply side constitute the main driver for market uptake of BEVs. BEV-friendly policies can do little to increase the market shares beyond the base scenario. Note that the Norwegian base scenario already consists of the world's most forceful BEV incentives. Any major increase from even stronger incentives is unlikely. The importance of technology/supply side corresponds well with the observations in figure 2.2 of Chapter 2.2.1. There, it was clear that the huge market expansion did not happen until the technology had made a leap – despite the fact that BEV incentives had been in place for many years. Chapter 5.3.5 shows that a larger selection of makes and models will have a large impact on sales, highlighting the need for supply side measures.

Only the "Oblivion" scenario generates a BEV market below the baseline.

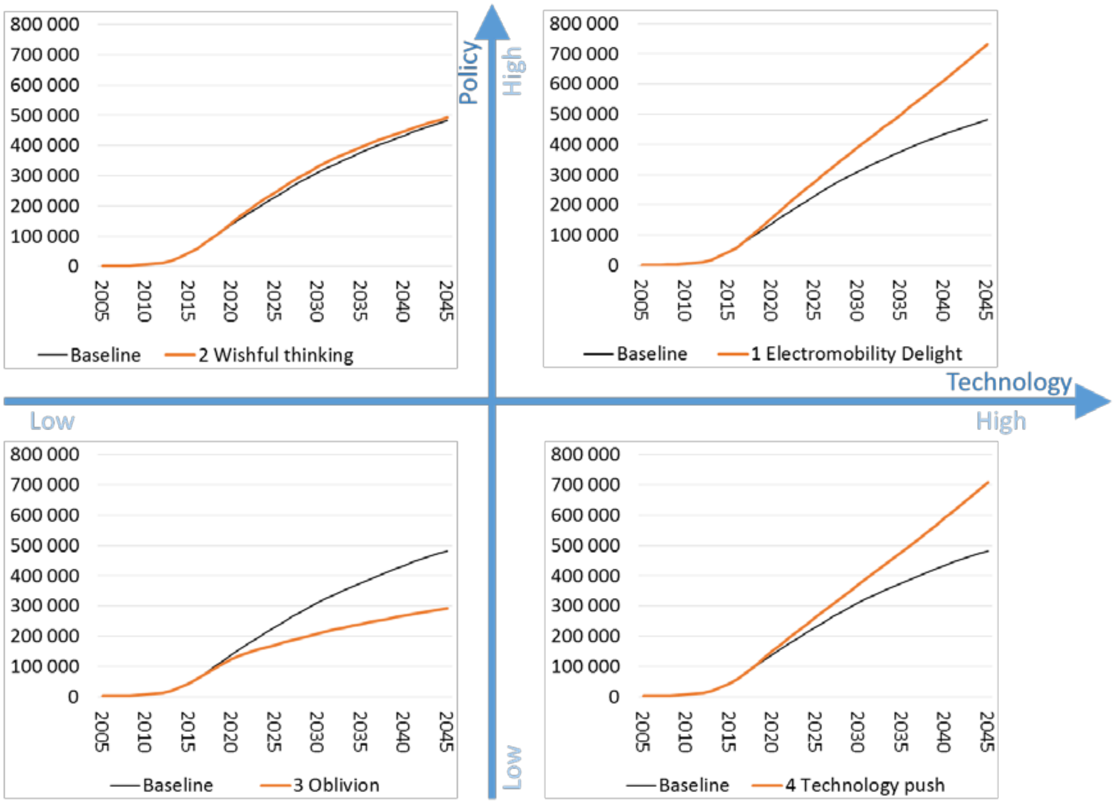



*Figure 5.3: BEV fleet development in Norwegian scenarios 1-4 (red line) relative to base scenario (black line).*

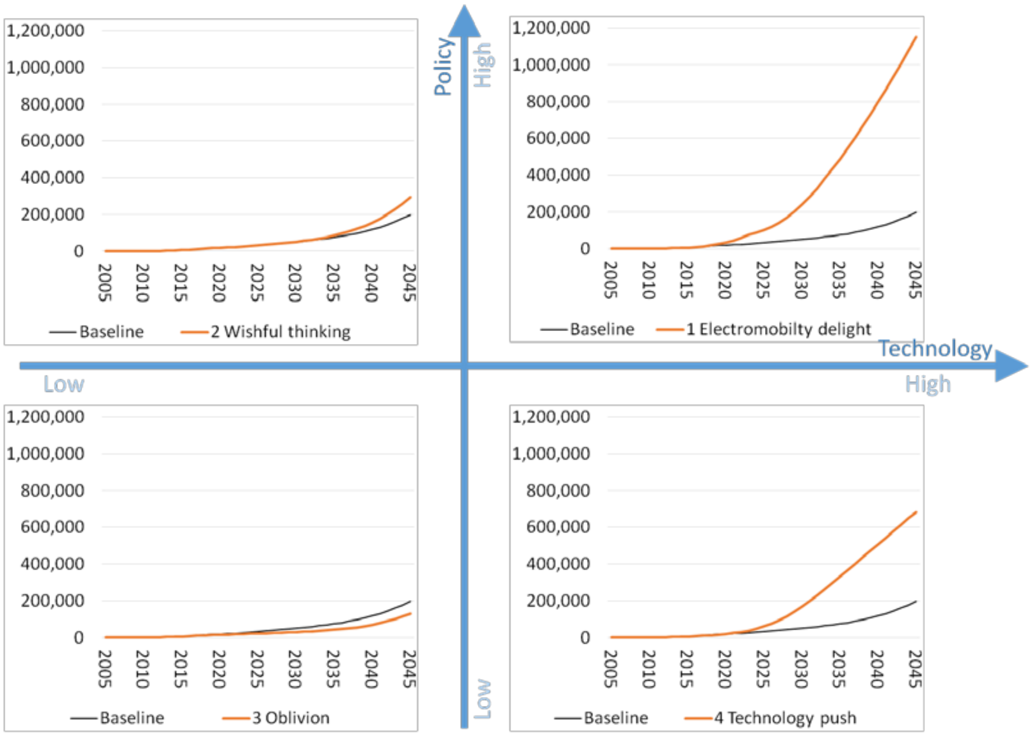



*Figure 5.4: BEV fleet development in Austrian scenarios 1-4 (red line) relative to base scenario (black line).*

### 5.3.2 Public budgets

The four scenarios affect public budgets in quite different ways. This is shown in figures 5.5 and 5.6, and detailed in a breakdown of revenue sources in figures 5.7 and 5.8. The "Oblivion" scenario where the BEV market stagnates, generate most public revenues from motoring. This is due to a combination of fewer BEV exemptions and rebates and to higher ICE market shares, which also generate fuel tax revenues. Fuel tax revenues remain high in Scenarios "1 Delight" and "2 Wishful thinking" due to the policy of increasing petrol taxation. In the two other scenarios, 3 and 4, fuel taxes are not different from the base scenario and therefore falling over time as electromobility increases and ICEs become more fuel-efficient.

Purchase tax revenues appear to be more influenced by BEV market share than by policy choice. Only the "oblivion" scenario maintains a stream of high purchase tax revenues throughout the period.

In Austria, a growing passenger vehicle fleet is assumed whereas in Norway it was assumed to be constant. This assumption will have an impact on the calculation of the budget costs of EVs. In a growing market, the budget revenue losses of an increasing share of EVs would be masked by the increase in the total number of vehicles, as seen in the different effects in Norway and Austria. See also chapter 5.3.5.

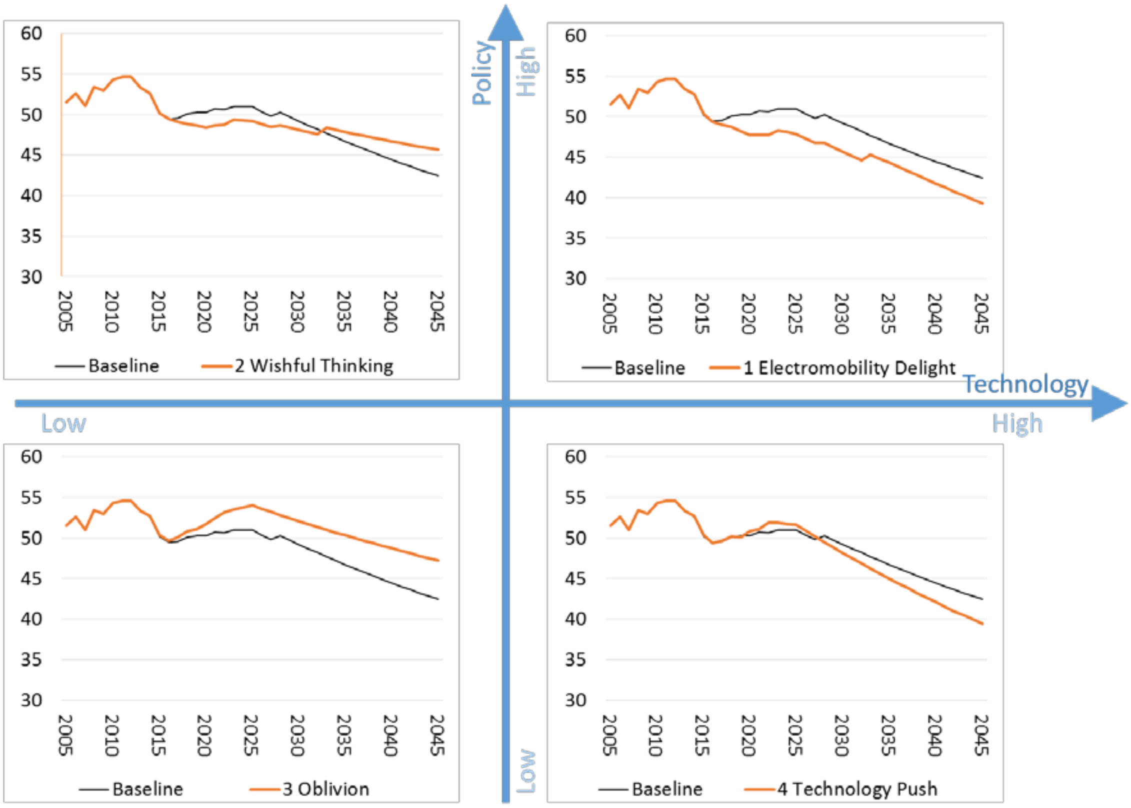



*Figure 5.5: Total Norwegian public revenues from private motorism. NOK billions.*

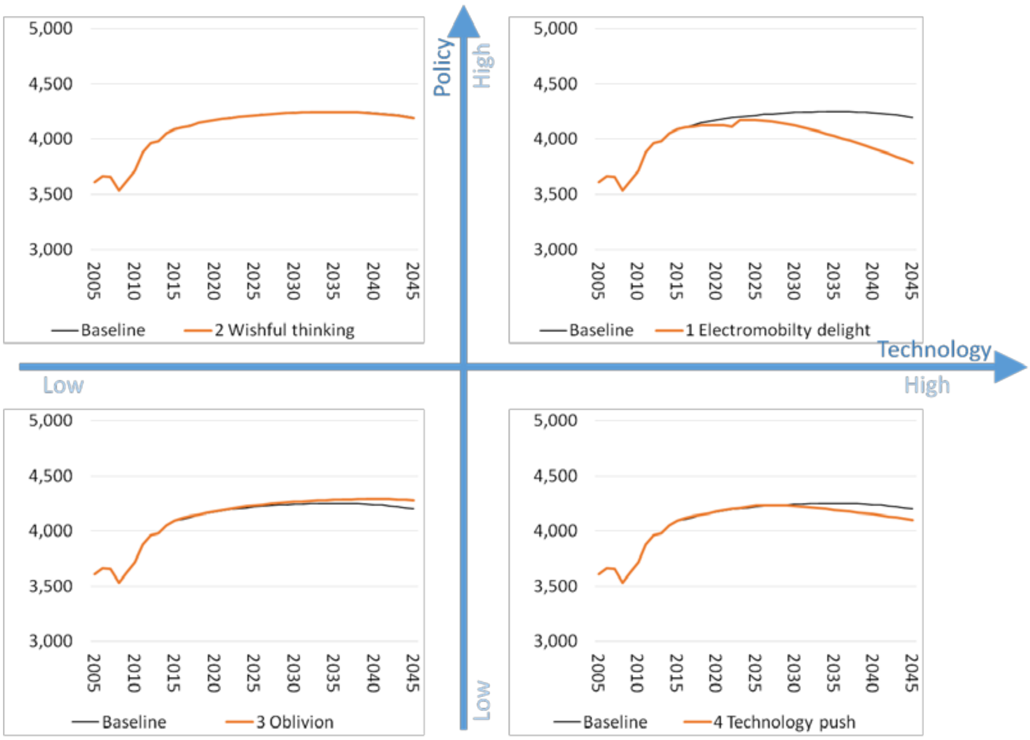



*Figure 5.6: Total Austrian public revenues from private motorism Austria. Million Euros.*

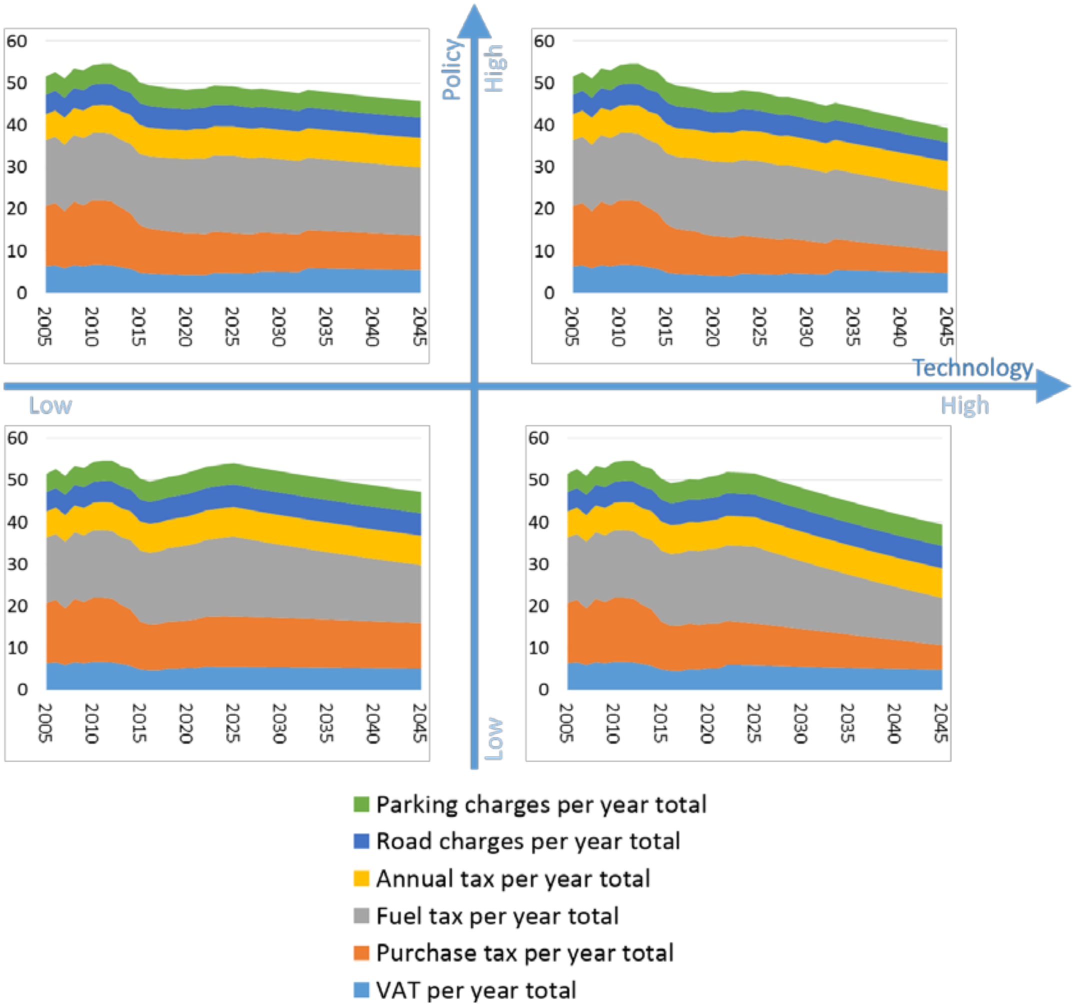



*Figure 5.7: Sources of government revenues in four Norwegian scenarios. NOK billions.*

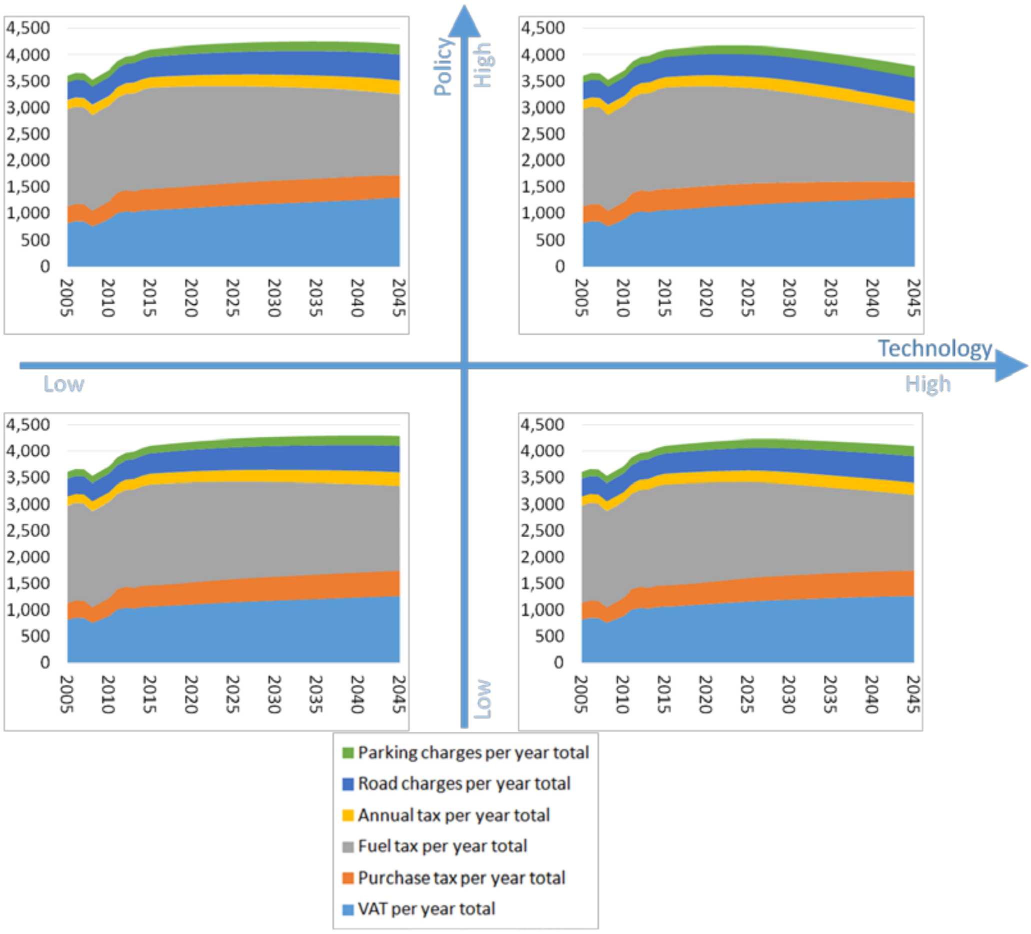



*Figure 5.8: Sources of government revenues in four Austrian scenarios. Million Euros.*

### 5.3.3 Energy consumption

Figures 5.9 and 5.10 show how consumption of liquid fuels and electricity, respectively, vary in the four scenarios. Again, we see that fuel and electricity consumption varies a lot more with different supply-side assumptions than with policies. The "1Electromobility delight" scenario reduces fuel consumption by approximately 15 percent or 156 million litres, but increases electricity consumption by about 70 percent or about 1300 million kWh per year.

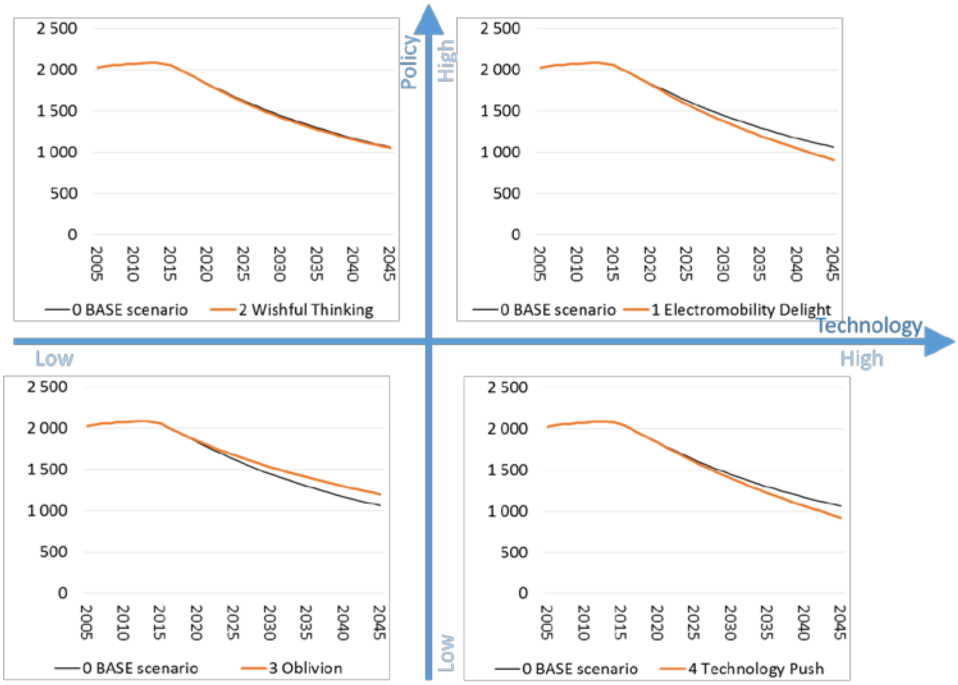



*Figure 5.9: ICE liquid fuel consumption per year, Norway, million litres.*

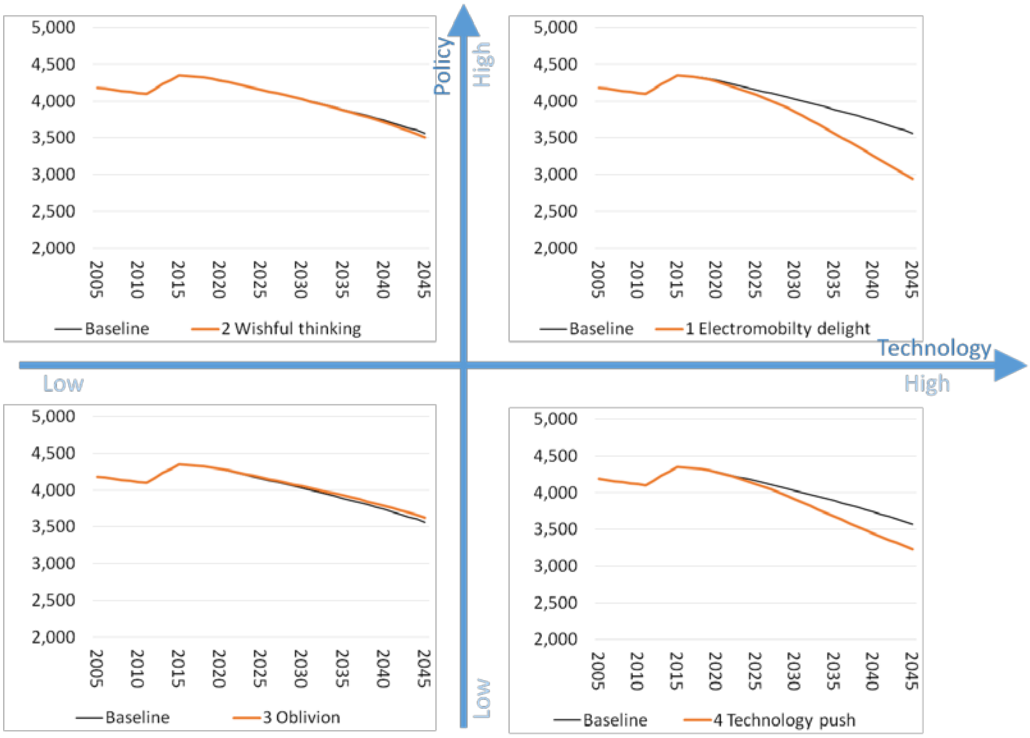



*Figure 5.10: ICE liquid fuel consumption per year, Austria, million litres.*

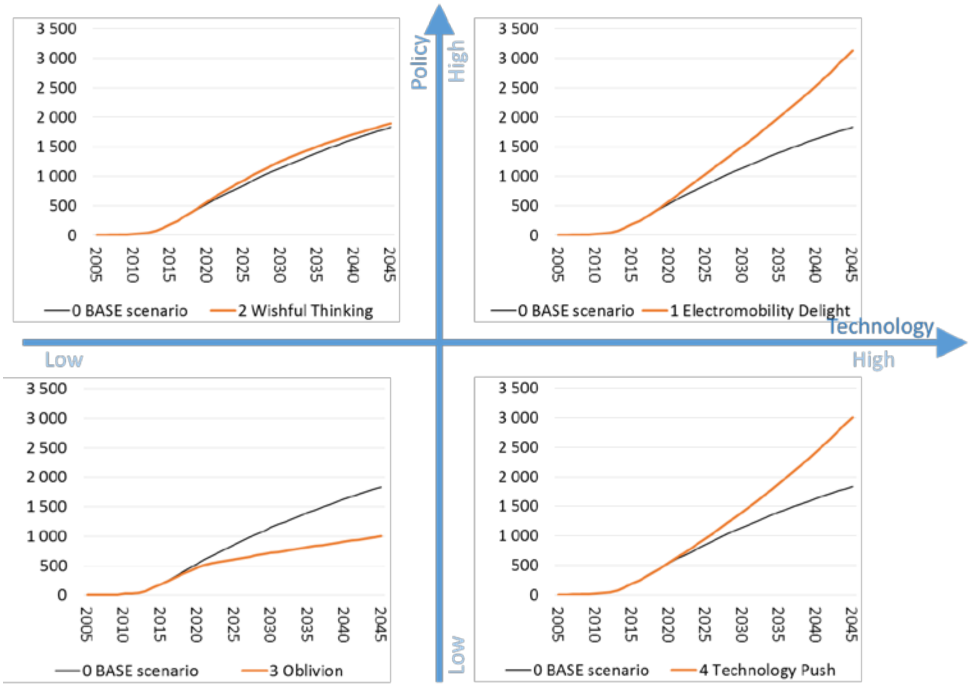



*Figure 5.11: BEV electricity consumption per year, Norway, million kWh/a.*

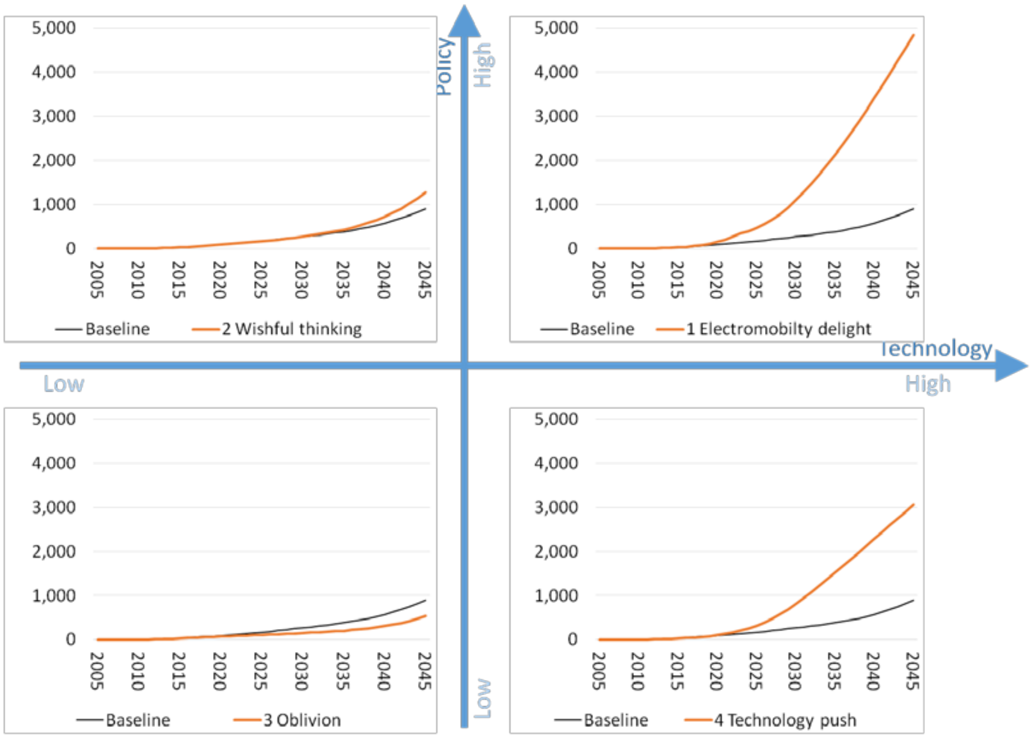



*Figure 5.12: BEV electricity consumption per year. Austria, million kWh/a.*

### 5.3.4 Effects on $CO_2$

Provided the EU Emission Trading scheme is functioning and we can assume zero $CO_2$ emissions from electricity production (see Figenbaum and Kolbenstvedt, 2015), emission reductions of some 0.4 million tonnes in 2045 will be achieved in the Electromobility delight and Technology push scenarios compared with the base scenario. The Oblivion scenario will lead to an increase of around 0.4 million tonnes, whereas the wishful thinking scenario is more or less neutral, see figure 5.13.

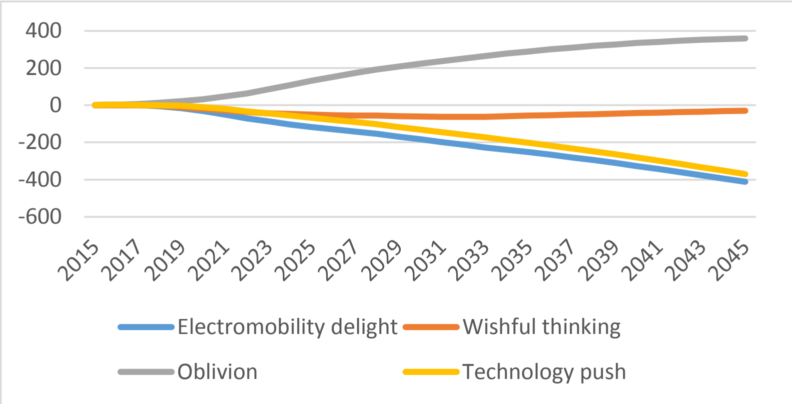



*Figure 5.13: Effect on $CO_2$ emissions in four scenarios relative to the base scenario, provided EU ETS is functioning and electricity production thus generates no extra $CO_2$ emissions in Europe.*

### 5.3.5 Reduce cost, or improve range, first?

Vehicle manufacturers have two possible strategies to follow to support further EV diffusion during a period of technological improvements. The first approach will be to keep range constant at the level today and decrease cost of the vehicles. The other is to first improve the vehicles range. The two approaches were tested using SERAPIS on Norway and Austria. The following assumptions were used:

- Approach one: Keep range constant, reduce cost by 2.5% per year until cost equal to ICE vehicle, then improve range 5% per year up to 2045. Otherwise same assumption as in the base scenario.
- Approach two: Is the same as the existing SERAPIS base scenario: Range increases up to where a threshold is reached, whereafter technology improvements result in lower net purchase prices.

The results on the number of BEVs in Norway and Austria are shown in figure 5.14 below. In Norway, it does not appear to make a big difference, as the incentives are decreased gradually in the base scenario, in the period the cost or range improves most. In Austria, however, cost reductions have a huge impact once a cost threshold is reached around 2022. It seems that in countries where there are few EVs today, the best strategy is to give priority to reduced purchase cost over improved range.

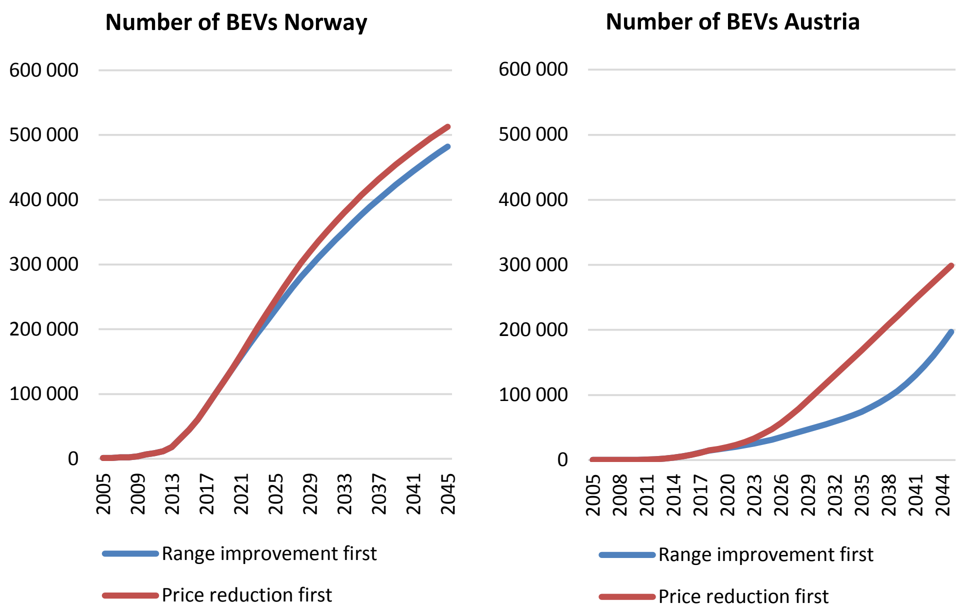
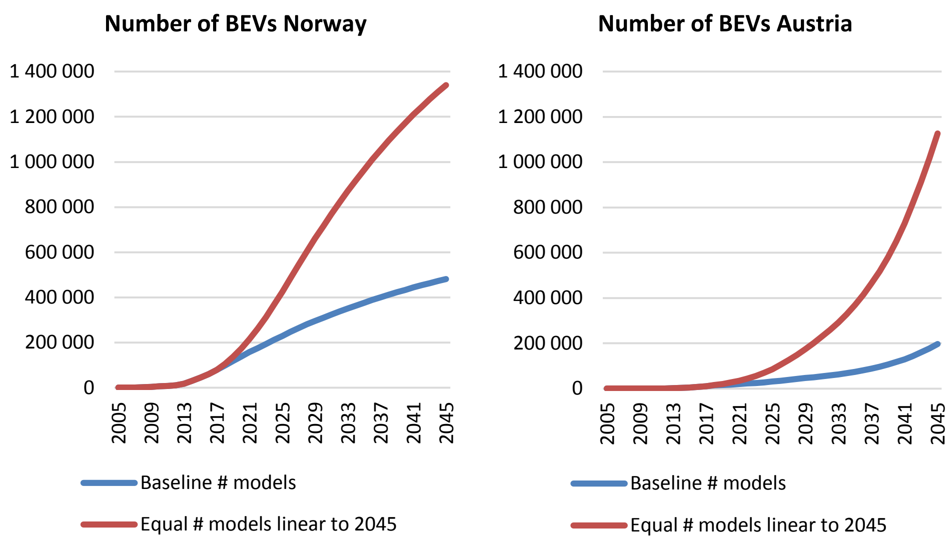



*Figure 5.14. The effect of range versus price reduction on the development of the EV fleet in Norway and Austria.*

### 5.3.6 The importance of a larger selection of makes and models

The number of makes and models have large importance especially in the family car segment where most sales happen in the SERAPIS model of Norway. In the base scenario, the number of makes and models increase linearly but at a slow pace. To get a better understanding of how this parameter influences sales, a new variant of the base scenario was constructed. In this scenario the number of models of BEVs and PHEVs are increased linearly from 2015 so that by 2045 one-third of models are ICEs, one-third are BEVs and one-third are PHEVs. Such a huge increase in models and makes can only be the result of a massive breakthrough for both technologies internationally. The results for BEVs and PHEVs are shown in figure 5.15 for Norway and Austria.



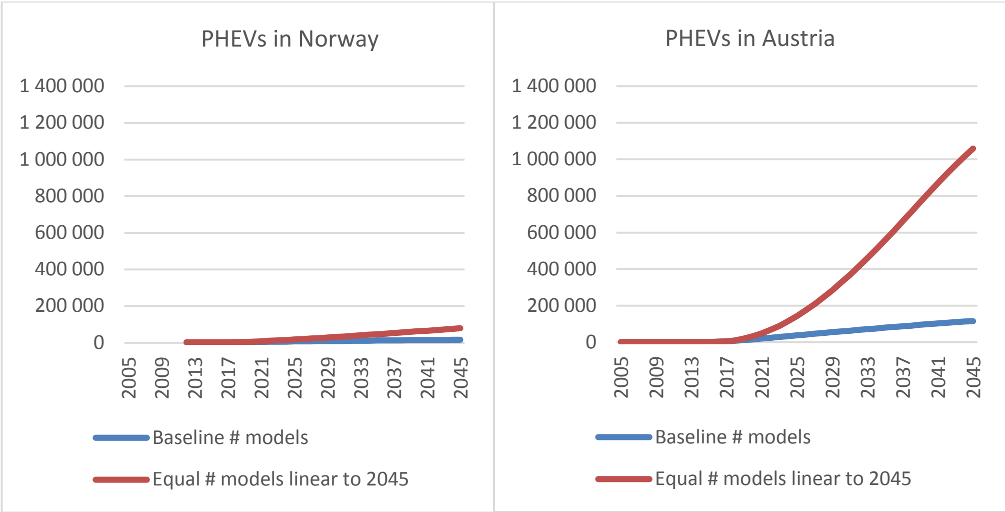



*Figure 5.15: The effect of an increase in the number of models and makes on the EV and PHEV fleets in Norway and Austria. Assumption: 1/3 of models in 2045 are EVs, 1/3 PHEVs, the rest ICE, BEVs and PHEVs increased linearly from 2015, ICEs decreased linearly.*

The results are influenced by the EV incentives being gradually removed from 2017 in the base scenario but still likely to be significant enough to make customers choose an EV rather than a PHEV in Norway. In Austria, the situation is different, both EVs and PHEVs proliferate. The changes to the total fleets are shown in figure 5.16. The assumption is a constant fleet in Norway after 2015, whereas the Austrian fleet increases. It could be argued that the fleet in Norway will also increase as the population is expected to increase. The rationale for keeping the fleet constant lies in the Norwegian government's target that future traffic growth in cities should be taken by other transport modes.

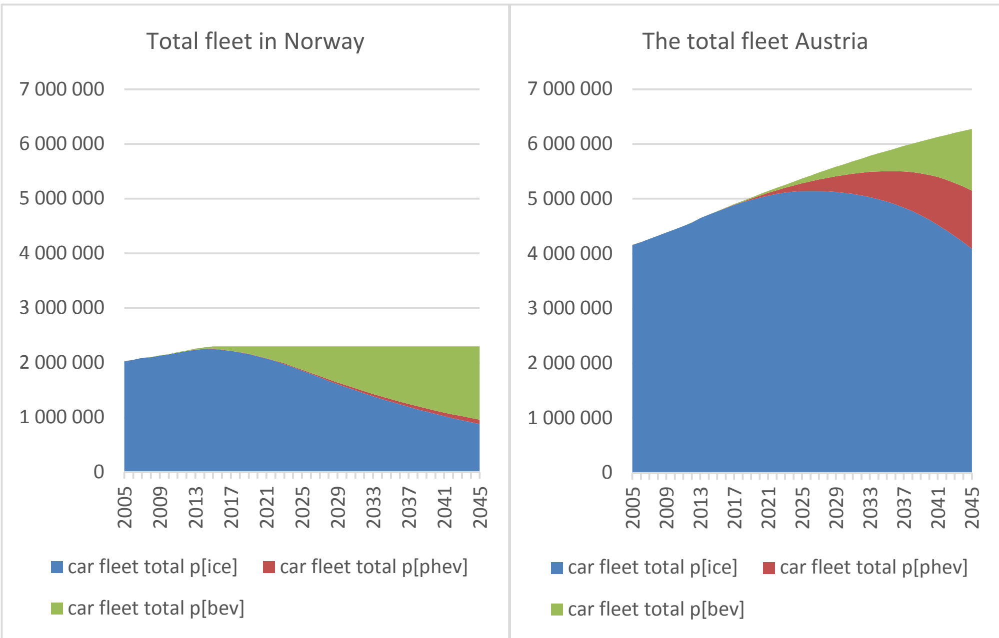



*Figure 5.16. The development of propulsion systems in the vehicle fleets of Norway and Austria.*

# 6 Implementation issues

A successful strategy for electromobility depends not only on identifying the most effective incentives. When electromobility goals are set, the process from policy formulation to implementation is paved with obstacles and challenges. This chapter addresses some of these:

- **Balancing government budget cost of incentives**: The previous chapters have shown that EV incentives come at a high cost. These can be recouped by adjusting the car taxation regime to be more progressive
- **Addressing barriers and build support**: Barriers and opposition can be managed in numerous ways and support can be gained with participatory processes, partnership and involvement
- **Phasing in and phasing out incentives**: The longer term goal is an EV market which thrives without preferential treatments. Some principles for phase-in and phase-out of EV incentives should be attended to
- **Provision and financing of EV charging infrastructure**: The future scenarios will demand rapid rollout of charging infrastructure, which currently struggle to establish profitable business models (see, e.g. Ihle, 2015).

Each of the following sub-chapters treat these implementation issues.

## 6.1 Budget balancing strategies

We have documented that electromobility can pose a considerable threat to government revenues. Exemptions from various taxes and charges are policies that directly affect government revenues. However, even without such policies, electromobility will reduce government revenues, e.g. from fuel taxes. Government revenues in any country where the purchase tax and annual tax are functions of tailpipe emissions will also be affected by electromobility and other low emission vehicles.

Figure 6.1 provides a decomposition of sources of public revenues from motoring in the Norwegian base scenario, as calculated with SERAPIS. Details about the base scenario are provided in chapter 5. During the period 2005-2045, total annual revenues fall about 20 percent from just over NOK 50bn to just over NOK 40bn.

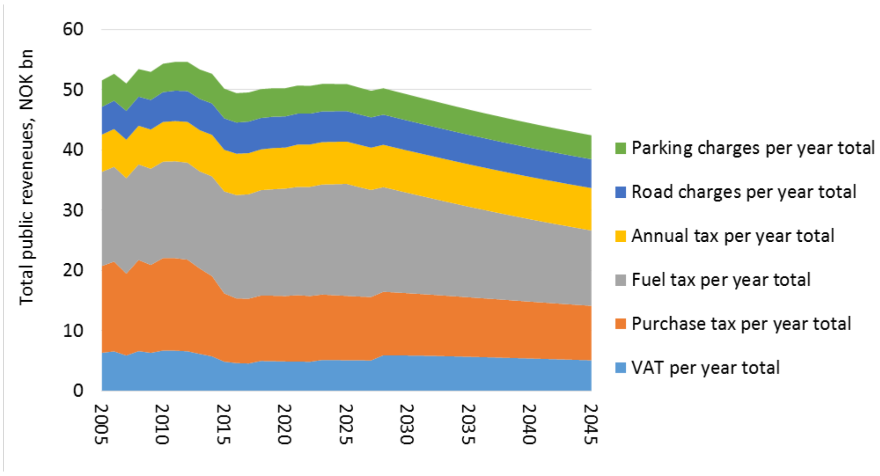



*Figure 6.1: Annual public revenue in base scenario, decomposed by source - Norway. NOK billions.*

To better show how the revenue sources develop and differ, table 6.1 compares revenue levels early in the period with revenue levels towards the end of the period. The largest drop in revenues relates to purchase taxes, which fall 36 percent from NOK 15bn to NOK 9bn. This is significant both in relative and absolute terms. Revenues from VAT, fuel tax and parking charges fall by approximately the same proportion, but fuel tax represents by far the largest amount of money. The annual tax is not affected since the BEV exemption is phased out in the base scenario and therefore annual tax revenues increase.

*Table 6.1: Average levels of revenue from different sources during the first 10 years and the last 10 years of the analysis period. Base scenario. NOK billions (rounded off figures) and percentages.*

| | VAT | Purchase tax | Fuel tax | Annual tax | Road charges | Parking charges | Total |
|---|---|---|---|---|---|---|---|
| Average 2005-14 | 6 | 15 | 16 | 7 | 5 | 5 | 53 |
| Average 2036-45 | 5 | 9 | 14 | 7 | 5 | 4 | 44 |
| Change | -16 % | -36 % | -15 % | 7 % | -2 % | -13 % | -17 % |

The situation in Austria differs from that in Norway. Electromobility related losses of public revenues due to tax exemptions, etc. are overcompensated by the total growth of the car fleet (see figure 6.2). Public revenues increase slightly until peaking in 2035. Despite a slight decrease, public revenues in 2045 are still about 2.5% higher than in 2015. Hence, we decided to base the following analysis of budget balancing strategies exclusively on the Norwegian case study.

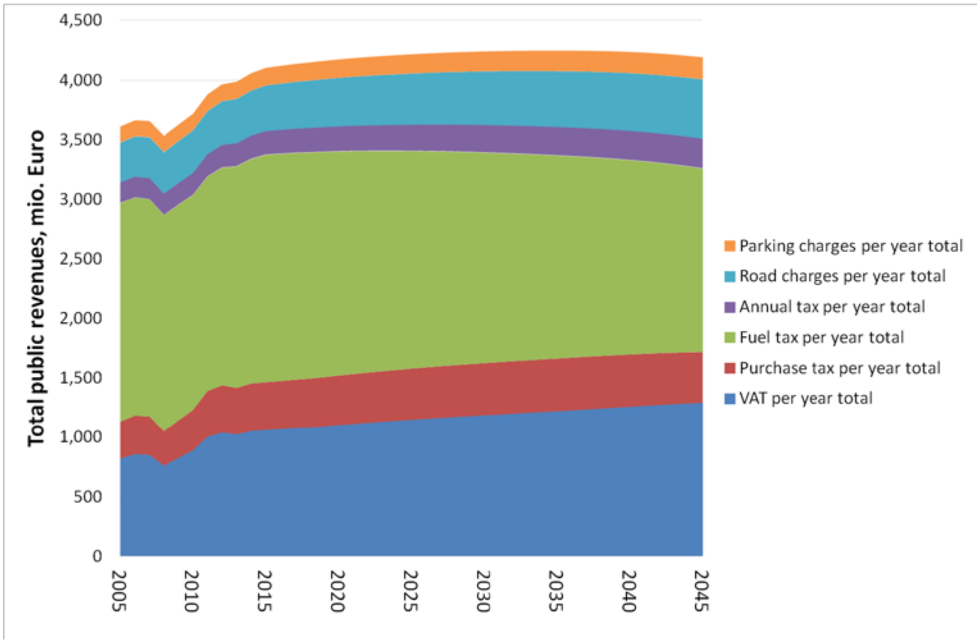



*Figure 6.2: Annual public revenue in base scenario, decomposed by source - Austria. Euro millions.*

We run SERAPIS to identify alternative ways to recoup these losses by changing motoring taxes and charges. The relevant taxes and charges are the *purchase tax*, the *fuel tax*, and the *annual tax*. VAT is not considered to be a relevant policy item because it affects the whole economy and not only the transport sector. The same applies to electricity tax, which would have wide-ranging effects beyond propulsion technology choice alone. We also exclude road charges as a policy option to recoup budget revenues because these are primarily transfers between ICE and BEV motorists due to the Norwegian road tolling legislation. Finally, we also exclude parking charges, since these affect local municipalities and not state finances directly.

The alternative to increase ICE related taxes in line with electromobility growth may not be sufficient to maintain government revenues for various reasons. Firstly, they would make BEVs relatively more attractive such that more BEVs and fewer ICE vehicles are sold and therefore the ICE revenue base shrinks. Second, as shown in the previous chapter, ICE revenues will fall in any event because also ICEs enjoy technology improvements and fuel efficiency gains that reduce fuel consumption and thereby fuel tax revenues. Third, any tax tightening will affect people's behaviour and make them consume less of what becomes more expensive. Only the annual circulation tax, which in SERAPIS base scenario will apply to all passenger vehicles, will in fact increase total revenues by almost exactly the same proportion. This is because the total stock of passenger cars is set as constant in the SERAPIS model runs, and because the Norwegian annual tax is a flat rate, which applies to all passenger cars.

### 6.1.1 Fuel tax adjustments

Our first exercise is to look at what fuel taxes are necessary to maintain them at their initial levels, i.e. around NOK 16bn annually. Total fuel tax revenues increase during the first period of the base scenario. Therefore, we need no large adjustment during this period. Figure 6.3 illustrates how a relatively stable fuel tax revenue over time can be achieved. Fuel taxes increase slower than in the base scenario during the first years after 2015, but when the level flattens out in the base scenario, it continues to increase as an intervention to keep fuel tax revenues up.

However, although fuel tax revenues are maintained, *total* government revenues from motoring are still substantially lower than in the early years of our analysis period - but the reduction is reduced from 17% (cf. table 6.1) to 13%. The intervention generates a marginally higher BEV stock in 2045: 486 thousands compared with 482 thousands in the base scenario. The result is influenced by the limited number of available makes and models severely limiting what can be achieved of additional sales, see chapter 5.3.5.

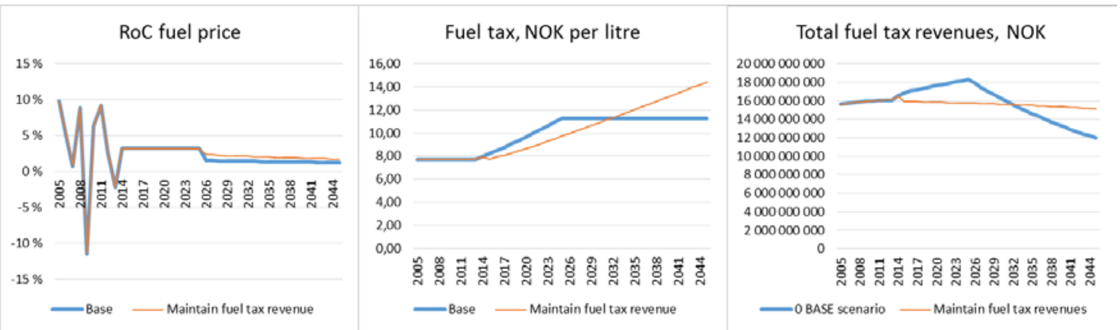



*Figure 6.3: Comparison of base scenario and fuel tax revenue neutral intervention, Norway. Rate of change (%) of fuel price (left), where base scenario and intervention scenario are equal up to 2025; fuel tax level (NOK/l) (middle), and total fuel tax revenues (NOK) (right).*

This relatively modest adjustment to fuel taxation, which in fact reduces fuel tax levels in some years relative to the base scenario, is sufficient to ensure an almost constant stream of fuel tax revenues.

### 6.1.2 Annual tax adjustments

We now turn to the annual tax, whose effect within SERAPIS is chiefly to raise government revenues, as described above, and not to affect total car fleet. As a BEV incentive, the Norwegian annual tax exemption will be completely phased out from year 2020. From then, all passenger cars pay the same annual tax. The base scenario assumes no change in real prices and keeps the level at NOK 3057 per year throughout the period.

We seek an annual real adjustment (i.e. above inflation) which is necessary in order to maintain total revenues from passenger cars. It turns out that an annual 3.5% increase is sufficient to obtain this. Figure 6.4 illustrates the necessary assumed annual increase and the impact on total government auto tax revenues.

Again, we find that a relatively modest annual increase is sufficient to ensure an almost constant stream of revenues. This time, it is the *total* government revenue from car taxation that is maintained.

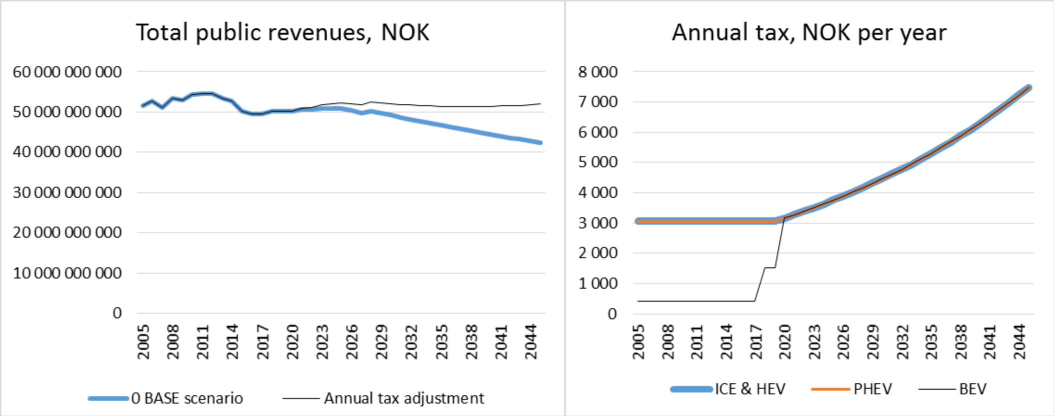



*Figure 6.4: Effect on total government revenues (NOK; left) of a 3.5% annual increase in annual tax (right).*

### 6.1.3 Registration tax adjustments

Baseline scenario assumptions with respect to purchase tax are illustrated in figure 6.5. ICE registration tax levels are fixed at 36 percent, 59 percent and 71 percent for compact, family and luxury cars, respectively. BEV registration tax is zero throughout the period for compact and family BEVs, but are gradually increased to 20 percent over five years for luxury cars. The current registration tax system would lead to zero tax on smaller family and compact BEVs (Figenbaum et al. 2015).

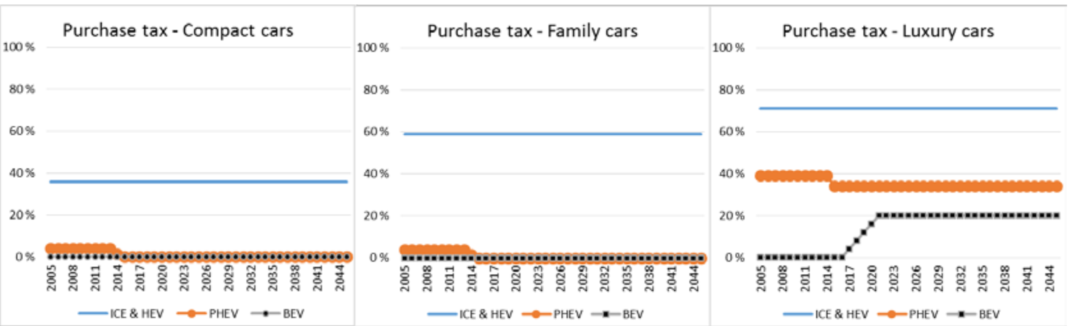



*Figure 6.5: Baseline scenario purchase tax assumptions. Percentages.*

We do not intend to change BEV (or PHEV) registration tax, so we solely focus on adjustments of ICE rates that are necessary to secure a stable government revenue stream.

An increase in ICE purchase tax will not only generate revenues, but will also shift demand away from this source of revenue. It is shown above that government revenues start to fall from the late 2020s on in our base scenario. We therefore adjust ICE purchase taxes from year 2020 onward.

Figure 6.6 shows one out of many combinations of purchase tax levels for compact, family and luxury ICE vehicles that keep the total revenue flow almost constant at just over NOK 50bn annually.

Maybe surprisingly to the reader, this strong increase in ICE purchase taxes only marginally affects BEV sales. The total BEV stock at the end of the analysis period increase to just over 500,000 vehicles, as opposed to the base scenario level of 482,000 BEVs. On the government revenue side, the imposed changes roughly double revenues from purchase tax in 2045. The impact on BEV demand is relatively small for several reasons: It takes time until changes in utility propagate into significant fleet developments. Differences in utilities are small in the earlier years but strong in the later years. This dampens the differences in fleet development. While the utility of BEV is higher than ICE in the later years in the compact and luxury class it stays worse in the family class, which dominates the total car fleet. The reason being that the utility function puts a large emphasise on available makes and models, which is assumed to be much lower than for ICE vehicles, see also chapter 5.3.5.

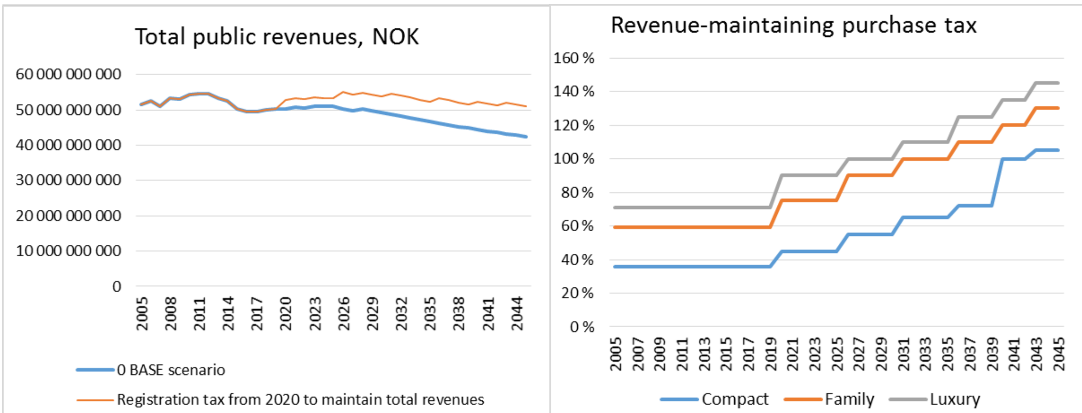



*Figure 6.6: ICE purchase tax developments that help maintain total public revenues from taxes and charges related to car ownership and use.*

### 6.1.4 Combining taxes and charges to maintain government revenues

So far, we have considered adjustments to individual components of car taxation in order to maintain government revenues. Clearly, a combination of smaller adjustments to all revenue sources would attract less opposition and be easier – politically– to implement.

Adjustments to annual tax levels are by far the least invasive and most obvious element to focus on. Especially for the Norwegian market with tight car taxation, an annual 3.5 percent increase may not be too different from what many people may expect. Adding to that, the current (2015) Norwegian annual tax of NOK 3057 is not very high compared to neighbouring countries.

Fuel prices in general –and fuel taxes in particular– are inherently subject to debate and protest. Sharp rises in fuel taxation have a high political cost and are considered difficult to implement.

The Norwegian ICE registration tax is already notorious for making motoring extremely expensive. We expect that only a very modest increase would be possible.

On this background, the following tax adjustment package is defined:

- **Fuel taxes** are set to the midpoint between the base scenario and the revenue offsetting levels described above. During the first period, this means that fuel tax levels lie below the base scenario, cf. figure 6.3 (middle)
- **Annual tax** levels are set to increase by 2.5 percent annually (as compared with 3.5 in the revenue-neutral exercise above)
- **Registration tax increases relative to the base scenario** are reduced to 1/3 of the revenue-neutral increases described above

Figure 6.7 shows the outcome in terms of government revenues, which are stabilised at just over NOK 50bn annually, and illustrates key characteristics of the assumptions listed above.

While this is just one combination of tax adjustments among many, it clearly shows the potential for maintaining strong BEV incentives while at the same time securing a steady stream of fiscal revenues. BEV carrots are reinforced by ICE sticks. This is achieved without extreme ICE tax increases. Our exercise supports Lindberg and Fridstrøm's (2015) assumption of a "feebate system" (p. 36; a bonus-malus system of BEV rebates and ICE fees) which implies that the fiscal effect by assumption is zero.

This approach suggests that $CO_2$ abatement can be "free" in the meaning that government net revenues are not affected – in contrast to the costs per tonne of $CO_2$ presented in chapter 4.5. However, of course, although public budgets are not strongly affected, the combined policies of BEV incentives and tightening of ICE taxation will redistribute income and have distributional effects to the disadvantage of ICE vehicle owners. This policy could be more controversial in countries with low existing taxes on motoring.

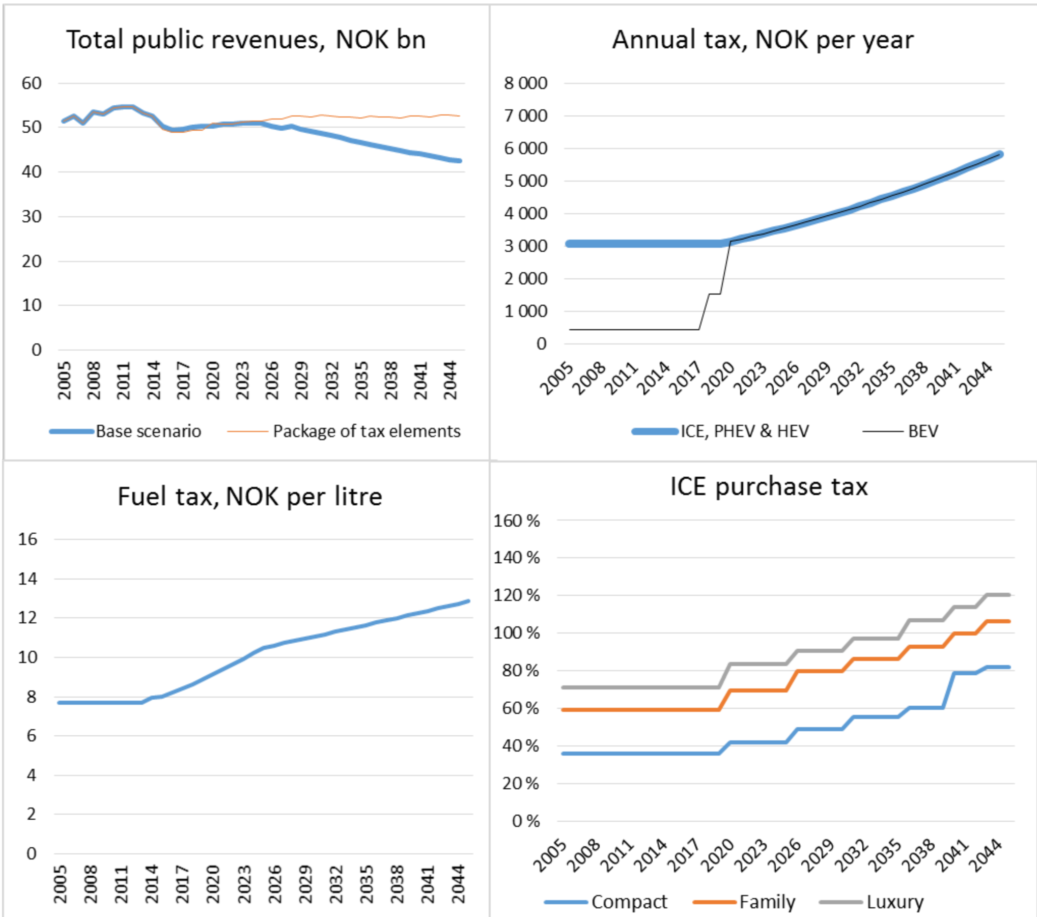



*Figure 6.7: Effect on total public revenues (top left) of a package of annual tax adjustments (top, right), fuel tax (bottom, left), and purchase tax (bottom, right).*

## 6.2 Barriers and support for EV policies

### 6.2.1 Factors influencing diffusion

Diffusion of environmental technology of value for society can imply some disadvantages for the users. Thus it is often necessary for society to stimulate concerted actions between society, industry and users and to put in compensatory measures to help the diffusion process (van den Bergh et al. 2011, Jacobsson & Bergek 2011).

An increasing EV market share among consumers requires that dealers and leasing companies actively promote EVs and that consumers opt for EVs when negotiating a vehicle purchase with the dealer, the leasing company or when selecting a company car.

The dealer earns more money the fewer man hours that are spent selling a vehicle. In the USA, dealers report that selling PEVs requires up to 3 times more man hours than selling ICEs (NRC, 2013). Dealers in Norway say the effort is the same when selling EVs as ICEs, but the handover of the vehicle may take longer time with the new functions and characteristics of EVs (Assum et al., 2015). New technologies also leads to a need to train the employees and may involve investments in tools or other equipment. Nissan, as an example, requires all EV dealers to invest in a fast charger.

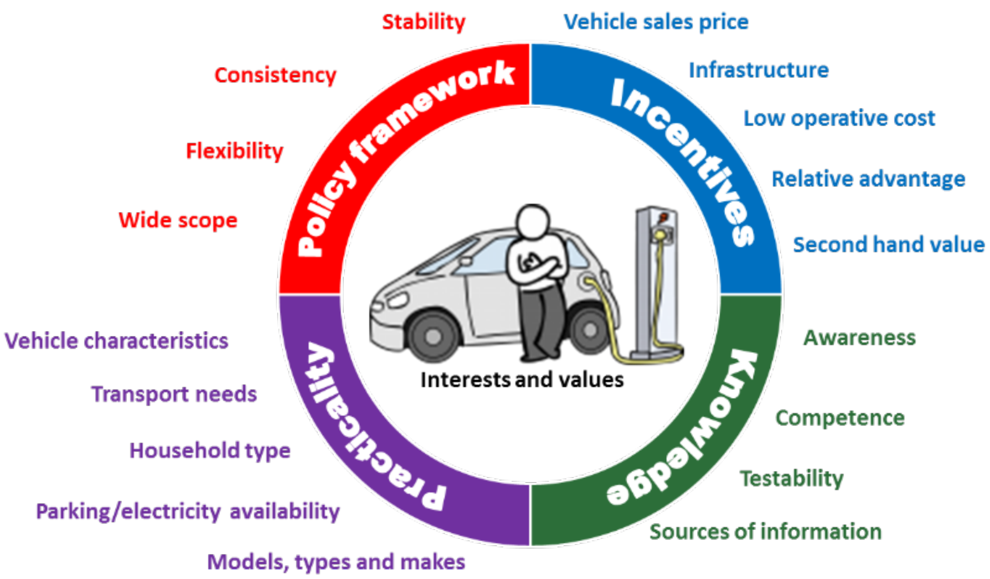



*Figure 6.8: Main factors influencing the diffusion process.*

Main factors that need to come together for the consumer to become interested in EVs are: see figure 6.7:

1. *Consumers have their interests and values* making them more (environment, technology) or less (traditionalist) interested in EVs. How these values limit or support a decision to buy an EV, can be influenced by developments in the other four factors.
2. *Consumers need to be knowledgeable*, i.e. aware of and get competence about EVs characteristics, through reliable information sources, and the ability to test them.

3. *The vehicles need to be practical* and cover users' transport needs. Users need to have parking with electricity available. The practicality depends also on the household type (single-/multi-vehicle) and the availability of different types and models from different makes and country specific factors such as driving distances, urban sprawl, climate and road speed limits.
4. *The policy framework should be stable over time* to reduce risk for market actors, i.e. consistent in scope and how it is communicated. It should be flexible to allow unexpected developments and wide in scope allowing for business creativity.
5. *Incentives smoothen the purchase process* by reducing the price disadvantage and provide users with a relative advantage. Low tax on energy and low energy consumption is part of the picture. Consumers are myopic and need to see that EVs are favourable on a 3-5 year time horizon. Infrastructure incentives makes life with an EV easier.

### 6.2.2 Target groups for Electromobility

Target customer groups for BEVs must be seen in relation to societal targets for electromobility and different groups ability to use EVs. Incentives can be used to make EVs attractive to these target groups.

Multi vehicle households buy 62% of EVs in Norway. Single vehicle households 18%; fleets 20%. In the Netherlands, most EVs are company cars (used by consumers). In other countries, fleets buy most EVs (Figenbaum and Kolbenstvedt 2015).

Target groups being defined as the most likely buyers of EVs, may not necessarily be the ideal buyers from a societal perspective. The primary target groups will thus be multivehicle households with home parking facilities and fleets.

Multi vehicle households have the best ability to manage with EVs' range and charge time limitations, are the most affluent, have the largest transportation needs, best home parking availability as well as other characteristics of early adopters (Figenbaum and Kolbenstvedt 2014 and 2015). There is no difference in target groups in cities compared to rural areas, as BEVs are equally capable of fulfilling daily transport requirements of rural citizens. EVs are now spreading out from urban areas to rural districts in Norway (Figenbaum et al 2014 and 2015). Buyers need a dedicated parking area that can be fitted with electricity, which is less available to consumers in dense city zones than rural areas.

Fleets will be the dominant buyers in countries without purchase incentives. The purchase process of fleets is different from private consumers. The purchase is often the result of a tender process. Total cost of ownership plays a large part in their decision process. Incentives for fleets should, therefore, have the intention to even out the total cost of ownership (TCO). Fleets often control their own infrastructure and park the vehicles on own land, making it easier to install charging stations.

Secondary target groups will be technology or environment oriented single vehicle households with parking facilities. Countries starting to introduce EVs should direct efforts to demonstration programs aimed at raising awareness of EVs.

Policies leading to households without vehicles adopting EVs or single vehicle households becoming multi vehicle households when adopting EVs, should in the long run be avoided, but may be tolerable in a transitional phase to get diffusion started.

Concerted actions and partnerships will be needed when consumers are in the target group. The types actions and partnerships needed will depend on how far electromobility has advanced. In an early phase there is a need to coordinate testing, demonstration and dissemination activities to raise awareness and build up a competence about Electromobility among stakeholders and in the population. In this phase, users, vehicle suppliers, infrastructure providers and authorities at different levels may work together with researchers in structured projects to capture systematic knowledge. Partnerships may reduce actors' risks in a later phase of EV deployment by sharing information and providing common funds for instance for infrastructure. In a final stage, when EVs have reached mass market, the need for partnerships and concerted actions will be over as each actor then respond to the general market conditions.

### 6.2.3 Barriers and how they can be managed

Prospective EV buyers have prior experience with ICE vehicles and will evaluate EVs based on this experience. They may perceive characteristics of EVs to be barriers compared to ICE vehicles. The main barriers to EV adoption are range, charge times, access to public charging stations and the higher vehicle costs. The incentives burden on public budgets is a barrier at the national level. For consumers, the perceived attributes of EVs compared with ICE vehicles, is what matters (Figenbaum et al., 2014). These attributes are the relative advantage they offer compared with ICEs, their compatibility with needs and basic values, norms and established practises, their complexity, the opportunities for trial and observation. Relative advantage, the most important attribute, can be financial, practical, environmental or personal.

The barriers and recommendations for how they can be managed, must also be seen in relation to the findings in Hjorthol et al (2014; a COMPETT WP2 output) that most daily transport can be accomplished using EVs. Figenbaum et al. (2014; a result of COMPETT WP4) showed that EV owners actually manage to use the vehicles for the majority of their daily transport needs. When the vehicle cannot cover the transport needs, the owners have many options to solve the issue. The range, charge time and infrastructure barriers appear to be less in practise than potential buyers tends to fear. The market is increasing in Norway, as potential buyers learn from peers that EVs work (ibid).

#### Acceptability and support in population and business

Acceptability of and support for electromobility require a fundamental understanding of how EVs work in everyday life and awareness of their existence as an option. In many countries, these basic requirements are not met. Authorities in those countries will in the short run need to focus on basic testing, demonstration and awareness-raising activities.

In Norway, a forerunning country on Electromobility, Figenbaum and Kolbenstvedt (2015) found that politicians and media in general have had a positive attitude to BEVs. The public support has evolved from allowing testing and experimentation with EVs, via support for the development of and EV industry in Norway, towards supporting climate policy targets. They found few indications of resistance in businesses or the population at large. The focus seems to be more on "what's in it for me" or my business.

Except for one stakeholder interviewed in Norway, there is no questioning of the objective of reducing GHG emissions. Some stakeholders think that the present incentives will do, whereas others are open to revision. Several stakeholders mention the dilemma of supporting EVs while changes of modality and reduction of total transport volumes in cities are other important objectives (Assum et al., 2014; pp. 6-7). The question of such a broad support for only one technology was raised.

Many stakeholders are active in dissemination and communications. The public in general or potential BEV buyers are important target groups. These target groups also appear to be communicating a lot between themselves and to be searching actively for information: "*There is a strong "neighbour effect" in the diffusion of BEVs",* meaning that people see neighbours, colleagues and friends driving BEVs and learn from their experiences. As more people buy BEVs this "neighbour effect" is likely to grow even stronger. If this communication is mainly positive, as it appears to be in Norway, the sales of BEVs may grow even faster in the future. (ibid, p. 26) This tendency is also supported by the fact that many more EV owners than ICE car owners see the advantages of BEVs (ibid, p. 39).

Figenbaum and Kolbenstvedt (2013) found that BEV specific number plates could be an option for increasing awareness and acceptability  in addition to facilitating control of local incentives.

## Financial incentives

Financial barriers are related to the cost of the vehicles, the risk associated with the new technology, the cost of financing infrastructure, the ability to charge users for using infrastructure to recover cost, as well as the burden of incentives on public budgets . Consumer wanting to adopt EVs face many risks associated with EVs being a new technology, such as reduced second hand value, failing components, the price of new vehicles falling rapidly or the technology improving fast and thereby further reduce second hand value (Figenbaum and Kolbenstvedt 2015). Buyers may put a risk premium on the technology leading to a need to overcompensate with incentives. EVs are more expensive to produce and sell given the low volumes and the technology being new. These issues sum up to being financial barriers to EV adoption leading potential buyers to wait until the technology and the prices stabilize unless risks are compensated by incentives. The uncertainty is seen in the lower residual value leasing companies set on EVs than ICE vehicles (Figenbaum and Kolbenstvedt, 2015; Assum et al., 2014).

The stakeholders considered the current incentives important, even sufficient, for further development of electromobility in Norway (Assum et al 2014). The financial incentives are considered the most important ones, in addition to access to bus lanes. However, the authorities interviewed realise that the financial incentives are expensive. A media debate in 2014 focussed on the costs of the financial incentives (ibid p. 17). The stakeholders emphasise the importance of gradual and predictable downsizing of the incentives. In other countries the focus should be on establishing more incentives.

When comparing stakeholders in Norway with BEV owners, potential BEV buyers and other ICE owners not interested in BEVs, there are similarities concerning the evaluation of the importance of the incentives (Assum et al. 2014). Economic purchase incentives are the most important followed by user incentives and lower operative cost. Potential BEV buyers and the other ICE vehicle owners are less aware of BEVs low operating cost and more interested in fast charge stations being available. Reduced imposed benefit taxation for company cars and increased mileage allowance rate when using private vehicles on business trips, are incentives that seem to have less importance. Lower annual licence fee and free parking (also supported by the SERAPIS Model runs) as well as reduced ferry rates are not seen as important incentives.

The Norwegian EV incentives were from the outset open ended, i.e. without end dates (Figenbaum et al 2015). Politicians have been EV friendly and lobbyists have followed up so that tax exemptions for EVs have survived over a long time period. In 2012, the parliamentary settlement on climate policy stated that these incentives should last until the end of 2017 or 50,000 EVs were on the road, which was achieved by April 2015. A new political agreement in connection with the revised national budget for 2015 specifies that these incentives shall remain in place till the end of 2017 and how they may be revised.

Most other countries have incentives that are limited in time or volume and based on allocations from government budgets (Figenbaum et al 2015). When allocations have been consumed a new allocation must be given, often leading to incentives being discontinued until the following year's budget has been agreed upon. Setting end dates, especially if the time horizon is short, is also problematic as business actors may be unable to recover investments within the time frame.

The COMPETT research in WP4 shows that it takes time for EV sales to pick up. Consumers must become aware of the alternative and be exposed to it in their social networks before sales really picks up (ibid). Incentives should be in place for a long time period to be effective.

### Legal aspects

The fiscal tax rate on vehicles and the exemption for EVs are not directly regulated by Norwegian law, but delegated to the government discretion by a law[15] allowing the setting of new tax rates each year in the national budget. The exemption from VAT is regulated in the Law on Valued added tax[16].

ESA, the body responsible for making sure that legal obligations of the EFTA/EU EEA treaty is fulfilled, made a verdict on Norwegian EV incentives in April 2015. They concluded that the incentives are legal state aid as they are directed at the vehicle buyer not the producer, although the latter may be an indirect beneficiary. ESA acknowledged that the incentives are there to reach legitimate societal goals of reduced emissions of greenhouse gases that cannot be reached without incentives (EFTA Surveillance Authority April 21 2015, http://www.eftasurv.int/media/press-releases/College-Decision---electric-cars-.pdf).

Legal barriers to introducing EVs, their infrastructure or incentives to promote them, should be identified early in the diffusion process as it may take a long time to change laws.

[15] «Lov om avgifter vedrørende motorkjøretøyer og båter» https://lovdata.no/dokument/NL/lov/1959-06-19-2

[16] https://lovdata.no/dokument/NL/lov/2009-06-19-58#KAPITTEL_6

Free parking and other incentives may not be legal according to national laws as proven in Norway prior to 1998, and Denmark and Germany now needing to adapt national laws to facilitate free parking.

In some countries, the establishment of charging infrastructure that can only be used by one type of vehicle could be illegal. In Spain, Tesla has to put up a fast charger all vehicles can use alongside their own superchargers (Audera, 2015).

## Organisational/Institutional framework

Figenbaum and Kolbenstvedt (2015) found that there is a complete regime of actors and established practises supporting ICE vehicles sales, usage and servicing.. 25 years of EV activities has led to the establishment of a complete EV regime in Norway. In the early years of this period, cooperation between the new actors was necessary to get the EV regime established. The pivotal cooperation occurred in the EV association that started as a business stakeholder interest group and later evolved into a consumer interest group (Figenbaum and Kolbenstvedt 2013, 2014 and 2015). The ICE regime established alliances with NGOs and contributed to reinforcing the EV regime by giving free membership in the EV association with every EV they sold.

Vehicle providers are cooperating with charging providers and companies installing home chargers, taking more supportive measures than with ICE vehicles (Figenbaum et al 2015).

Institutional barriers have been an issue in Norway. The first EV imported in 1990 to Norway could initially not be registered, as the technical requirement of vehicles had been defined for ICE vehicles. Technical safety standard were not in place, leading to the Think City EV developed between 1997-2000 to be type approved both as a vehicle and as an electrical appliance (Figenbaum 2015). Standardisation issues are now taken care of in various EU, UN and IEC standardisation groups.

## Technological barriers

According to the stakeholders, uncertainties about the durability of the batteries is one of the main barriers to further sales of BEV (Assum et al 2014). The non-users are however more concerned about range and the time to recharge the vehicles than the EV owners. The large reduction in range and fast chargers being slower in the winter, are characteristics that EV users mention as disadvantages.

Installing chargers in public locations and in workplaces and fast chargers along main roads may halve the number of days when range is insufficient (Figenbaum and Kolbenstvedt 2015). The longer range vehicles coming on the market from 2017 will further assist in reducing the range challenge.

## Interaction with current infrastructure

The current fuel infrastructure has been put in place to support the ICE vehicle regime. Filling stations are available in cities and at regular intervals along major roads to support local and long distance driving.

Electric vehicles also need access to charging stations but most local transport will be achievable with electricity charged at home (Figenbaum et al 2014). Public charging stations in cities are not much used by the average EV owner and will mainly have the purpose of providing user confidence in exploiting the vehicles range.

Longer distance driving must be supported by fast charge stations at regular intervals along main roads just as for ICE vehicles. EV fast charging stations require more land than ICE filling stations. Whereas a filling of a gasoline or diesel tank is done in minutes, fast charging may take 20-40 minutes requiring 10 times the land area to support the same number of vehicles. In dense cities where land has a high cost, there could be difficulties in finding good locations for fast chargers with enough space, but should be unproblematic along trunk and main roads between cities. Fuel station operators may however prioritize liquid fuel pumps as the turnover of customers is faster, leading to more retail sales revenues. Fuel stations are positioned on attractive spots along main roads with established access roads to the stations. New actors may find it difficult to find equally suitable locations for fast chargers. Apps and navigation systems are thus needed to assist drivers in finding charging stations.

Parking availability in the home location and the possibility to furbish that with electricity is crucial for the ability to take EVs into use. 97% of EV owners in Norway have the ability to charge at home (Figenbaum et al 2014), i.e. a parking space with electricity available. 89 percent of all inhabitants aged 13 and above have access to parking near their house. 84 percent of these on own land, 14% under 100 meters away and 2% more than 100 meters away (Hjorthol et al 2014). Limitations in supply of parking spaces is mainly a city phenomenon with Oslo the lowest parking availability at 72% (ibid). 71% in the 10 largest city regions (Ellis and Øvrum, 2015) have free parking at work.

In Denmark 46% of private household parking spaces have electricity available, 34% can easily be fitted with electricity, another 15% with some difficulty (Figenbaum et al 2015).

Allowing EVs access to dedicated road lanes has proven effective in Norway. Two types of dedicated lanes exist; 1) high occupancy vehicle (HOV) lanes; 2) bus lanes. The purpose of HOV lanes is to promote ride sharing to lessen congestion. Bus lanes are used to give priority access to buses into and in a city area. EVs have had unlimited access to bus lanes in Norway from 2005 (Oslo area from 2003) to May 2015, utilizing spare capacity in the bus lanes. HOV lanes are used in the USA and in many US states EVs can get a sticker allowing them to use the HOV lanes.

When implementing these incentives it is important to think through how they influence total traffic flow. As long as bus lanes have spare capacity, allowing EVs to use them will increase the total road capacity and decrease congestion. When EVs reach a critical level, the speed in the bus lane will go down due to queuing. In Norway, the limit was reached in the spring of 2015 for the bus lane going from south west into Oslo. In May 2015, it was decided that from now on EVs will only be allowed to use this bus lane in the rush hour when more than one person is in the vehicle.

### 6.2.4 Organizing and implementation strategies

The actors involved in planning and implementation, identified in WP4 are manifold and include different levels of government, the EV and charge infrastructure industry, communities, NGOs, individuals and firms as well as press and media. Two approaches have globally been taken to foster electromobility:

1. *Bottom up* where the initiative come from users and businesses, pressuring governments to introduce incentives. Norway is the prime example of this approach.
2. *Top down* in which governments aims to impose electromobility on society. Most countries in Europe follows this approach setting up targets and incentives.

The same type of actors will be involved in both approaches but assume different roles. The engagement in the first approach comes from actors with a direct interest in electromobility, such as manufacturers, users, interest groups, businesses, research communities and others. in a form of democratic process were politicians react to the pressure by introducing incentives.

In the second approach politicians and governments have the intent to build up engagement among businesses and users. In many ways, a form of elitism that could be an uphill struggle as real engagement is difficult to create with outside pressure.

## Concerted action and partnerships

Electromobility as a complete socio technical system, needs to be established if EVs are to succeed in the market (Figenbaum and Kolbenstvedt 2015). Standards, type approval, regulations, fiscal policies, environment and energy policies, established practices, products and services, user needs and experiences, parking and charging infrastructure needs to be in place to make EVs attractive so that they can compete with ICE vehicles.

The EV history in Norway can give insights into the need for concerted action. Norway introduced EV incentives one by one to promote EVs (Figenbaum et al 2015). Sales failed to respond and more incentives were introduced. Limited production by small upstarts, unable to scale up their business, resulted in high manufacturing cost and limited sales even with incentives. These enthusiastic actors are needed in an early phase to allow experimentation, get incentives introduced and to put pressure on regime actors. Sales did however not take off until the resourceful traditional vehicles manufacturers delivered EVs into the market from 2011, taking advantage of existing incentives, unlimited manufacturing capacity and nationwide dealer and service networks (Ibid). In the automotive sector, the start-up costs are huge and customers loyal. Rapidly rising market shares for new technologies are difficult to achieve without traditional manufacturers playing a large role.

Purchase price is the main barrier to adoption of EVs. Purchase incentives may therefore work as a standalone policy as EV owners can manage their daily travels by charging at home (Hjorthol et al. 2014, Figenbaum et al. 2014). Incentives must remain in place for a long time to allow actors to mobilize resources. Without purchase incentives or only small incentives being available, countries such as Germany, Italy, Spain, Portugal, Finland, Greece etc. have low EV sales suggesting that incentives only, for instance, for charging infrastructure is pointless (Figenbaum and Kolbenstvedt 2015).

Cooperative agreements between cities or countries and the car industry involving simultaneous supply of vehicles and introduction of public support schemes, is an example of a concerted action that have been tested by the Renault-Nissan group (Renault 2010). The idea being that countries, regions, municipalities and businesses should be prepared to support the EV market when vehicles were launched. In retrospect, it seems that none of these agreements that Renault/Nissan entered into have been crucial to their EV deployment achievements.

When mass-market customer groups are targeted, infrastructure becomes a bigger issue leading to a need to coordinate the build out of infrastructure. ICE vehicle owners see infrastructure as a bigger challenge than EV owners (Figenbaum et al 2014) and are thus less willing to consider EVs. A Norwegian partnership between an NGO and a government source of funding, resulted in an open source database of charging stations becoming available for businesses to build into navigations systems and applications for mobile phones.

Countries later in the introduction process can learn from forerunning countries such as Norway what works and what does not work, and who the customers will be. It will then be easier to develop policy packages that works. Flexible policies are needed to take into account technical and economic developments and to be able to adjust policies leading to unwanted side effects.

## Manage risk and financial constraints

When introducing new technologies the question about how to implement it arises. Should the policies be fully integrated from day one or should a more stepwise approach be taken?

Better place is an example of an EV business model that was fully integrated from the start, offering a complete mobility service that eliminated battery limitations such as charge times, range and battery lifetime risk to vehicle owners. The customer leased the battery from Better place and bought the vehicle from Renault. Better place installed a home charger for the customer and chargers at public locations were made available to these subscribers. Long distance trips were supported by battery swap stations. The concept only makes sense with a large number of subscribers joining the network fast to recover the huge up front investments, which proved difficult to achieve in Denmark where the concept was tested. When Better place went bankrupt owners were in a squeeze owning the vehicle not the battery.

Another example of a fully integrated approach is found in Estonia where EVs and fast chargers were traded for greenhouse gas emissions quotas (ELMO 2015). A complete network of 165 fast chargers were built out across the nation every 40-60 km. After the initial 507 vehicles were deployed sales slowed down. About 1100 EVs were in Estonia as of March 2015 leading to a huge underutilization of the installed charging network.

On the other hand, Norway had 54,000 EVs and only slightly more fast charger points than Estonia as of May 2015 (Figenbaum et al 2015) and they have been built out stepwise. Most EV owners in Norway rarely use public charging and 40% never use fast chargers, another 31% less than once per month (Figenbaum et al 2014). EVs market share nevertheless reached 20% in first quarter of 2020 and 2 % of the fleet were EVs suggesting that a low risk stepwise establishment of infrastructure works. Electric vehicles have the advantage of being able to use existing electricity distribution networks. Electricity is available, or can be made available, with little effort most places. Buyers of EVs can charge at home not relying on external charge infrastructure to get the daily transport needs covered. In case of emergency, there are numerous places to find electricity available already. COMPETT WP 2 showed that most daily transport can be done with home charging only. COMPETT WP 4 showed that EV owners manage with the range of the vehicles and very limited public infrastructure. Future generations of EVs will get longer range further reducing the need for external chargers for daily transport needs. These facts should point in the direction of a step-wise low risk implementation strategy for infrastructure for EVs being advisable.

For hydrogen, the situation would be totally different. The consumer market will require a fully integrated approach. A minimum of hydrogen fuelling infrastructure enabling national and transnational driving must be available from the start of introduction of these vehicles.

### 6.2.5 The way forward – Public private initiatives

Experience from Norway and from Austria indicates that once EVs are bought the owners quickly come to terms with their limitations and like their vehicles (Figenbaum et al 2015, Jellinek et al 2015). The primary policy parameter will be to equalize the cost difference between EVs and ICEs over an introduction period until EVs are able to compete with ICEs without incentives. The secondary policy parameter will be to build out the infrastructure needed to make EVs as useable as possible and to make it possible for those living in dense cities without parking at home to start using them.

The Governmental costs will be significant when economic incentives lead to a rapid take-up of BEVs. Smart policies and purchase incentives can reduce the burden on public budgets. Purchase incentives can be completely offset by taxes on polluting vehicles, thus not burdening public budgets.

Raising awareness and schemes to allow testing are important in the early phase of BEV diffusion but will not lead to significant sales unless they are coupled with incentives. Also consumers representing the potential market in later diffusion phases need information about what BEVs can and cannot do.

Attractive user incentives can be very effective in the absence of purchase incentives. An example is offering BEV owners access to bus lanes, thereby saving time in rush hours, which proved very effective in Norway..

Incentives work most effectively when BEVs are available from different manufacturers, consumers are aware of BEVs assets and the neighbourhood effect speed up diffusion. Policies should be carefully planned and implemented as a stable national framework involving cooperation with organisations and industry.

The next generation EVs coming 2017-18, boosting up to twice the range, may tempt existing EV owners to replace their vehicles leading to another surge in sales in Norway. A similar surge was seen in Norway when the current generation EVs replaced the simpler EVs made before 2010. Countries with a base of 1st gen. EV owners will see faster growth from 2017 than those that do not.

Nations are better off introducing incentives late. If everyone does so then costs may not come down and EVs may not develop, as seen in table 6.2. Therefore, a joint international effort will be called for to unleash the full potential for the EV technology at minimum cost and maximum benefits too nations.

*Table 6.2: Effects of combinations of incentives in different nations.*

| | Nation A introduce incentives early | Nation A introduce incentives late |
|---|---|---|
| **Nation B introduce incentives early** | Cost will be shared and the EV market will develop fast | Nation A saves money but will be later in the development of EV based transport<br>Nation B will pay most of the cost but get sooner to an EV based transport sector. |
| **Nation B introduce incentives late** | Nation B saves money but will be later in the development of EV based transport<br>Nation A will pay most of the cost but get sooner to an EV based transport sector. | BEV technology and market do not develop, cost do not decline and manufacturers may abandon the technology |

Source: ITF discussion paper Lindberg and Fridstrøm 2015

## 6.3 Phasing in and phasing out incentives

The introduction of EVs and departure from ICEs clearly require large subsidies and investments as well as a political commitment – especially during the first stages of early diffusion, and especially if ICE taxation remains unchanged. However, the goal is to establish a self-sustaining market that could eventually thrive in a future time without public sector support. The questions are: what is the size of a self–sustaining market, and how to adjust different subsidies as the market for EVs grows in a manner that would not harm the take-off of the EV market?

As the EV market grows, the different factors that create a gap between the price and other obstacles of a typical EV relative to a typical ICE vehicle will decrease. Figure 6.9 gives a schematic illustration of the principle. (Here, we only look at EV incentives and not at offsetting tax increases in alternative markets.) In the early years, the industry suffers from primitive and expensive technology, consumers face uncertainties with respect to second-hand market value, range, safety, etc., and a vast majority of the population is largely unaware of the EV market characteristics compared to that of ICEs. The gap between the two technologies decreases over time because of technology improvements, diffusion of knowledge and so on. Hence, the amount of the incentives should also decrease. It will eventually become overly costly, inefficient and ineffective to maintain the high levels of incentives.

Which incentives should be first abolished or reduced in size? Clearly, those incentives that were identified in chapter 4.4 as the least cost effective ones in Norway, should be considered removed or reduced such as free parking and the toll road exemptions. Purchase tax exemption and the combination of VAT and purchase tax exemption are effective but expensive incentives that over time should be adjusted.

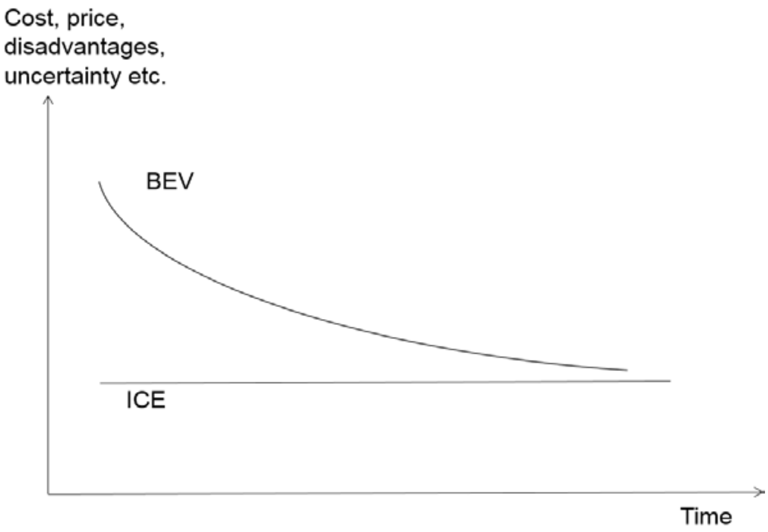



*Figure 6.9: As EV disadvantages fall, less incentives are needed in order to make EVs competitive.*

The Norwegian example of successful EV policies underline the importance of foreseeable long-term EV policies which are backed by central government commitment. This also relates to out-phasing of incentives. A broad Norwegian government agreement in 2012 ensured that the generous package of benefits would stay in place till the end of year 2017 or till 50,000 BEVs are registered, whichever came first (50,000 BEVs were reached in April 2015). This provided the EV market with predictable and general incentives, but also with an anticipation that incentives one day are bound to be reduced or removed.

## 6.4 Financing charging infrastructure

At the European level, the Directive on the deployment of alternative fuels infrastructure (EU, 2014) requires that members shall ensure that an appropriate number of recharging points are accessible to the public, and indicates that one recharging point per 10 EV as an appropriate average level. The same Directive requires member states to facilitate deployment of alternative fuels infrastructure like charging points.

In figure 6.10, Norwegian facts about number of charging points are plotted against the number of charging points that would be judged as appropriate according to this definition. Note that this definition does not take into consideration the longer run (beyond year 2020) developments in battery range, which are likely to reduce the need for publicly available charging.

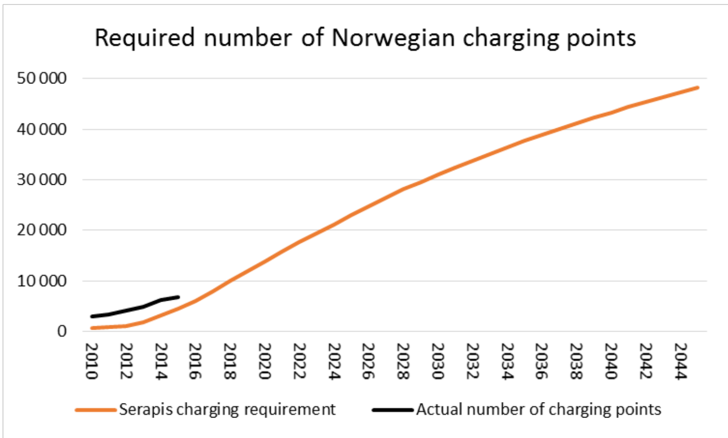



*Figure 6.10a: Observed (actual) number of Norwegian charging points, December 2010-June 2015 and required number of charging points as generated by SERAPIS base scenario.*

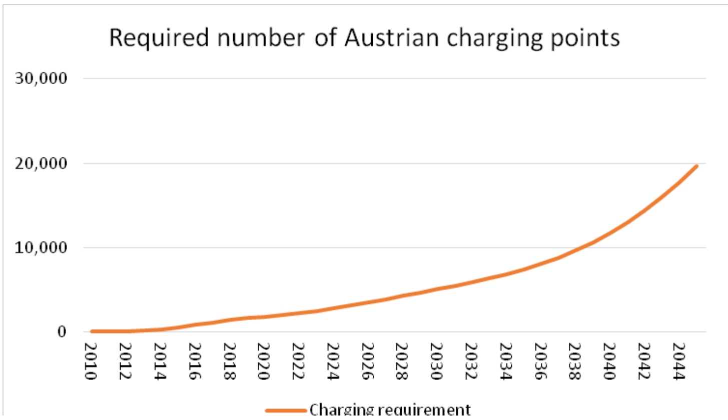



*Figure 6.10b: Required number of charging points as generated by SERAPIS base scenario - Austria.*

Tables 6.3a, 6.3b and 6.3c depict what amount of charging points the future stock of BEVs will require based on the assumption of one point per 10 vehicle. A robust cost estimate is impossible because of the huge variation in costs depending on local circumstance and because of uncertainty about future costs. Therefore, the table provides very broad ranges of cost estimates for the required infrastructure supply. Maintenance costs and cost of electricity are not included since they are assumed to be recovered by user payments.

The critical assumptions for the investment cost estimate are, firstly, the direct investment cost and, secondly, the share of fast chargers. Fast chargers are substantially more expensive to put in place than normal chargers. We use cost figures from COMPETT (2014). The *lower bound* cost estimate consists of only normal chargers. COMPETT (2014, table 12) indicates an average investment cost of €4-7,000 per public normal charger (Mode 3 type 2), and therefore we assume €5,000 investment cost. The *upper bound* assumes that 5 percent of all public charging points are fast chargers. COMPETT (2014, table 12) suggests an installation cost range between €67,000 and €134,000. For our purposes, we use €100,000 per charging point. It also suggests total investment costs given that 5 percent of charging points are fast chargers and 95 percent are normal chargers.

The table shows that, because Norway in 2015 lies ahead of the 1:10 requirement, the investment peak will happen in 2019 but costs will steadily lessen throughout the period. On average, annual investment costs lie between NOK 64m and NOK 147m.

*Table 6.3a: Required number of new charging points in Base scenario and upper and lower bound of annual investment cost.* Norway

| Year | New points required | Investment cost, NOK millions | |
|---|---|---|---|
| | | Lower bound (all normal) | Upper bound (5% fast) |
| 2017 | 1 201 | 52 | 120 |
| 2018 | 1 929 | 84 | 193 |
| 2019 | 2 001 | 87 | 200 |
| 2020 | 1 935 | 85 | 194 |
| 2021 | 1 926 | 84 | 193 |
| 2022 | 1 961 | 86 | 196 |
| 2023 | 1 805 | 79 | 181 |
| 2024 | 1 825 | 80 | 183 |
| 2025 | 1 764 | 77 | 177 |
| 2026 | 1 765 | 77 | 177 |
| 2027 | 1 756 | 77 | 176 |
| 2028 | 1 739 | 76 | 174 |
| 2029 | 1 663 | 73 | 166 |
| 2030 | 1 480 | 65 | 148 |
| 2031 | 1 442 | 63 | 144 |
| 2032 | 1 402 | 61 | 140 |
| 2033 | 1 366 | 60 | 137 |
| 2034 | 1 327 | 58 | 133 |
| 2035 | 1 292 | 56 | 129 |
| 2036 | 1 254 | 55 | 126 |
| 2037 | 1 215 | 53 | 122 |
| 2038 | 1 175 | 51 | 118 |
| 2039 | 1 135 | 50 | 114 |
| 2040 | 1 100 | 48 | 110 |
| 2041 | 1 065 | 47 | 107 |
| 2042 | 1 032 | 45 | 103 |
| 2043 | 999 | 44 | 100 |
| 2044 | 969 | 42 | 97 |
| 2045 | 940 | 41 | 94 |

*Table 6.3b: Required number of new charging points in Base scenario and upper and lower bound of annual investment cost - Austria.*

| Year | New points required | Investment cost, Euro millions | |
|---|---|---|---|
| | | Lower bound (all normal) | Upper bound (5% fast) |
| 2017 | 144 | 0.72 | 1.65 |
| 2018 | 199 | 1.00 | 2.28 |
| 2019 | 276 | 1.38 | 3.16 |
| 2020 | 308 | 1.54 | 3.52 |
| 2021 | 328 | 1.64 | 3.76 |
| 2022 | 167 | 0.84 | 1.92 |
| 2023 | 192 | 0.96 | 2.19 |
| 2024 | 217 | 1.09 | 2.49 |
| 2025 | 236 | 1.18 | 2.70 |
| 2026 | 262 | 1.31 | 3.00 |
| 2027 | 291 | 1.45 | 3.33 |
| 2028 | 322 | 1.61 | 3.68 |
| 2029 | 356 | 1.78 | 4.07 |
| 2030 | 388 | 1.94 | 4.44 |
| 2031 | 391 | 1.96 | 4.48 |
| 2032 | 395 | 1.97 | 4.52 |
| 2033 | 404 | 2.02 | 4.62 |
| 2034 | 413 | 2.06 | 4.73 |
| 2035 | 422 | 2.11 | 4.83 |
| 2036 | 432 | 2.16 | 4.95 |
| 2037 | 500 | 2.50 | 5.73 |
| 2038 | 574 | 2.87 | 6.58 |
| 2039 | 655 | 3.27 | 7.50 |
| 2040 | 742 | 3.71 | 8.49 |
| 2041 | 835 | 4.18 | 9.57 |
| 2042 | 969 | 4.84 | 11.09 |
| 2043 | 1,111 | 5.55 | 12.72 |
| 2044 | 1,261 | 6.31 | 14.44 |
| 2045 | 1,420 | 7.10 | 16.26 |

The EU (2014) Directive does not intend to place an additional financial burden on member states or on regional and local authorities. Instead, it suggests, "*making use of a wide range of regulatory and non-regulatory incentives and measures, in close cooperation with private sector actors, who should play a key role in supporting the development of alternative fuels infrastructure.*" (para 15)

To date, charging infrastructure providers in general struggle to establish profitable business models. Most rely on government full- or part funding or kick-start support schemes. Some have gone bankrupt and others stay in business despite red numbers in order to be better positioned when a critical mass is established (see, e.g. Ihle, 2015).

There are numerous more or less innovative ways to (co-)finance charging infrastructure, even when profitability of purely commercial operations is impossible.

Among these are: national support schemes including partially or fully funded and tendered installations (see, e.g. Øyn, 2015), subsidised lending, various forms of public-private partnerships (PPP), legal requirements e.g. of gas stations to also supply electricity, hypothecation of revenues from e.g. special electricity or fuel charges, lending from inter-governmental agencies like the European Investment Bank. Various forms of smart grid solutions are also put forward as future solutions to profitability (see, e.g. Paturet, 2015). One example is the vehicle-to-grid (V2G) idea that BEVs can charge during off peak periods when electricity prices are low, and discharge back to the grid in peak periods when the price is higher – and in that way make money while at the same time help smoothen out electricity demand fluctuations. Another example is to buy (in cheap off-peak periods) and store large amounts of electricity in BEV batteries that are no longer in use, which then supply either EV charging or the national grid, charging full prices.

# 7 Conclusions and recommendations

This report has documented state and regional electromobility incentives across Europe with strong emphasis on 1) battery electric vehicle (BEV) incentives and 2) Austria and Norway. There is a very strong and clear relationship between the amount and intensity–i.e. money used–of incentives on the one side, and market penetration of BEVs on the other side. National incentives appear to out-perform local and regional incentives and are, usually, appreciated by the market as more stable and predictable. However, the benefit of local incentives lie in the way they can be tailored to local circumstance: access to parking or bus lanes can have huge effects on BEV sales in some areas; in other places, free ferry rides have similar effect.

To better understand and explore the dynamics of BEV markets, and to carry out an economic assessment of the implementation of different incentives for e-vehicles, the SERAPIS model was used. SERPAIS simulates markets for alternative propulsion technologies. The model was brushed up and calibrated to replicate the Norwegian and Austrian automobile markets. SERAPIS models the effect of incentives on user costs/benefits, and sales and market shares of electromobility. These results feed into calculations of energy use and other environmental indicators, public revenues and expenditures, and much more. The analyses performed in this report rely heavily on SERAPIS model runs.

Policies that address the purchase price of a BEV are found to be most effective in the way that they contribute significantly to BEV market shares. They are, however, costly. Without any adjustments to the overall profile of car purchase taxing regimes, BEV purchase subsidies or tax exemptions place heavy burdens on public budgets. At the other end of the scale, we find “free” BEV incentives that mainly improve convenience. Bus lane access in Norway is the prime example. As long as there is ample bus lane capacity, BEV access is associated with close to zero cost and has noticeable effect on BEV sales in urban and suburban areas. However, the market potential that stems from bus lane access is limited. The main conclusion of this report is, therefore, that successful and large market uptake of electric vehicles require massive, stable, expensive and combined policies.

The high market penetration in Norway has been achieved through a broad package of continued incentives, which include reductions in the cost differences between conventional vehicles and e-vehicles, preferential treatment with respect to parking, road charging exceptions, access to bus lanes, a strategy for charging stations which is accompanied by generous government support, and technological advances. These policies do not primarily reinforce each other, since there is little evidence of synergies between them. Instead, they address different (local) needs and opportunities to grow the EV market locally[17]. This way, the Norwegian BEV market is not limited to major cities, but is expanding all across the country. With

[17] In line with Moch and Yang (2014), cited in chapter 2, we also identified limits as to what market uptake individual BEV incentives can generate.

continuation of current incentives and a well-communicated plan for gradual changes, the market share of EVs will continue to increase rapidly.

The growth stems also from factors outside of the policy domain – notably advances in technology – and from diffusion mechanisms that can only in part be managed by policy intervention.

The fact that Norwegian BEV incentives have state backing and apply to all parts of the country has probably reduced the perceived risk for market players like car importers. The policies are clear, stable and predictable. Compared with Norway, Austria has followed a path which relies less on market mechanisms and which is more top-down in the sense that much responsibility and initiative lies with the e-mobility regions rather than general incentives in the market. The Austrian EV market has evolved in a similar fashion to Norway, but the size of the Norwegian market is considerably larger - by a factor of about 10.

The differentiated use of incentives and our EV user surveys point to an important aspect of the Norwegian success. Since the users have different needs, national and local stakeholders and the industry should use a broad package of incentives in marketing this new technology in order to speed up its diffusion. The Norwegian package of incentives primarily address different local barriers to EV use. In total, the package of incentives sums to a forceful and reinforcing combination market stimuli.

For countries which are still in an early phase of promoting EVs, like Austria, the COMPETT project has shown that the potential for EV uptake is promising. EVs are already a real option for the majority of peoples' everyday trips and trip chains. However, the EVs' relative disadvantages to the ordinary car must be reduced by applying incentives in the initial market launch phase, and the lack of knowledge in the population at large must be addressed.

A scenario assessment identifies two main dimensions that affect the BEV market: 1) technology and supply-side factors, and 2) policy factors. In Norway as well as in Austria, the role of supply side developments is prominent. The main contribution of favourable BEV policy is to support and speed up technological development. This fact suggests free rider problems: Countries with generous policies bear a high cost, while any country can reap the benefits of technological advances.

Finally, this report highlights some crucial implementation issues. Among them are the importance of cost-effective policies, strategies to recover fiscal tax revenue losses, a broad perspective to gain popular support and manage barriers, and a plan for the phasing out of costly incentives. Most EV incentives have a high cost. Inefficient policies should be avoided, including those which may be unduly harmful to other parts of society, like, e.g., bus lane access which could severely delay buses if not implemented properly. Cost-effective policies should be the first to be introduced, and the last to be withdrawn.

With the S-shaped market penetration curve in described in section 3.1.2 in mind, it is evident that the Austrian BEV market will experience increased growth rated for a long period of time. The Norwegian BEV market, on the other hand, will reach its inflection point and experience growth rates that slow down because it approaches its saturation level. Figure 7.1 suggests where the two countries are on the saturation curve. Increasing the available makes and models faster and beyond the assumptions in the scenarios may increase sales further, essentially having the effect of lifting the saturation level.

Most European countries and any country where electromobility has not yet taken off should look to and learn from the analyses of the Austrian market. Austria replicates the level of BEV market penetration that is seen around in Europe to a larger extent than Norway. However, the degree of transferability of the Austrian findings to other European settings depend crucially on the local circumstances with respect to such factors as culture, legislative framework, public finances, taxation regimes, and many more. The Austrian case suggests that VAT exemption plays a much stronger role in building a BEV market than is the case in Norway. For a country like Austria, the best strategy for car manufacturers appears thus to be to prioritise reduced purchase cost over improved range. Another priority would be to maximise the availability of EV makes and models. It is worth noting that bus lane access, which has a huge positive impact on the Norwegian BEV stock, only will play a minor role in building the Austrian BEV market.

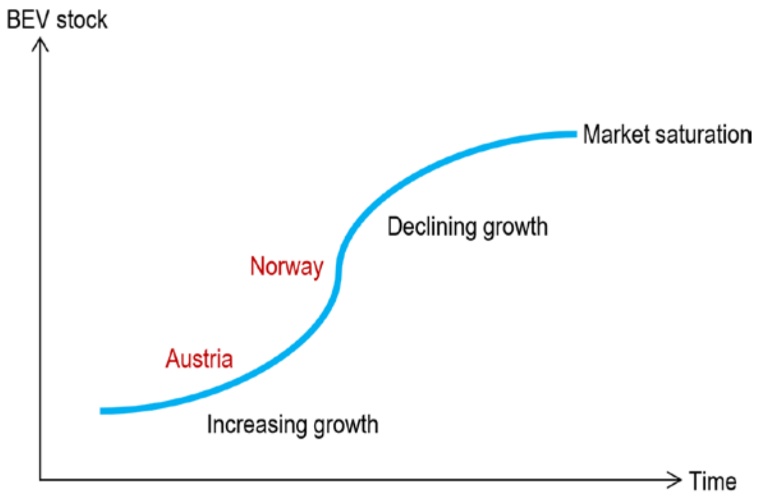



*Figure 7.1: Schematic illustration of market saturation curve and Norway and Austria's position.*

The Norwegian case, on the other hand, bears some lessons to be learned about the prospects of electromobility: The potential is huge and can in fact be achieved with sufficient political commitment and budget spending over a long period.

# References


Assum, T., Kolbenstvedt, M., Figenbaum, E., 2014. *The future of electromobility in Norway – some stakeholder perspectives*. TØI-report 1385/2014

Asphjell, A. Asphjell, Ø. and Kvisle, H., H., 2013 (in Norwegian), *Elbil på norsk*. Transnova. ISBN 978-82-7704-142-1.

Audera, V., 2015. Personal communication, Spain's Industry and Energy ministry.

Banister, D., Hickman, R., 2013 Transport futures: Thinking the unthinkable. *Transport Policy* 29, pp 283–293. doi:10.1016/j.tranpol.2012.07.005

Budget agreement 2001, *Agreement in the Storting* (the Norwegian parliament) about the national budget for 2001. https://www.regjeringen.no/nb/dokument/dep/fin/statsbudsjettet/budsjett-2001/budsjettavtale-for-statsbudsjettet-for-2/id411925/).

Ellis, I. O., Øvrum, A., *Parkering som virkemiddel*. Urbanet Analyse. Report 64/2015

ELMO, 2015. http://elmo.ee/about/

EU, 2014. *Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure (Text with EEA relevance)*. Official Journal of the European Union, L 307/1, 28.10.2014

COMPETT, 2014. *State of the Art Electric Propulsion: Vehicles and Energy Supply*. Work Package 1 Report, December 2013. http://compett.org/documents/wp_1_report_status_quo_electric_propulsion.pdf

Fearnley, N., 2014. *Parking revenues lost due to mandatory free public parking of electric vehicles*. TOI report 1340/2014

Figenbaum 2015, Personal communication

Figenbaum, E., Kolbenstvedt, M., 2013. *Electromobility in Norway - experiences and opportunities with Electric Vehicles*. TOI report 1281/2013

Figenbaum, E., Kolbenstvedt, M., Elvebakk, B., 2014. *Electric vehicles - environmental, economic and practical aspects: As seen by current and potential users*. TØI report 1329/2014

Figenbaum, E., Fearnley, N., Pfaffenbichler, P., Hjorthol, R., Kolbenstvedt, M., Jellinek, R., Emmerling, B., Bonnema, G.M., Ramjerdi, F., Vågane, L., Iversen, L.M., 2015. Increasing the competitiveness of e-vehicles in Europe. *EUROPEAN Transport Research Review: Springer*

Figenbaum and Kolbenstvedt 2015, forthcoming. *Competitive Electric Town Transport*. Main results from COMPETT – an Electromobility+ project. http://compett.org/

Frey, H., Mayerthaler, A. and Pfaffenbichler, P. (2011) *Stadtauto e-Mobil - Chancen und Risiken für Wien*, Beiträge zu einer ökologisch und sozial verträglichen Verkehrsplanung, H. Zukal (Hrg.); Institut für Verkehrswissenschaften - Forschungsbereich für Verkehrsplanung und Verkehrstechnik, Technische Universität Wien. Wien.

Frey, H., Mayerthaler, A., Pfaffenbichler, P. and Brezina, T. (2012) E-mobility in urban areas and the impact of parking organisation, *2nd International Conference on Road and Rail Infrastructure (CETRA 2012)*, 07.05.2012 - 09.05.2012, Dubrovnik/HR.

Fridstrøm, L., Østli, V., 2014. The resource cost of vehicle electrification in Norway (in Norwegian). TØI report 1350/2014.

Greene, D. L. (2001) *TAFV Alternative Fuels and Vehicle Choice Model Documentation*, Center for Transportation Analysis, Oak Ridge National Laboratory. http://www-cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2001_134.pdf.

Hjorthol, R., 2013. *Attitudes, ownership and use of Electric Vehicles – a review of literature.* TØI rerport 1261/2013

Hjorthol, R., Vågane, L., Foller, J., Emmerling, B. (2014). *Everyday mobility and potential use of Electric vehicles.* TØI, Report 1352/2014.

Hoogma, R., Kemp, R., Schot, J., and Truffer, B. (2002) *Experimenting for Sustainable Transport: The Approach of Strategic Niche Management.* Spon Press, London, ISBN-13: 978-0415271172

Ihle , J.H., 2015. *How to make business of charging*? Presentation to the International Conference - Learnings from a European full-scale laboratory, Breakthrough for Electric vehicles!, Oslo 11-12 June 2015

Lindberg, G., Fridstrøm, L., *Policy Strategies for Vehicle Electrification.* ITF Discussion Paper 2015:16 OECD/ITF

McDonald, J.F., Moffitt, R.A., 1980. The Uses of Tobit Analysis. *The review of Economics and Statistics* 62:2, pp 318-231

Ministry of Finance, 1989 (page 19). *National budget 1990*, White paper to the parliament. St.prop. 1, 1989-1990.

NRC, 2013. *National Research Council. Overcoming barriers to Deployment of Plug-in Electric vehicles.* Interim report, Washington DC: The National Academic Press.

Paturet , O., 2015. *Making and Selling EVs in the European market.* Presentation to the International Conference - Learnings from a European full-scale laboratory, Breakthrough for Electric vehicles!, Oslo 11-12 June 2015

Pfaffenbichler, P. (2003) *The strategic, dynamic and integrated urban land use and transport model MARS (Metropolitan Activity Relocation Simulator) - Development, testing and application*, Beiträge zu einer ökologisch und sozial verträglichen Verkehrsplanung Nr. 1/2003, Vienna University of Technology, Institute for Transport Planning and Traffic Engineering. Vienna.

Pfaffenbichler, P., Castro Fernández, A., Emberger, G., Frey, H., Kloess, M., Rezanina, R. and Krutak, R. (2012) *SOL Studie für die Organisation der zukünftigen Ladeninfrastruktur für E-Fahrzeuge in Österreich. Notwendige Anzahl und wirtschaftliche Standorte*, Österreichs Energie. Wien.

Pfaffenbichler, P., Emmerling, P., Jellinek, R. and Krutak, R. (2009) *Pre-Feasibility-Studie zu „Markteinführung Elektromobilität in Österreich"*, Österreichische Energieagentur, im Auftrag von Bundesministerium für Verkehr, Innovation und Technologie (bmvit), Abteilung Mobilität und Verkehrstechnologien (III/I4). Wien. www.bmvit.gv.at/innovation/downloads/markteinfuehrung_elektromobilitaet1.pdf

Pfaffenbichler, P., Krutak, R. and Renner, S. (2011) Modelling the development of vehicle fleets with alternative propulsion technologies, Belambra Presqu'île de Giens, France.

Renault 2010. *A driving force behind sustainable mobility for all*. Press release June 3rd, 2010 Environment workshop

Renner, S., Baumann, M., Jamek, A., Lang, B. and Pfaffenbichler, P. (2010) *Visionen 2050 - Identifikation von existierenden und möglichen zukünftigen Treibern des Stromverbrauchs und von strukturellen Veränderungen bei der Stromnachfrage in Österreich bis 2050*, Österreichische Energieagentur im Auftrag von Österreichs Energie. Wien.

Stead, D., Banister, D., 2003. Transport policy scenario-building, *Transportation Planning and Technology*, 26:6, 513-536, DOI: 10.1080/0308106032000167382

van Notten, P.W.F., Rotmans, J., van Asselt, M.B.A., Rothman, D.S., 2003. An updated scenario typology. *Futures* 35:5, pp 423–443, doi:10.1016/S0016-3287(02)00090-3

Øyn, P., 2015. *National support for the introduction of EVs*. Presentation to the International Conference - Learnings from a European full-scale laboratory, Breakthrough for Electric vehicles!, Oslo 11-12 June 2015

# Appendix 1 The SERAPIS v2.0 software

## Installation of SERAPIS v2.0

### Software requirements

The model SERAPIS was written using the System Dynamics software Vensim® (www.vensim.com). The model was converted into the file format "vpm" which stands for Vensim Packaged Model. This type of models can be run with the software "Vensim Model Reader" which can be downloaded from the Vensim® homepage for free (http://vensim.com/vensim-model-reader/). In order to be able to run SERAPIS the user has to install the "Vensim Model Reader". The explanations and screenshots in the following sections are based on version 6.2 of the "Vensim Model Reader".

The user interface to define background and policy scenarios uses Microsoft Excel® and Visual Basic for Applications. The use of macros has to be enabled in Microsoft Excel®. Base year input and scenario definition data are also stored in Microsoft Excel®.

### SERAPIS files and data structure

To install SERAPIS the user has to unpack all files from the file "Serapis-V20.zip" into one directory. The name and location of the directory can be selected freely. Nevertheless the internal order of the unpacked files and directories has to be kept as it is (Figure A.1).

The file "serapis-v20.vpm" is the core model. The file "serapis-user-interface.xls" is the user interface where background and policy scenarios can be compiled from a set of different pre-defined sub-scenarios. The directory "data" contains two xls-files and a sub-directory. One of these files ("serapis-data.xls") contains the base year input data and model parameters. The other file "serapis-scenario.xls" stores the time series scenario data as defined in the user interface ""serapis-user-interface.xls". The sub-directory "scenarios" contains the pre-defined sub-scenarios. The details concerning scenario definition are explained in more detail below.

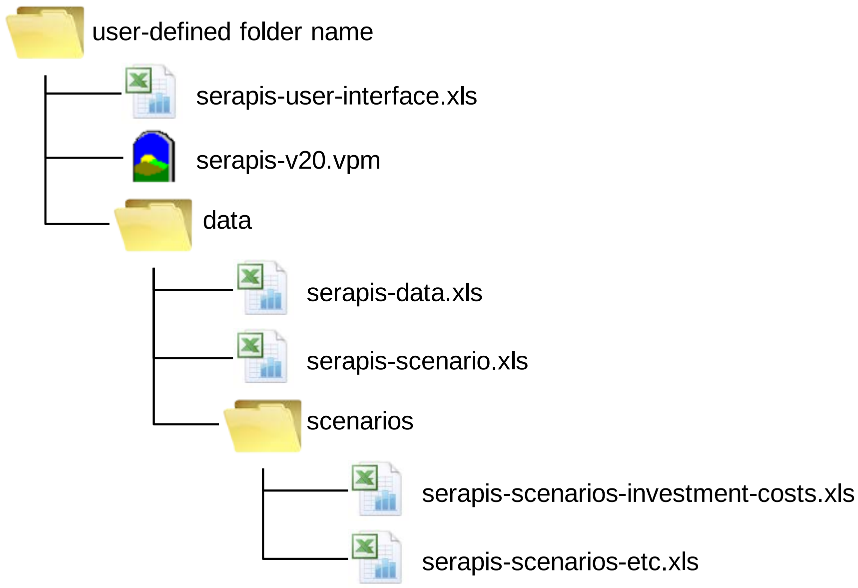



*Figure A.1: Files and directories SERAPIS v2.0*

## Run SERAPIS v2.0

Figure A.2 gives an overview of the procedure how to run SERAPIS v2.0.

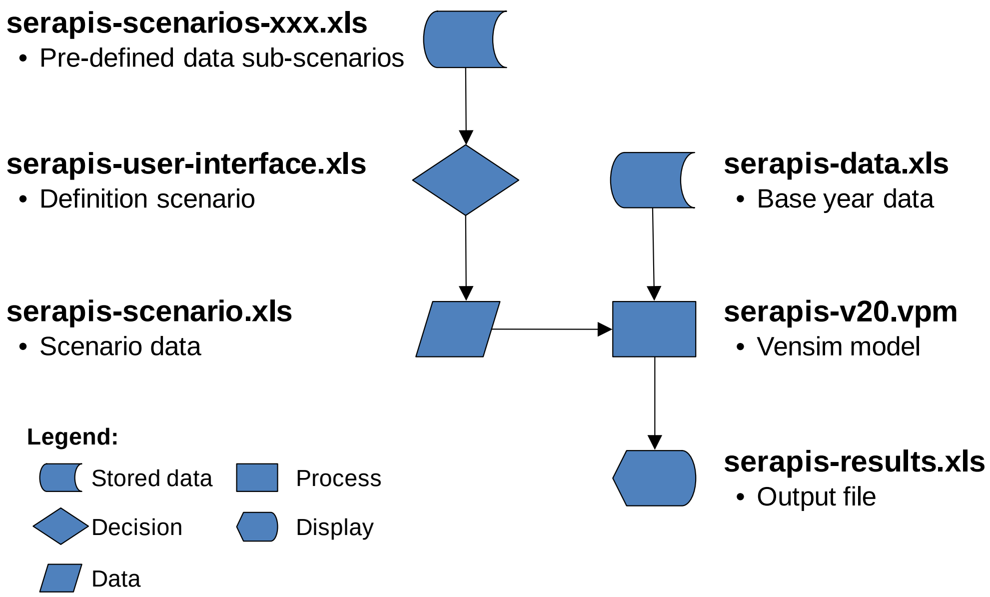



*Figure A.2: Flow chart SERAPIS v2.0*

## Scenario definition

The user interface "serapis-user-interface.xls" has to be opened to define a background and/or policy scenario (Figure A.3). Columns B and C show the different sub-systems which can be used to define complex scenarios. To load a pre-defined sub-scenario for one of the sub-systems press the corresponding button in column D. A list of selectable pre-defined sub-scenarios will appear (Figure A.4).

Pressing the OK button will copy the data from the corresponding file in the sub-directory “scenarios” in to the file “serapis-scenario.xls”. To run a simulation open the file “serapis-v20.vpm” using the Vensim Model Reader®.

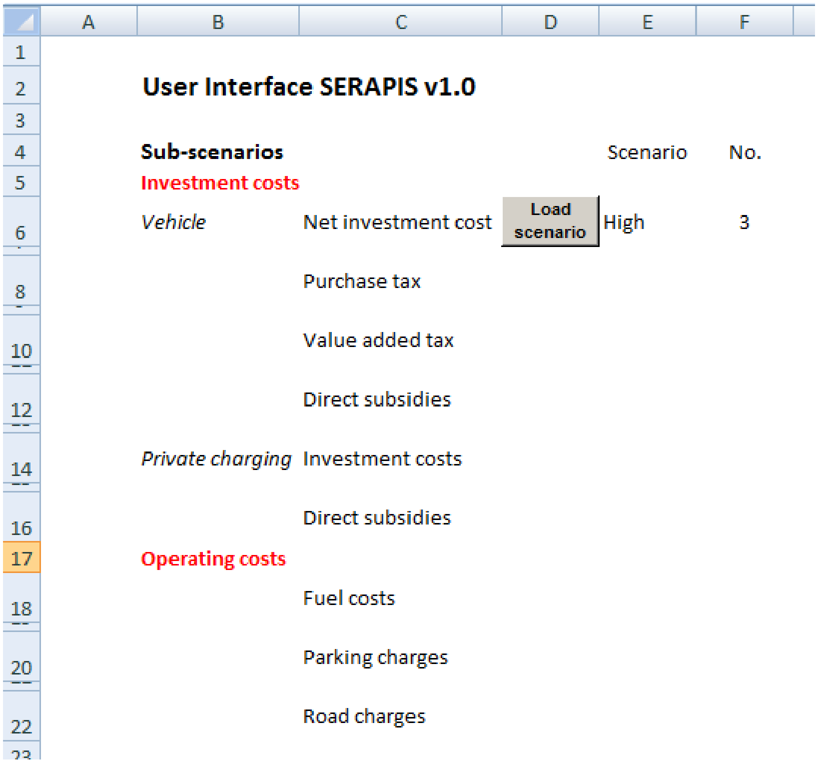



*Figure A.3: Screenshot of the sheet “UserInterface” in “serapis-user-interface.xls”*

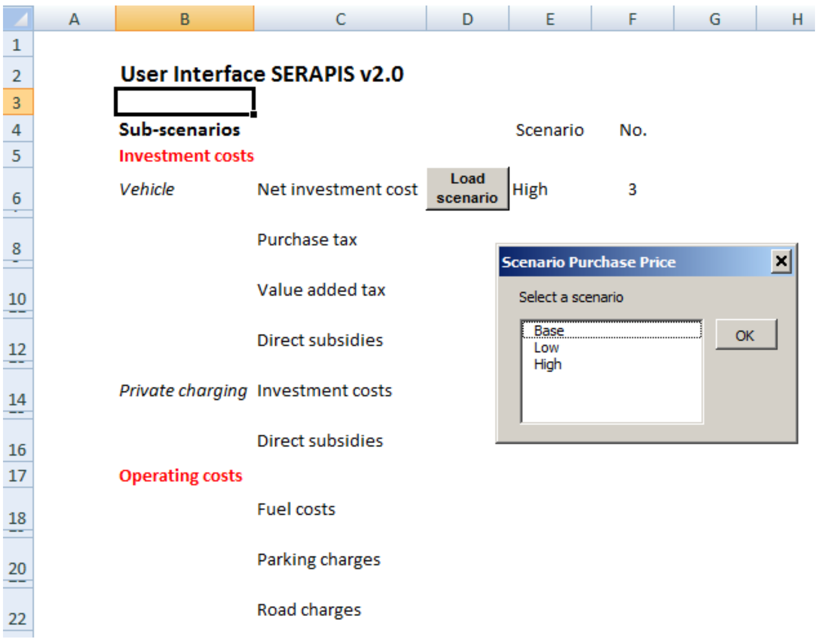



*Figure A.4: Screenshot of the drop down list of sub-scenarios for the sub-system vehicle net investment costs in “serapis-user-interface.xls”*

## Main user interface

For the sake of readability it is possible to organise the content of complex Vensim® models in different views containing different sub-models. Opening the file "serapis-v20.vpm" using the Vensim Model Reader® shows the view "user interface" (Figure A.5). The coloured push buttons navigate the user to different sub-systems of the model. The green buttons navigate directly to the different views. Pushing e.g. the button "go to view car fleet" leads the user to the view "car fleet" where the multinomal LOGIT model and stock-flow-models of the car fleet are located. The grey button navigates to the next view. Other views also contain grey buttons navigation to the previous view and back to the main user interface. Clicking on the logos opens the webpage of the corresponding organisation or project. The diagram in the centre of the view shows the development of the fleet of battery electric cars.

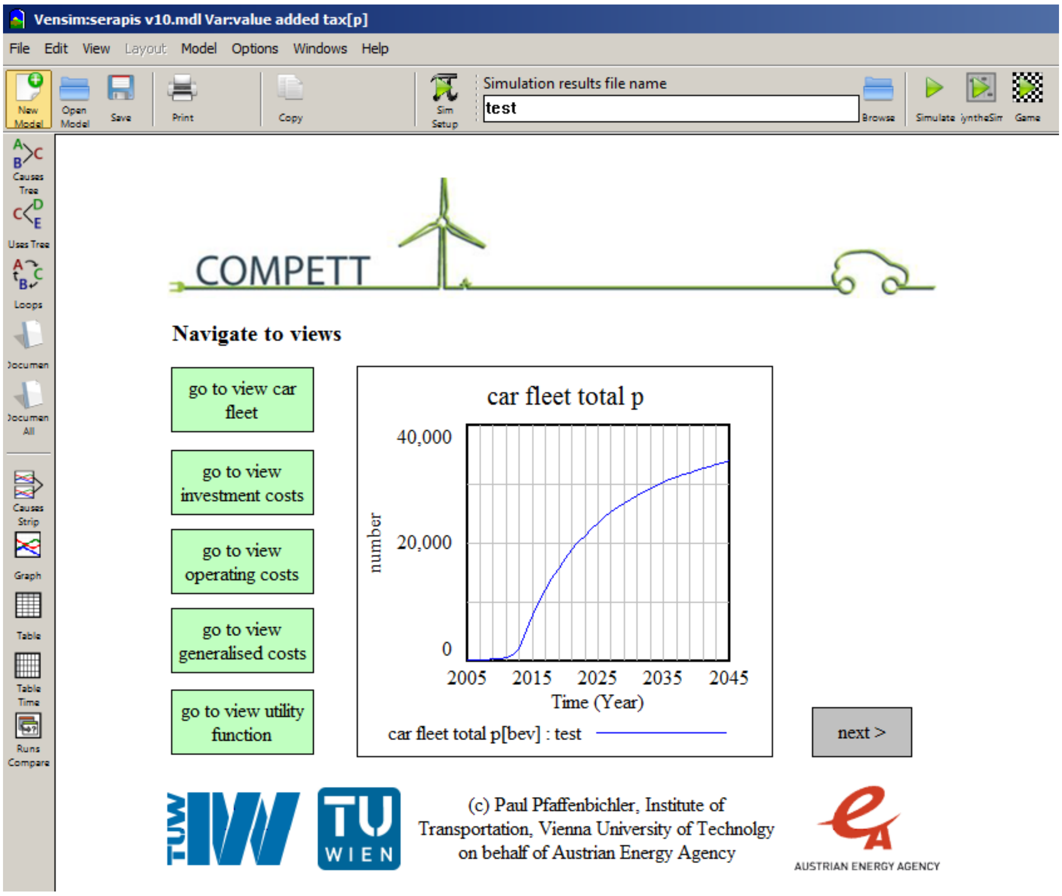



*Figure A.5: SERAPIS v2.0 view „user interface"*

## Run a simulation

To run a simulation define a file name (1) and the press the simulate button (2) (Figure A.5).

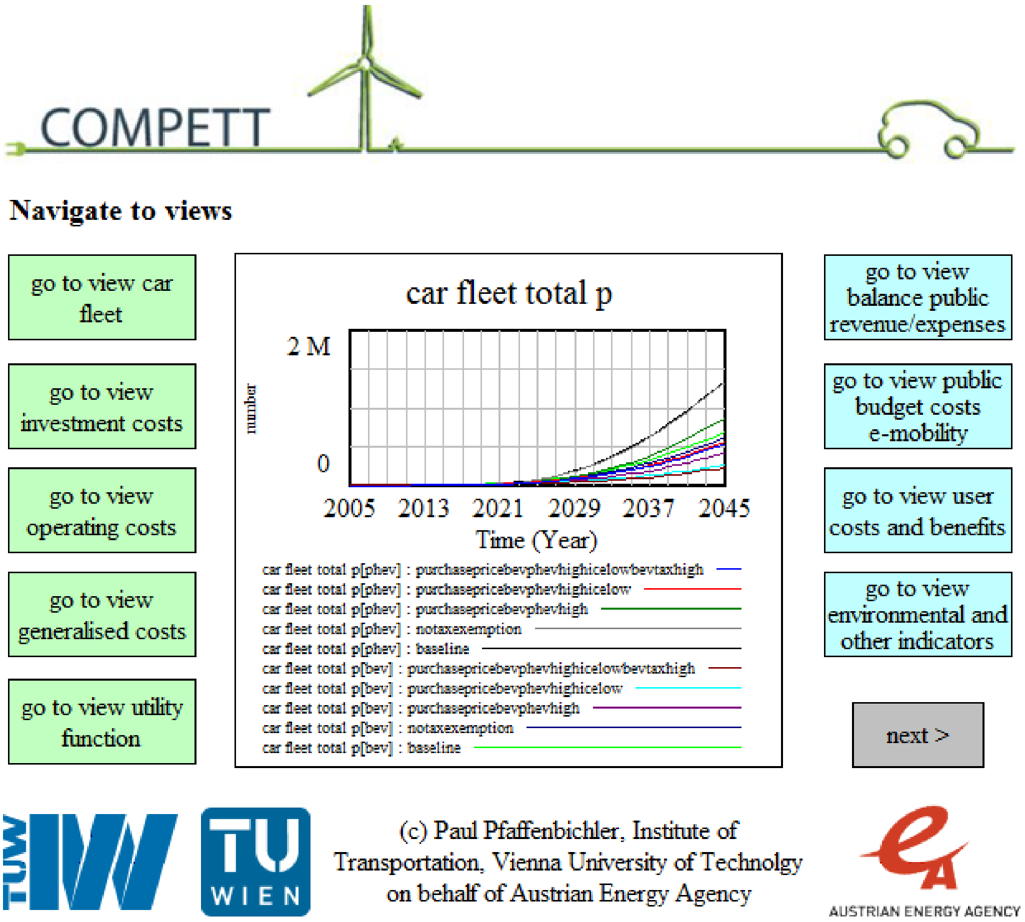



*Figure A.6: SERAPIS v2.0 view „user interface"*

## Analyse the model

### Analyse the model structure

The push buttons in the lower right corner of each view allow the user to navigate to the next view, the previous view or back to the user interface view (Figure A.7). Elements written in red colour indicate base year input data which are read in from the data file "serapis-data.xls" (2). Elements written in blue colour indicate time series scenario definition data which are read in from the file "serapis-scenario.xls" (3). Elements written in green colour indicate constants which are defined directly in Vensim®. Elements written in black colour are model internal variables. The tools in the upper left corner can be used to analyse the model structure (4) and the model output (5).

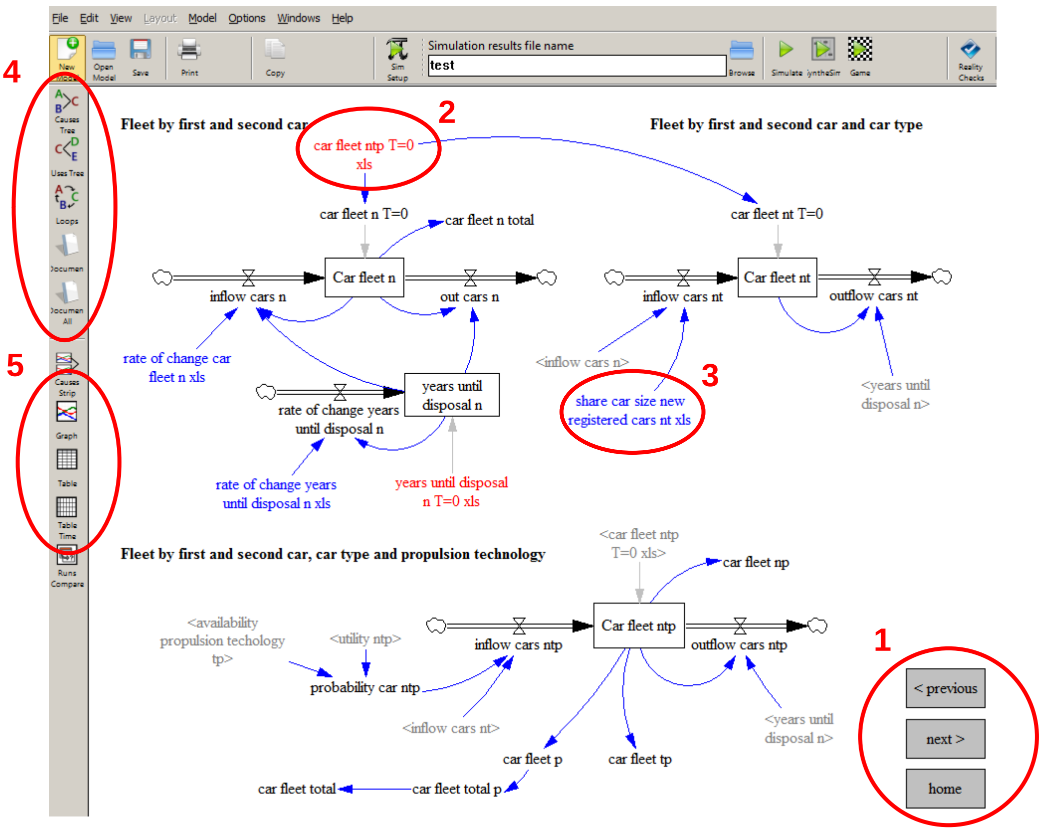
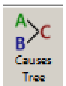



*Figure A.7: Screenshot view „car fleet" SERAPIS v2.0*

The most important tools to investigate and analyse the LUNA model structure are summarised in Table A.1. Figure A.8 shows the causes tree for the variable number of cars subdivided into first and second plus cars. The tools in the upper left corner allow the user to print, copy to the clip board (1) or save the result. Figure A.9 shows the uses tree for the variable number of cars subdivided into first and second plus cars as copied using the clip board tool. Figure A.10 shows the equations underlying the variable number of new cars per year subdivided into first and second plus cars. As the user is able to investigate all relationships of the model in a qualitative and quantitative way SERAPIS v2.0 qualifies as a white box model.

*Table A.1: Summary tools to investigate and analyse the model structure*

| Symbol | Name | Explanation |
|---|---|---|
|  | Causes tree | Shows which variables are influencing a selected variable. The depth of the causes tree is two levels backwards. |
|  | Uses tree | Shows which variables are influenced by a selected variable. The depth of the causes tree is two levels forward. |
|  | Document | Shows the equation behind a selected variable. |

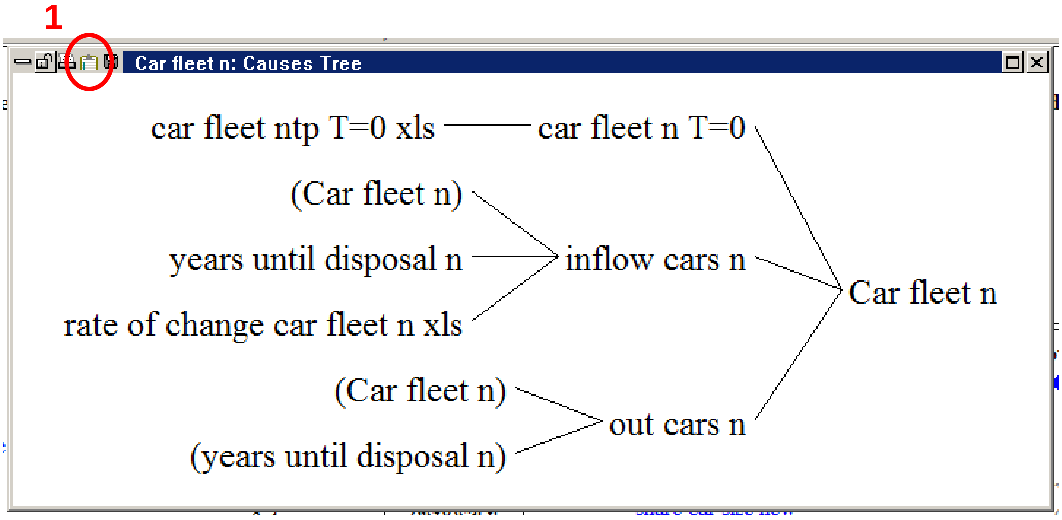



*Figure A.8: Causes tree variable „Car fleet n" (number of cars by first and second+ car)*

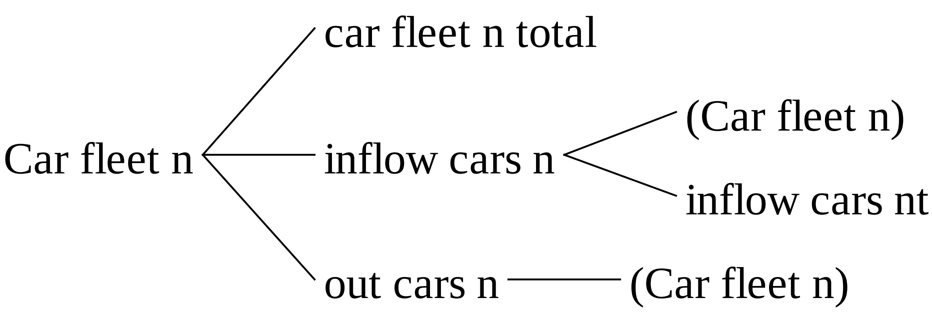



Figure A.9: Uses tree variable „Car fleet n" (number of cars by first and second+ car)

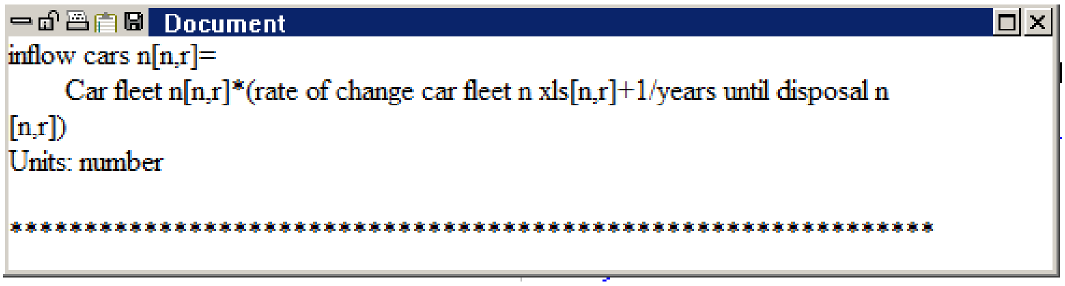
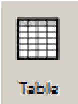



*Figure A.10: Equation variable „inflow cars n" (number of new cars by first and second+ car)*

## Analyse the model output

The model output and the value of every element, variable or constant can be shown using either the Graph or the Table tool (Table A.2). Figure A.11 shows the graph of the variable number of battery electric vehicles. Table A.3 shows the table of the variable number of cars by propulsion technology. Again the tools in the upper left corner allow the user to print, copy to the clip board or save the results.

*Table A.2: Summary tools to investigate and analyse the model output*

| Symbol | Name | Explanation |
|---|---|---|
|   | Graph | Shows the value of a selected variable in each iteration in form of a diagram. |
|   | Table | Shows the value of a selected variable in each iteration in form of a table. |

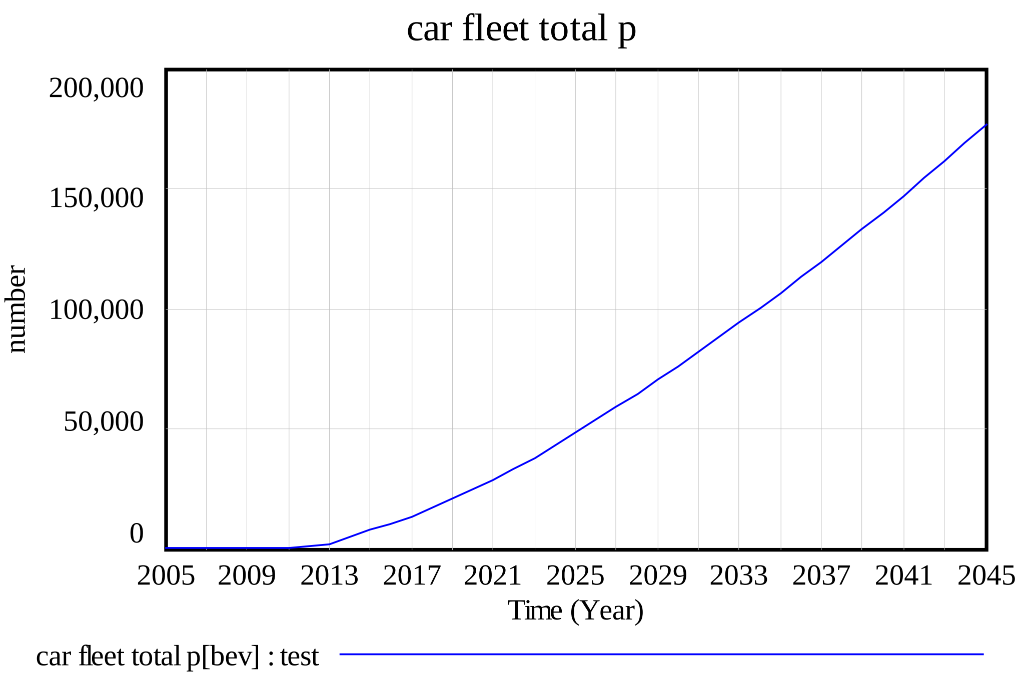



*Figure A.11: Graph development battery electric cars*

*Table A.3: Table development number of cars by propulsion technology*

| Time (Year) | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|
| "car fleet total p[p]" Runs: | test | | | | | | | | |
| car fleet total p | | | | | | | | | |
| [ice] | 4.15662e+006 | 4.2114e+006 | 4.2672e+006 | 4.32401e+006 | 4.38185e+006 | 4.4407e+006 | 4.5005e+006 | 4.50003e+006 | 4.49904e+006 |
| [phev] | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22.8465 |
| [bev] | 127 | 137.107 | 150.767 | 167.736 | 216.552 | 329.927 | 584.168 | 1053.31 | 2017.07 |

The Control Panel (Figure A.12) can be used to change the start and end time of simulation (Figure A.13) and load/unload data from previously calculated scenarios (Figure A.14).

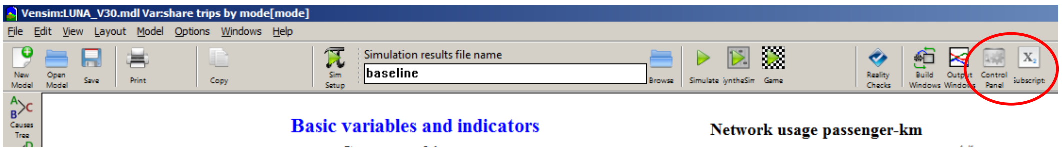



*Figure A.12: Control Panel and Subscript Control*

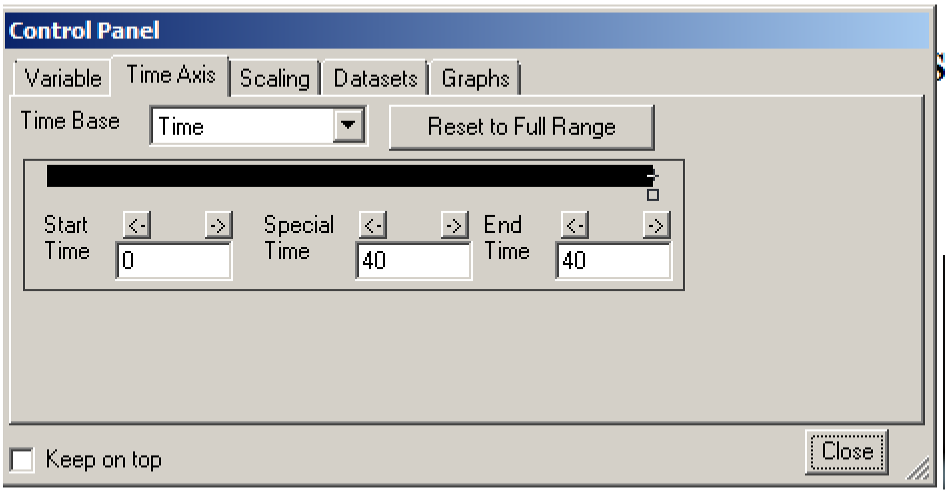



*Figure A.13: Defining the start and end time of a simulation*

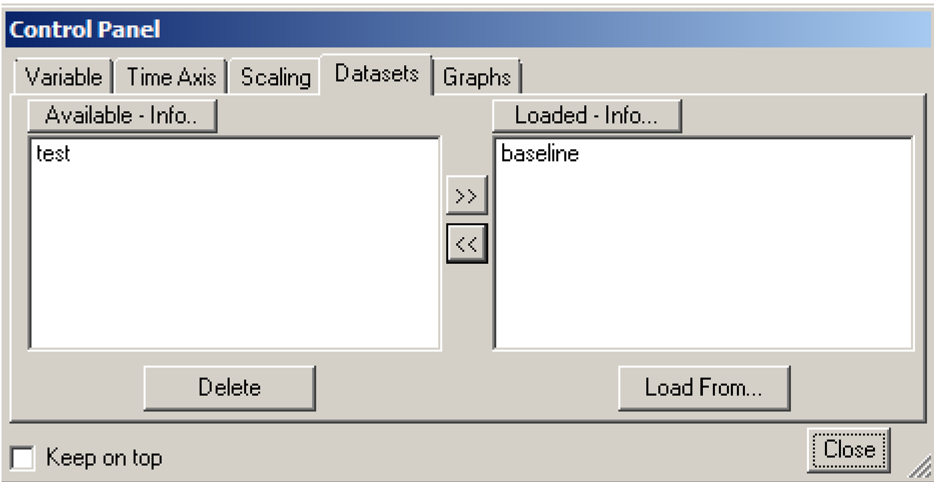



*Figure A.24: Loading/unloading of datasets*

The Subscript Control (Figure A.12) allows to define a selection from the range of available subscripts, e.g. to view only the values for the propulsion technology battery electric vehicles from the list of all propulsion technologies (Figure A.15).

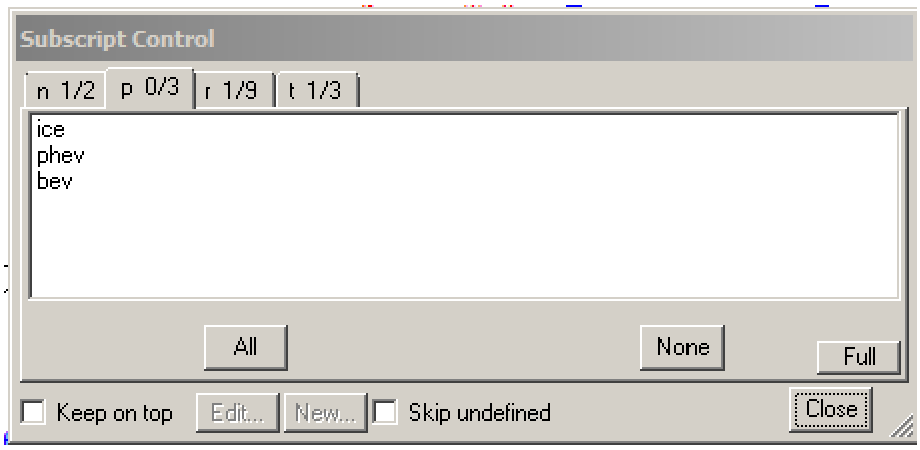


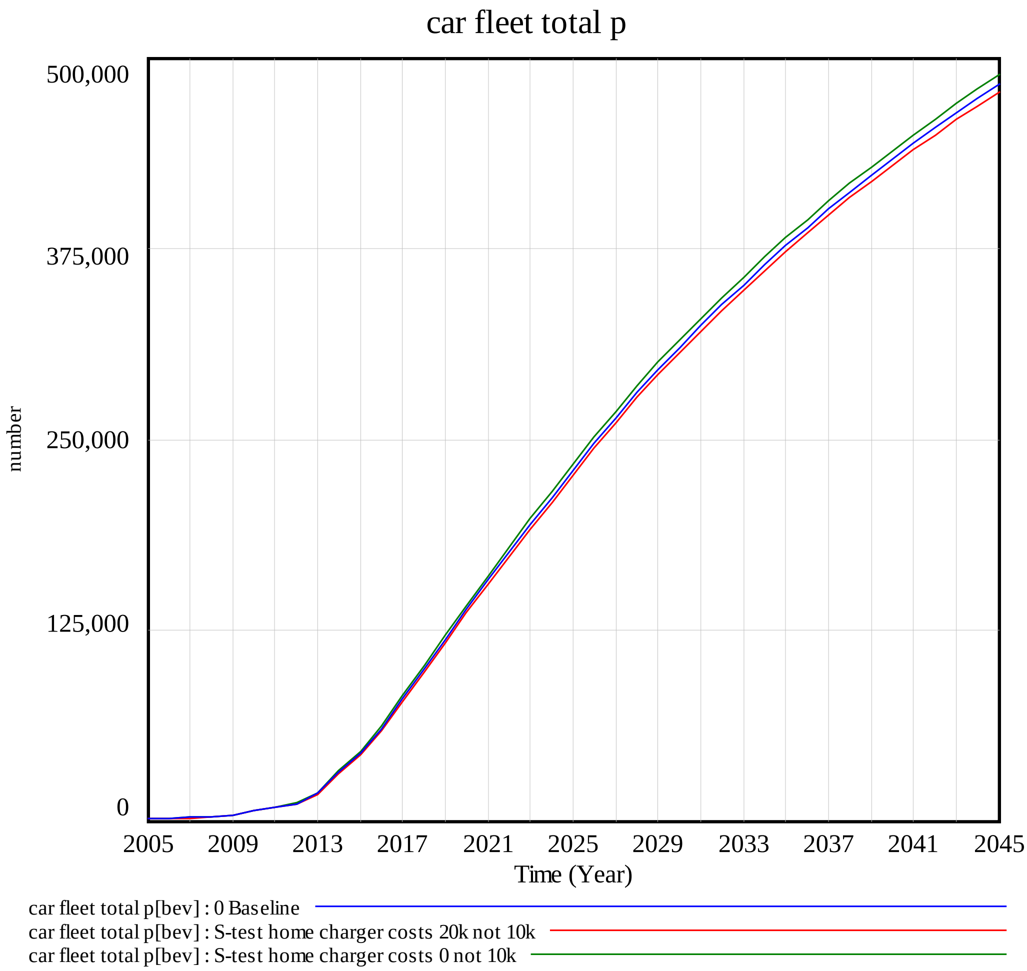

*Figure A.15: Subscript Control – countries*

# Appendix 2: Sensitivity testing of SERAPIS calibration and assumptions

The following sensitivity tests are performed in order to identify assumptions, parameters and input data that have strong bearings on the outcome. We run the Base scenario and relate it to outcomes where these items are changed. We then assess, briefly, the extent to which the outcome depend on this item.

## Investment cost of BEV charging NOK 100k instead of 10k

This assumption is interesting because not all choose to install charger and instead use existing ordinary electric socket. We see from the figure below that this assumption has minor impact on the results. Neither a zero (0) or double (NOK 20k) cost assumption affect results in any substantial way.



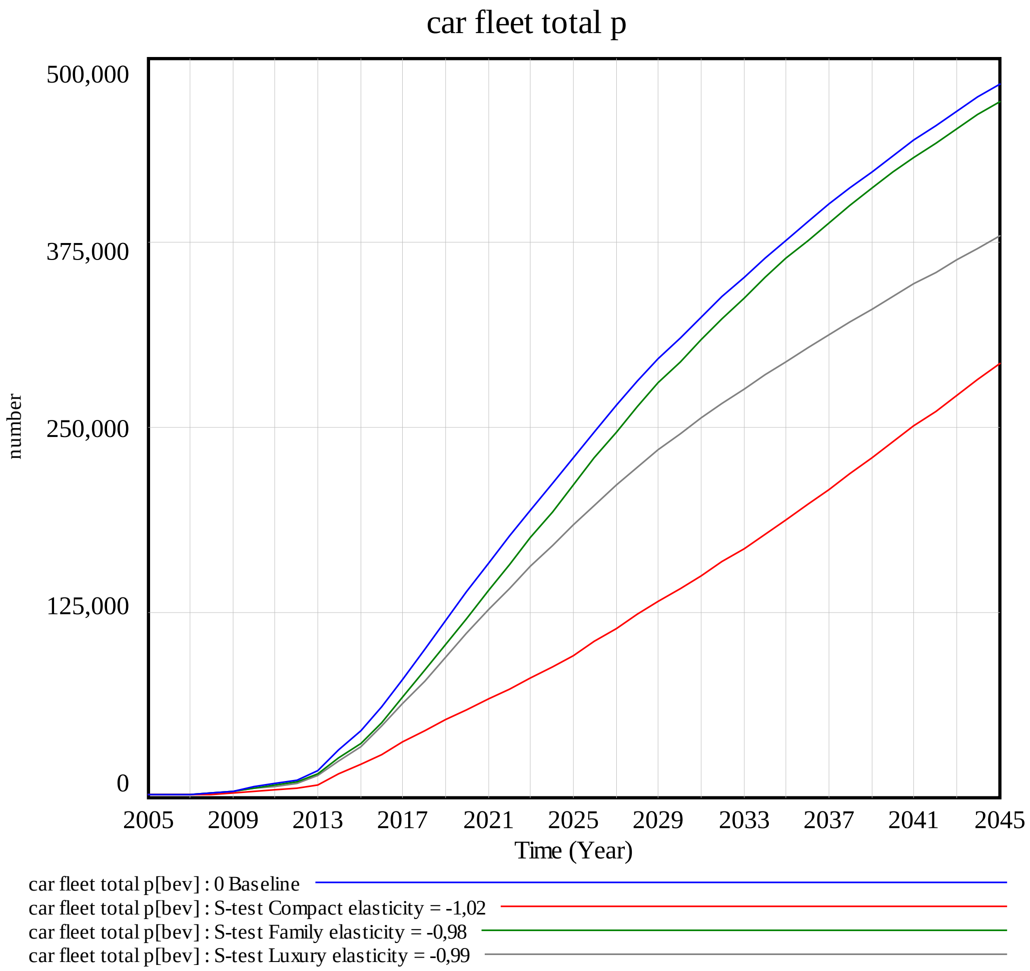

## Price elasticities between propulsion technology within car class

SERAPIS rests on the following assumptions:

| | Compact | Family | Luxury |
|---|---|---|---|
| Elasticity | -2,04 | -1,97 | -1,98 |

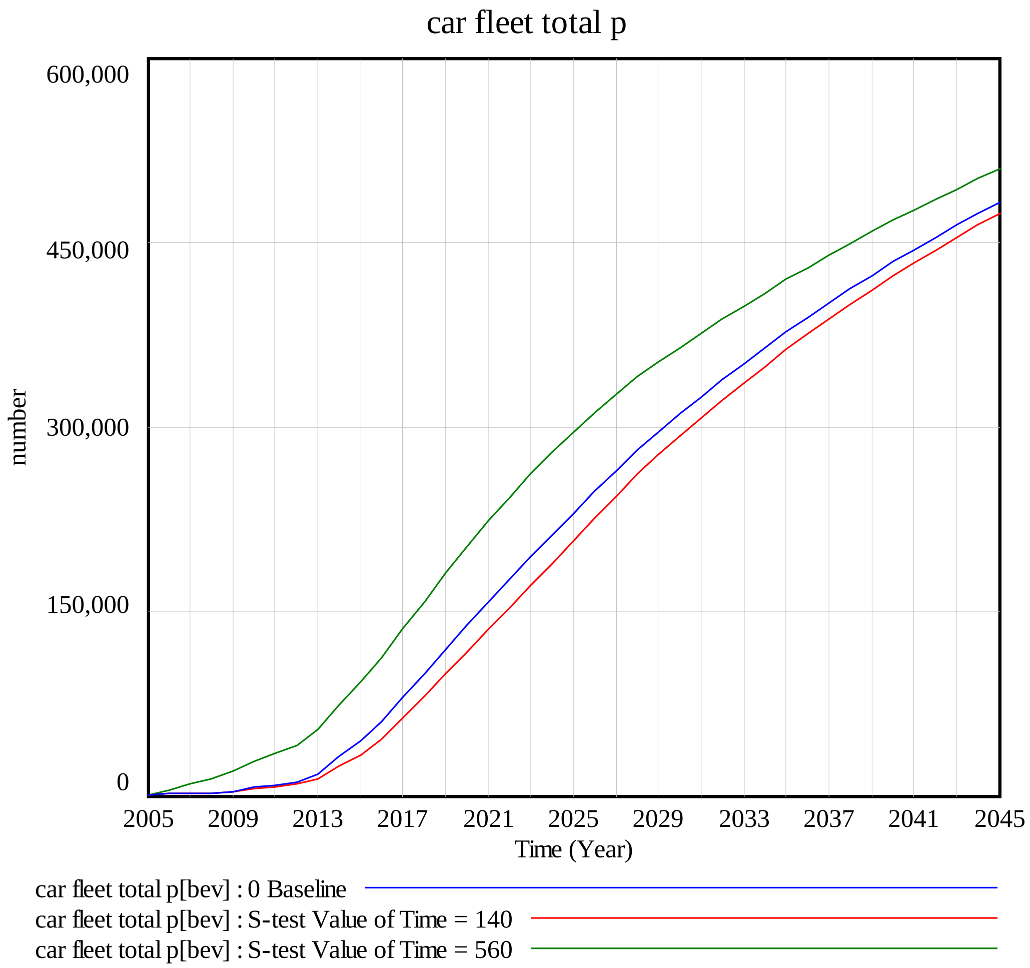
The figure below shows how the outcome changes when each of these are reduced by ½. We see that the elasticity assumptions for compact car and luxury car segments has very large effect on the outcome. SERAPIS model output rests critically on these assumptions.

Elasticity assumptions for family size cars have relatively small effect.



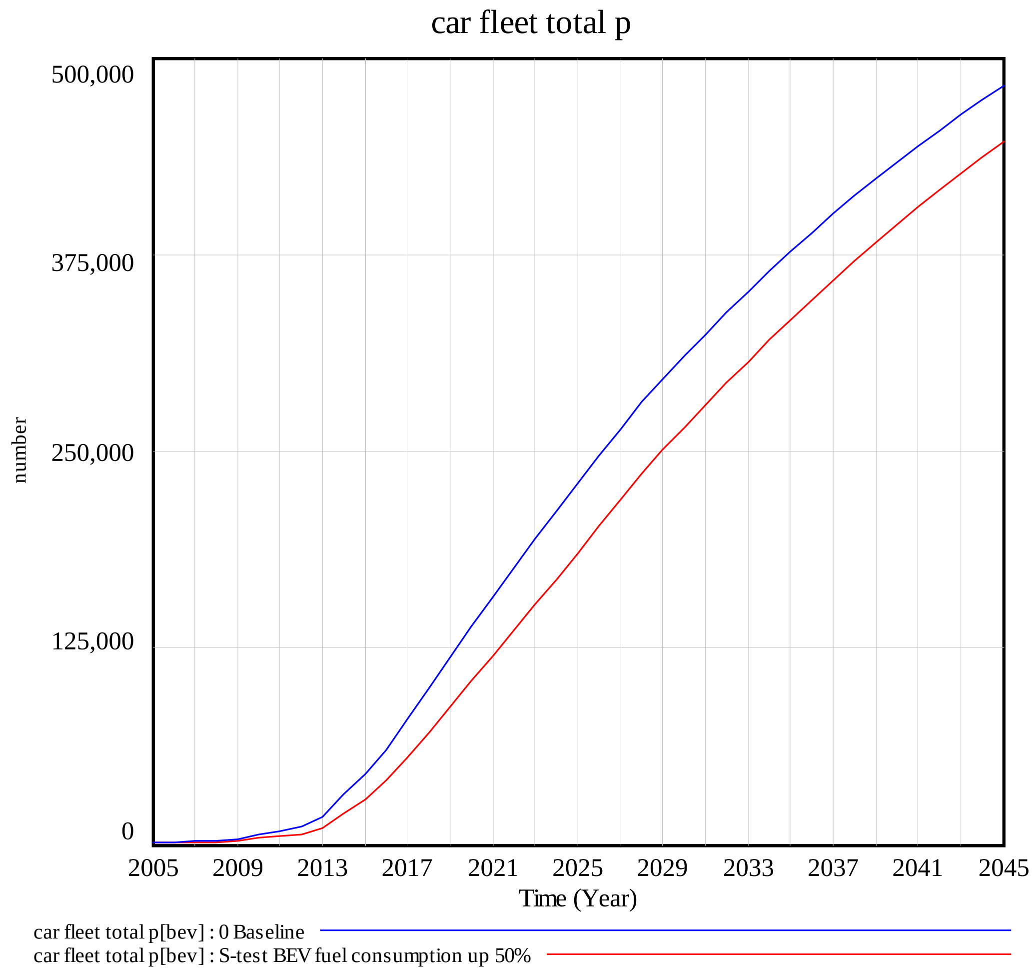

## Value of time

The convenience of travel time saving, especially due to bus lane access is valued at NOK 280 per hour in SERAPIS. The figure below shows that model results depend to some degree on this assumption. Here, we have doubled and halved this value. However, due to the relatively recent Norwegian National Value of Time study there is no reason to believe that the real value of time is as much twice the assumed value.




## BEV fuel consumption

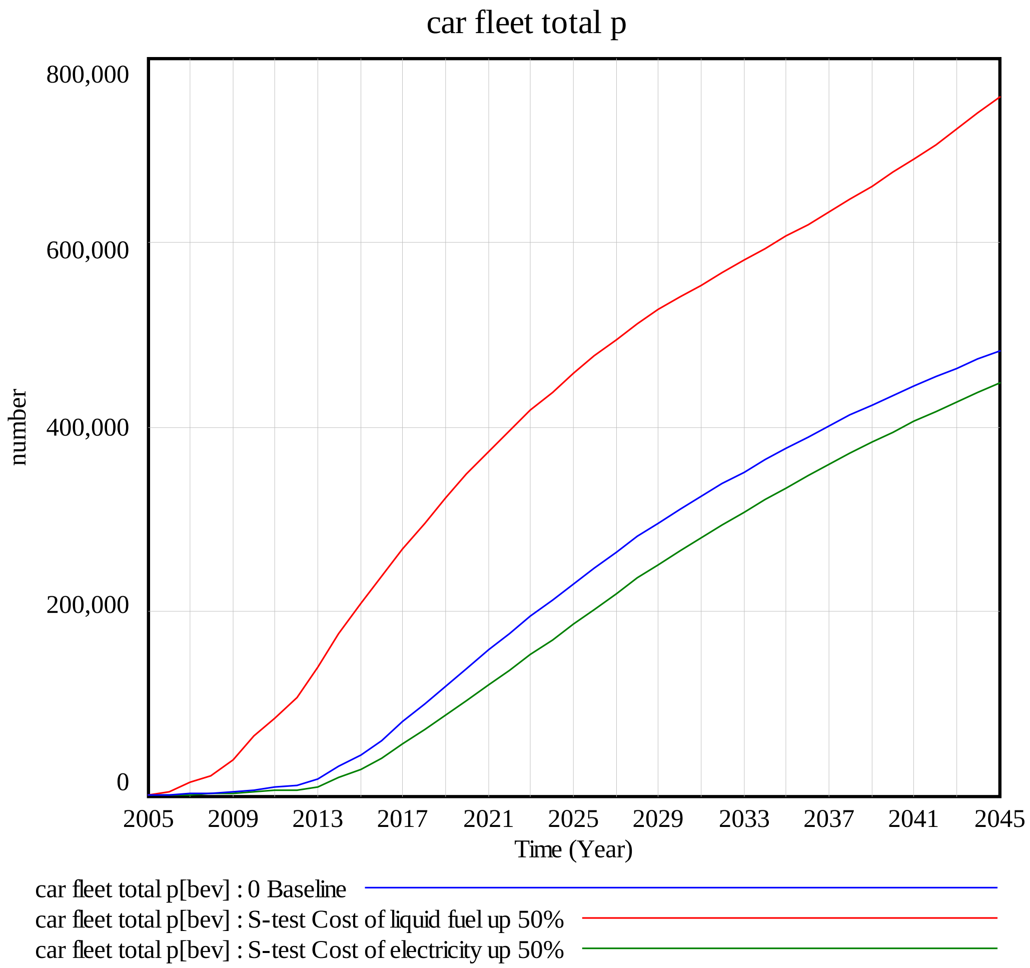
The Base scenario assumes BEV fuel consumption to be 0.2 kWh, 0.25 kWh and 0.30 kWh for compact, family and luxury cars, respectively. The figure shows how the results are affected by increasing these assumptions by 50%. The change has a noticeable but not large effect on the outcome.




## Fuel costs

In the figure below, the cost of liquid fuel (petrol and diesel) is increased by 50% from NOK 21 per litre from NOK 14, which is the base assumption. In another model run, electricity costs are increased similarly, from NOK .83 to NOK 1.25.

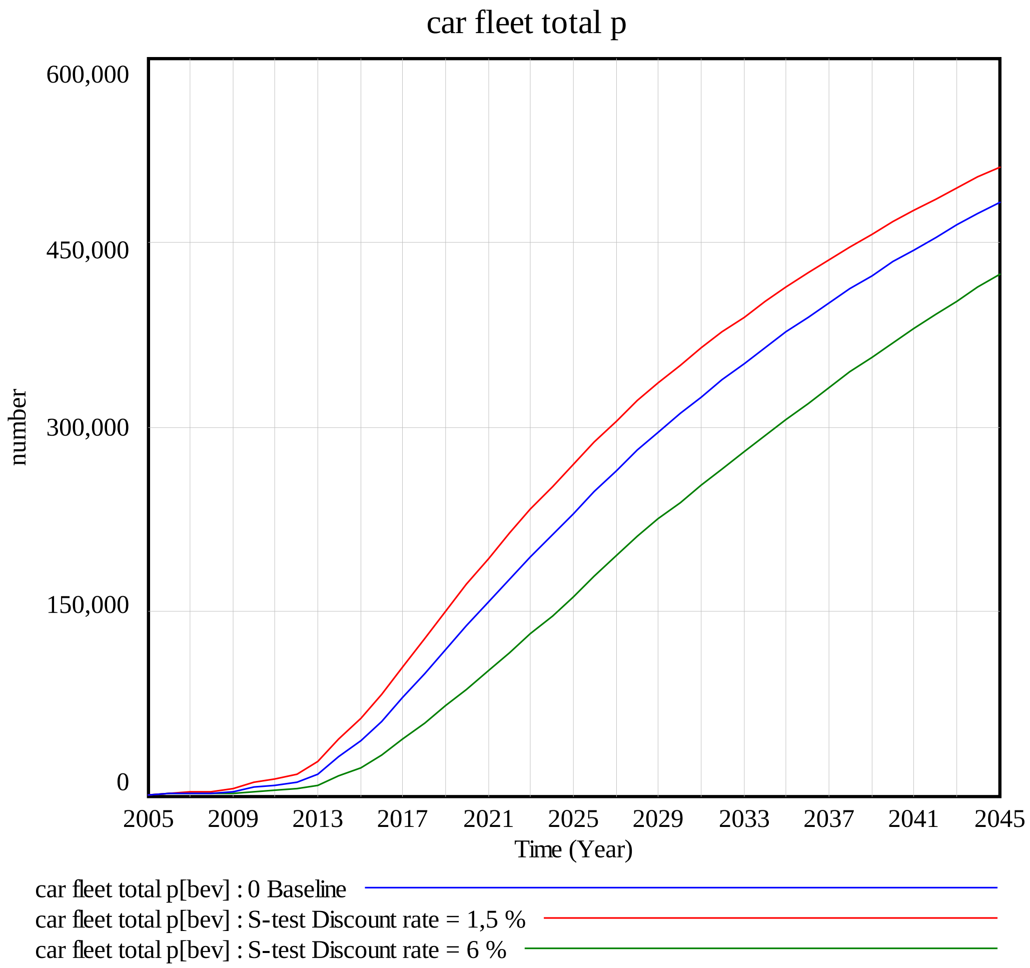
The effect of liquid fuel price increase is a large increase in BEV sales, which suggests not only that the model is sensitive to this assumptions, but also that the BEV market largely depends on ICE operating costs. The model suggests that BEV energy costs has a lesser effect on BEV sales.




## Discount rate

The discount rate reflect consumers' time preference and thereby to what degree a future cost of benefit is valued today. This is important, e.g. for the choice of incentives targeted at the purchase decision versus incentives related to future costs. The base assumption is 3% discount rate.

The figure compares this with 1.5% and 6% discount rate. We see that a much higher discount rate, 6%, results in a visible drop in the BEV market, mainly because future benefits of exemptions from taxes and charges and bus lane access are valued less. A high discount rate may be correct for the BEV market, since there is uncertainty with respect to the future of these incentives. So it may be that SERAPIS over-estimates the BEV market size when using 3%.

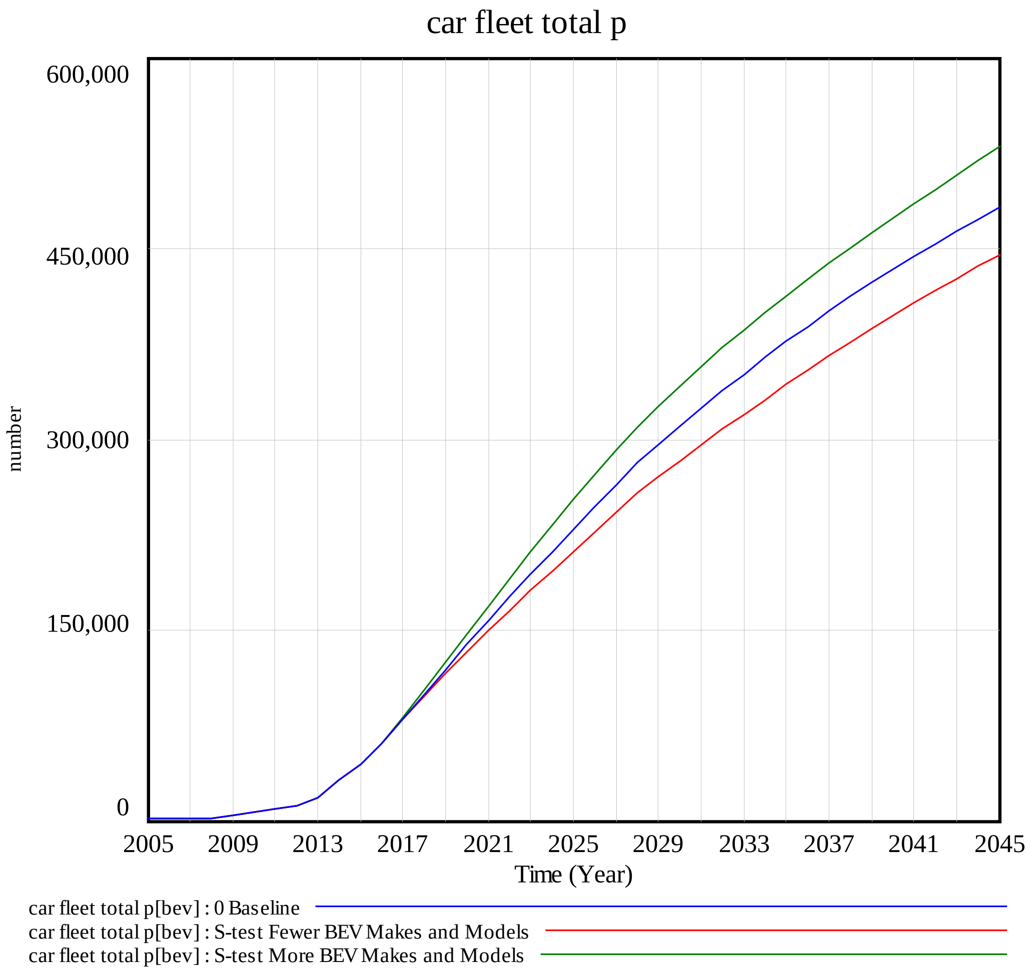



## BEV Makes and models

There is uncertainty as to how many BEV brands and models will be offered in future market. While we believe that the ICE market is mature and stabilised, it is clear that as the BEV market expands, globally, more models and makes will become available.

In the base scenario, it is assumed that ICE market is stabilised at 390 compact, 2588 family and 871 luxury size makes and models. For BEVs it is assumed 5, 7, and 4, respectively, in the base year and that two additional makes and models are added to each segment every year.

It is apparent from the figure below that the supply side is important and has visible effects on the model outcome. The results appear plausible.


car fleet total p
600,000
450,000
300,000
150,000
0
number
2005
2009
2013
2017
2021
2025
2029
2033
2037
2041
2045
Time (Year)
car fleet total p[bev] : 0 Baseline
car fleet total p[bev] : S-test Fewer BEV Makes and Models
car fleet total p[bev] : S-test More BEV Makes and Models

# Appendix 3: Tobit model output (EasyReg software)

EasyReg International [June 12, 2014]
Session date: Tuesday March 3, 2015
Session time: 09:56:29
----------------------------------------------
Dependent variable:
Y = BEV Share percent

Characteristics:
BEV Share percent
  First observation = 1
  Last observation  = 428
  Number of usable observations: 428
  Minimum value: 0.0000000E+000
  Maximum value: 8.0882353E+000
  Sample mean:   3.5627810E-001
  This variable is nonnegative, with 115 zero values.  A Tobit model is therefore suitable

X variables:
X(1) = Saved Parking Cost
X(2) = Road charges saved
X(3) = Value bus lane access
X(4) = Ferge

Tobit model:
y = y* if y* > 0, y = 0 if y* <= 0, where y* = b'x + u
with x the vector of regressors, b the parameter vector, and u a N(0,s^2) distributed error term.

Dependent variable:
Y = BEV Share percent

Characteristics:
BEV Share percent
First observation = 1
Last observation = 428
Number of usable observations: 428
Minimum value: 0.0000000E+000
Maximum value: 8.0882353E+000
Sample mean: 3.5627810E-001
This variable is nonnegative, with 115 zero values. A Tobit model is therefore suitable

X variables:
X(1) = Saved Parking Cost
X(2) = Road charges saved
X(3) = Value bus lane access
X(4) = Ferge

Frequency of Y = 0: 26.93% (115 out of 427)
Newton iteration succesfully completed after 1 iterations
Last absolute parameter change = 0.0000
Last percentage change of the likelihood = 0.0000

Tobit model: Y = max(Y*,0), with
Y* = b(1)X(1) + ... + b(4)X(4) + u, where u is distributed N(0,s^2), conditional on the X variables.

Maximum likelihood estimation results:

| **Variable** | **ML estimates** | **(t-value)** | **[p-value]** |
|---|---|---|---|
| x(1)=Saved Parking Cost | b(1)= 0.0000057 | (0.4570) | [0.64766] |
| x(2)=Road charges saved | b(2)= 0.0001458 | (15.2095) | [0.00000] |
| x(3)=Value bus lane access | b(3)= 0.0000487 | (5.4769) | [0.00000] |
| x(4)=Ferry | b(4)= 0.0000362 | (3.8278) | [0.00013] |
| standard error of u | s= 0.5556791 | (24.9592) | [0.00000] |

[The p-values are two-sided and based on the normal approximation]

Log likelihood: -3.39100675709E+002
Pseudo R^2: 0.53595
Sample size (n): 427
Information criteria:
Akaike: 1.611712767
Hannan-Quinn: 1.630475740
Schwarz: 1.659216092

If the model is correctly specified then the maximum likelihood parameter estimators b(1),..,b(4), minus their true values, times the square root of the sample size n, are (asymptotically) jointly normally distributed with zero mean vector and variance matrix:

| | | | |
|---|---|---|---|
| 6.64561906E-08 | -1.29501406E-08 | -1.53402848E-08 | -9.32288099E-09 |
| -1.30155450E-08 | 3.92611165E-08 | -7.66655132E-09 | -9.46618569E-09 |
| -1.53617363E-08 | -7.70748407E-09 | 3.37489280E-08 | 2.63941032E-10 |
| -9.31678562E-09 | -9.49728226E-09 | 2.44180715E-10 | 3.82517198E-08 |

## Institute of Transport Economics (TØI)

### Norwegian Centre for Transport Research

Established in 1964, the Institute of Transport Economics is an interdisciplinary, applied research centre with approximately 70 professionals. Its mission is to develop and disseminate transportation knowledge that has scientific quality and practical application.

A private, non-profit foundation, TØI receives basic funding from the Research Council of Norway. However, the greater part of its revenue is generated through contract research. An important part of its activity is international research cooperation, mostly in the form of projects under the Framework Programmes of the European Commission.

TØI participates in the Oslo Centre for Interdisciplinary Environmental and Social Research (CIENS) located near the University of Oslo. See www.ciens.no

TØI covers all modes of transport and virtually all topics in transportation, including road safety, public transport, climate change and the environment, travel behaviour, tourism, land use and urban planning, decision-making processes, freight and travel demand, as well as general transport economics.

Claiming copyright to its products, TØI acts independently of its clients in matters of scientific approach, professional judgment and evaluation. TØI reports are generally downloadable for free at www.toi.no.

**Visiting and postal address:**
Institute of Transport Economics
Gaustadalléen 21
NO-0349 Oslo

+ 47 22 57 38 00
toi@toi.no
**www.toi.no**