TØI report 1422/2015

Erik Figenbaum

Marika Kolbenstvedt

COMPETT

Electromobility+

Institute of Transport Economics
Norwegian Centre for Transport Research

Vejdirektoratet
Danish Road Directorate

AUSTRIAN ENERGY AGENCY

Competitive Electric Town Transport

Main results from COMPETT – an Electromobility+ project

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Summary:

The main research question of the Electromobility+ project COMPETT was: “How can e-vehicles come into use to a greater degree?”. The project investigated the e-vehicle market, travel behaviour of drivers, cost of vehicles, the effectiveness of incentives, did case studies in Norway and Austria, measured noise of these vehicles and developed the SERAPIS model. Factors influencing e-vehicle sales are: Customers values and attitudes, knowledge, the vehicles practicality and relative advantage, policies and incentives.
Barrier are cost, range, awareness, infrastructure availability and charge time. Most daily travel can be done with BEVs and multi vehicle households and fleets adopt them easily. Most owners charge at home. Awareness raising is essential in the initial phase of deployment. Incentives can be effective in increasing sales when implemented as a stable framework, but can also burden government budgets. Smart policies can reduce that burden.

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Sammendrag:

Forskningsmålet til COMPETT var a forstå: «hvordan elbiler kan tas i bruk i større grad». Prosjektet undersøkte elbilmarkedet, bilkjøreres reisemønstre, bilkostnader, virkninger av insentiver, gjennomførte “case” studier i Norge og Østerrike, målte elbiler støyegenskaper og utviklet beregningsmodellen SERAPIS. Faktorer som påvirker elbilsalget er bilkjøperes holdninger og kunnskap om elbiler, elbilenes praktiske egenskaper og relative fordeler, politikk og insentiver.
Barrierer er kostnader, rekkevidde, kjennskap til elbiler, tilgjengelighet av ladeinfrastruktur og ladetid. Mesteparten av daglige reiser kan gjennomføres med elbiler og husholdninger med mer enn en bil og bilflåter tar dem enkelt i bruk. De fleste eiere lader bilene hjemme. Tiltak for gjøre elbiler mer kjent er essensielt i starten av spredning av elbiler. Insentiver kan øke salget når de implementeres som et stabilt rammeverk, men kan også bli en byrde for offentlige budsjetter. Smart politkkutforming kan redusere den byrden.

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Preface

Transport is a necessary activity in all societies. Transport connects countries and regions together, giving people access to various activities and aspects of social welfare, as well as making goods and services provided by businesses and public institutions available to users. At the same time, transportation provides considerable challenges to the environment and the climate. The electrification of vehicles is one important way of achieving the goals of reducing greenhouse gas emissions and improving local air quality related to transport.

Electromobility at the EU level is anchored in the 2011 EU White Paper on Transport which sets ambitious goals for phasing out conventionally fuelled cars in cities. Diffusion of electric vehicles is one way to achieve this goal, as proposed by, the European Green Cars Initiative, the EU Action Plan on Urban Mobility and the European alternative fuels strategy. These policies form the background for the Electromobility+ programme, which funds eighteen European electric vehicle projects. This report presents and discusses the main results of one of these projects, Competitive Electric Town Transport, COMPETT.

The objective of COMPETT is to contribute to facilitating the use of electric vehicles, with particular focus on private passenger cars, thus contributing to the reduction of transport-related CO_2 emissions. The main research question to be answered is: *"How can electric vehicles come in to use to a greater degree?"*

The COMPETT project is jointly financed by the EU's 7th FP (Electromobility+ programme), Transnova (up until 31.12.2014), the Norwegian Public Roads Administration (from 01.01.2015), the Research Council of Norway (RCN), the Austrian Research Promotion Agency (FFG) 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). We hereby express our gratitude to all these contributors to COMPETT.

Erik Figenbaum, project manager for COMPETT, has been responsible for this main report. He has cooperated with Marika Kolbenstvedt, also at TØI. Following the COMPETT's quality assurance guidelines, the COMPETT partners Reinhardt Jellinek (AEA) and Lykke Møller Iversen (DRD) have reviewed the report. Terje Assum has been TØIs quality assurer.

Oslo, August 2015
Institute of Transport Economics

Gunnar Lindberg
Managing director

Michael Wølck Jæger Sørensen
Research director

Contents

Acronyms used in the report

BEV	Battery electric vehicle
COMPETT	Competitive Electric Town Transport
EU ETS	European Emission Trading Scheme
EV	Electric Vehicles are used about both BEVs and PHEVs
EVSE	Electric Vehicle Supply Equipment (Equipment for safer charging)
e-vehicles	Used in the project proposal for BEVs and PHEVs
FCEV	Fuel cell electric vehicles
GHG	Greenhouse gas
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
NAF	Norwegian Automobile Association
NOK	Norwegian Kroner (2014 currency rate: 1€=8.35 NOK)
NEVA	Norwegian Electric Vehicle Association
NTS	National Transport Survey
OFV AS	The road transport information agency
PHEV	Plug-in Hybrid Electric Vehicle
SOC	State of Charge
TCO	Total Cost of Ownership
WTT	Well To Tank
WTW	Well to Wheel
TTW	Tank To Wheel
NGO	Non-Governmental Organisation

Institute of Transport Economics
Norwegian Centre for Transport Research

Summary:

Competitive Electric Town Transport

Main results from COMPETT – an Electromobility+ project

TØI Report 1422/2015
Authors: Erik Figenbaum, Marika Kolbenstvedt
Oslo 2015, 127 pages

The main research question of the Electromobility+ project COMPETT was: *"How can e-vehicles come into use to a greater degree?"* To answer this question the project:

- Investigated the present status of the e-vehicle (BEV-Battery Electric Vehicles and PHEV-Plug-in Hybrid vehicles) market, i.e. the costs and characteristics of the vehicles, the availability of infrastructure, sales as well as the expected development the coming years. Fuel cell vehicles were not investigated, as they are not on the market yet.
- Investigated the travel behaviour of the population, using results from national travel surveys to estimate the share of transportation that can be accomplished with different types of e-vehicles. Focusing on BEVs, COMPETT has shown how the availability of parking supporting the possibility to recharge at home over night, and how stops during the day, can be used to recharge and extend BEVs range.
- Investigated noise of BEVs to see if noise in cities can be reduced with BEVs.
- Investigated regional cases in Norway and in Austria to understand how e-vehicles are used, focusing on BEVs and consumers, what the barriers and opportunities are, and the way incentives and policies influence markets and support market expansion. BEV owners, Internal Combustion Engine (ICE) vehicle owners and stakeholders where surveyed.
- Developed a model (an improved version of SERAPIS a model originating in Austria) that simulate the automotive markets in Austria and Norway, and how the e-vehicle fleet and government budgets costs evolve with different policies and incentives. The model was used to identify the cost-effectiveness of the EV incentives.

An increasing BEV market share requires dealers and leasing companies to promote BEVs actively, and that consumers and fleets choose BEVs. Consumers will do so if they find it beneficial. The main factors to make consumers interested in BEVs (figure 10.1), are:

1. *Their attitudes and values,* which make them more (environment, technology) or less (traditionalist) interested in BEVs. How these values limit or support a decision to buy a BEV, will be influenced by the other four factors.
2. *Consumers need to know about BEVs*, i.e. be aware of the BEVs characteristics, through reliable information sources (incl. producers, authorities) and testing.
3. *The vehicles need to be practical, reliable, and economically viable* and meet the users' needs. Users must have parking with electricity available. The practicality

depends on household type (single-/multi-vehicle), availability of types, makes and models, and country specific factors such as driving distances and climate.

4. *The policy framework should be stable over time* to reduce risk for market actors, i.e. consistent in scope and communication, but also flexible to allow for unexpected developments and wide in scope to allow for business creativity.
5. *Incentives will improve the purchase process* by reducing the price disadvantage, and provide users with relative advantages. Low tax on electricity, high tax on fossil fuels and the low energy consumption of BEVs are parts of the picture. Consumers may think primarily in a short-term perspective, and need to see that BEVs are favourable 3-5 years ahead. Local incentives can provide enough relative advantage to get diffusion started. Public charging stations make life with a BEV easier. This infrastructure may not materialize without incentives in the initial phases.

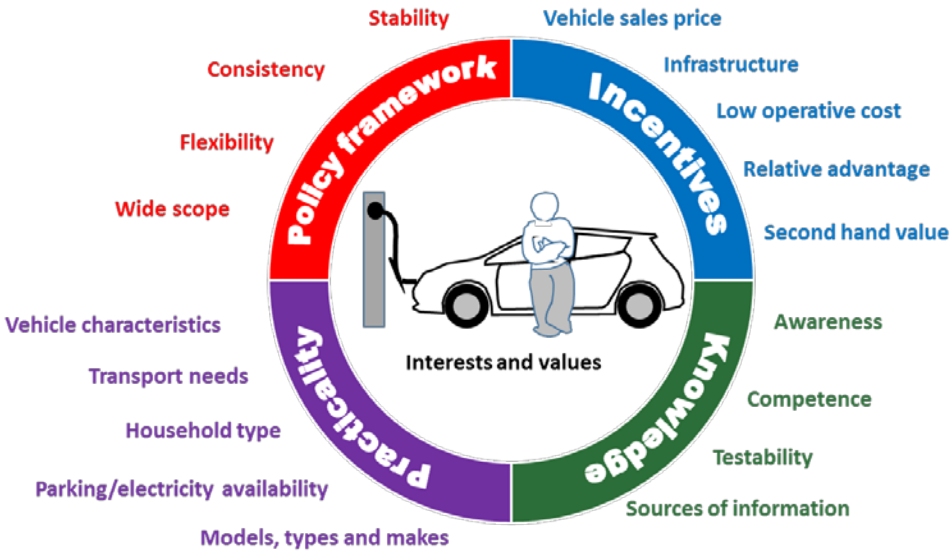


Figure S.1 Main factors influencing the BEV diffusion process.

COMPETT learnings on taking BEVs into use to a greater degree

- Important real barriers to BEV diffusion are range, price, awareness, and the availability of charging infrastructure. Society can support BEV diffusion by introducing flexible policies and incentives that reduce these barriers.
- BEVs can cover a large share of people's transportation needs. The current selection of BEVs and their characteristics match people's needs better than before. A larger selection of vehicles will stimulate future diffusion.
- Multi-vehicle households and fleets have the best ability to take BEVs into use.
- BEV owners mainly charge at home in private parking places. Some owners do soat work. Charging in other public locations is rare, and on average, the owners fast-charge 14 times per year. Public infrastructure can extend the range of BEVs and increase their usefulness.
- Government costs will be significant when economic incentives lead to a rapid take-up. Smart policy formulation can reduce the burden on public budgets. Purchase incentives can be offset by progressive taxes on polluting vehicles.

- Awareness raising and schemes to allow testing are important in the early phase of BEV diffusion but will not lead to significant sales unless coupled with incentives. Later in the diffusion process, there are new potential customer groups who have scarce knowledge of BEVs. A national communication strategy will therefore be a valuable tool in speeding up EV diffusion. An important part of such a communication plan will be to spread information about BEV assets such as a comfortable ride, the high energy efficiency leading to low energy costs and the advantages of being able to charge at home.
- User incentives providing BEV owners with a relative advantage, can be very effective in the absence of purchase incentives; an example is access to bus lanes, free parking and free toll roads (or congestion charges).
- Incentives only work effectively when vehicles are available from several manufacturers, and consumers have become aware of the BEV's assets. The neighbourhood effect speeds up diffusion in the early majority group
- Policies should be carefully planned and implemented as a stable national framework involving organisations and industry as well.

1 The COMPETT project

"Competitive Electric Town Transport" (COMPETT) is part of the EU's 7th FP and its Electromobility+ programme, which funds eighteen European research projects on electromobility related topics.

1.1 Research questions

Although electric vehicles (EVs), comprising battery electric vehicles (BEVs) and Plug-in hybrid vehicles (PHEVs), have existed for years, the number of such vehicles in practical use is very limited compared to the number of internal combustion engine (ICE) vehicles. The objective of COMPETT is to facilitate the market entry and increased use of EVs, thus contributing to the reduction of transport-related CO_2-emissions. The main research question of the project: "*How can EVs come into use to a greater degree?"* was decomposed into the following questions:

- *What are the most likely niches for EVs use from a social-economic and regional point of view for households and businesses?*
- *What kind of EVs can easily become competitive alternatives to ICE vehicles?*
- *How to bring about the social acceptability and travel-behaviour changes needed?*
- *What barriers and potentials exist for the use of EVs on the individual, regional and national level?*
- *How can barriers be overcome and benefits be used in promoting EVs and strategic planning?*
- *Who will be the main actors involved and what facilities will be needed?*
- *What is the economy of existing regulations and incentives for EVs and how should innovative new measures be designed?*
- *How can research-based knowledge stimulate marketing and policy making related to EV use?*

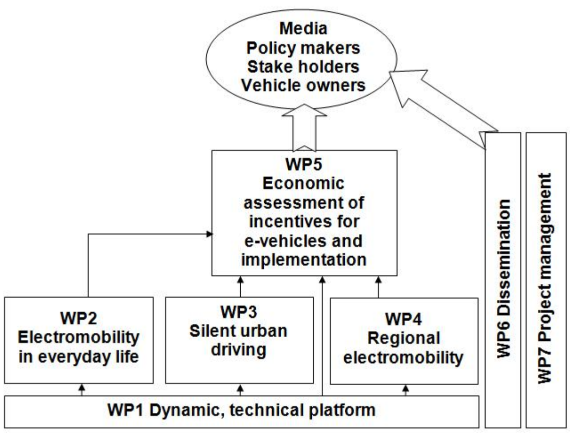


Figure 1.1 Work packages of the COMPETT project.

COMPETT included partners in Norway, Denmark and Austria. Figure 1.1 shows the Work Packages from which this report presents results. For details on theoretical background and methodology, see the reports listed in chapter 11.1.

1.2 A multidisciplinary approach

COMPETT has used a multidisciplinary approach to answer the above questions. A *dynamic technical platform* (WP1) showing the vehicles technological development and market diffusion in different European countries was generated as a base, for details see Krutak et al. (2014).

Knowledge on user profiles and travel needs have been derived from a literature review (Hjorthol 2013) and the analysis of national and regional travel surveys from Austria, Denmark and Norway (WP2). These patterns and profiles show for what kinds of trips – both leisure and working trips - BEVs easily can replace ICE vehicles. The results are found in Hjorthol, Vågane, Foller and Emmerling (2014).

With regards to the environment COMPETT has measured the BEV *noise level in various urban settings* (WP3), see results in Iversen (2012, 2013) and Iversen and Holck Skov (2015, 2015b). Data on Greenhouse Gas (GHG) emissions and air pollution from different types of vehicles are well covered by other research projects.

User needs, expectations, attitudes to and the acceptability of BEVs have been surveyed in two regions (Klagenfurt/Austria and Kongsberg/Norway WP4) and Denmark (WP2). In Norway and Austria both BEV owners, potential BEV owners, and ICE car owners who are not considering purchasing a BEV when they next purchase a vehicle, have been chosen as the respondents. The results are reported in Figenbaum, Kolbenstvedt and Elvebakk (2014), Jellinek, Emmerling and Pfaffenbichler (2015) and Hjorthol, Vågane, Foller and Emmerling (2014).

The regional studies (WP4) also comprised personal interviews and workshops with actual stakeholders taking part in the EV diffusion processes. Strategies, barriers to and options for electromobility were key themes for this part of the work, see Assum, Kolbenstvedt and Figenbaum (2014).

Economic models and scenarios, mostly for BEVs where much more market data and ownership information have been available, have been developed (WP5) based on the analyses, surveys and interviews mentioned above and data on the EV market and EVs characteristics (WP1). The model and the results can be found in Fearnley, Pfaffenbichler, Figenbaum and Jellinek (2015) and Figenbaum et al. (2014, 2015). COMPETT's scenarios illustrate the conditions necessary for achieving a competitive EV market in Europe. They can also help in the discussion of the possible effects of different future scenarios for vehicle adoption and the costs and benefits to society, businesses and the individual users of BEVs.

Decisions concerning *factors influencing the use of e-vehicles* are studied on several levels, the individual, the regional, the national and the global. COMPETT has studied how solutions on all levels should work together to reduce barriers and facilitate the use of BEVs. This work comprise studies framing BEV diffusion in different socio-technical perspectives, using Geels (2012) Multi-Level Perspective and Roger's theory of diffusion (Rogers, 1995). The analyses are presented in Figenbaum and Kolbenstvedt (2015) as well as in this main report.

1.3 Surveys, samples and user groups

Two of COMPETT's WPs used interviews with different user groups:

- WP2 on electromobility in everyday life, where the purpose was to use data from national travel surveys on people's travels to find the potential use of BEVs, given different range limits.
- WP4 on rgional electromobility, where the purpose was to study different user groups' attitudes to BEV characteristics and different incentives as well as gaining insights into why BEVs were bought and how they are used, in order to analyse future potential.

1.3.1 National travel surveys (WP2)

In the national travel surveys (NTS) a trip is defined as any movement outside one's own residence, school, working place or leisure home, independent of length, duration, purpose, or transport mode. Daily trips are defined and limited by the purpose of the trip. Upon reaching the destination, the trip has ended. Trips ending at home are defined by the previous purpose. In the COMPETT analyses we also study trip chains defined as "*A series of t rips where the first one starts and the last one ends at home*".

The surveys of travel behaviour collect data of a certain day (often the day before the interview). To secure that long trips and holiday trips are not underrepresented in the data, people can be contacted and interviewed several days after the day of travel that the interview is concerned with. All days of the year are being covered.

The Norwegian travel survey 2009 (Vågane, Brechan and Hjorthol, 2011) is the sixth national survey of travel behaviour conducted in Norway. It covers personal travel of all types, including short trips taken on a daily basis and longer journeys (100 km and longer) that are undertaken less frequently, as well as all modes of transport. In NTS 2009 19 000 respondents of the ages 13 years and above were interviewed. 13 695 persons with cars and driving licenses were included in the COMPETT analyses. The NTS yields socio-demographic information about the respondents and their households. The respondents were interviewed by telephone and a computer-aided system (CATI) was used to register the answers. The origin and destinations of all trips were geo-coded. The interviews were carried out between February 2009 and September 2010. For details on NTS 2009 see Vågane, Brechan and Hjorthol (2011).

The Danish national travel survey (continuous) has been conducted every year since 1992 with a short break 2004-2005. The survey has been undergoing some changes over the years, but the core remains the same. In recent years, it has covered Danes between 10 and 84 years of age. The number of people included each year has varied from around 25 000 to around 10 000 in 2013. The survey is mostly done by interview (telephone, aided by computers), but sometime it is carried out through a web-service.

There was no national travel survey from Austria at hand, only some data on *car use in Lower Austria in 2003 (*HERRY CONSULT 2003).

1.3.2 Interviews with user groups (WP4)

The COMPETT regional studies aimed at making comparisons with EV owners, potential EV owners and other car owners. Different approaches were used in the three countries.

Interviews in Norway::

- 1721 BEV owners, all members of the Norwegian Electric Vehicle Association (NEVA), comprising:
  - 542 from the Oslo-Kongsberg region
  - 1179 from the rest of Norway
- 2241 ICE vehicle owners, all members of the Norwegian Automobile Association (NAF) in the Oslo-Kongsberg region, comprising:
  - 672 (30%) Considering a BEV next time buying a car
  - 941 (28%) Do not know
  - 628 (42%) Not considering a BEV.

The interviews were internet based. The members of the two organisations involved got a link to the questionnaire together with a member newspaper. Not knowing the exact number of members who actually opened the paper, makes it difficult to define the real rate of response. An estimate is 20-45%.

Interviews in Denmark:

- 5152 driving licence holders (a part of the NTS sample) answered special questions on electromobility online. The sample comprised:
  - 309 (6%) Considering a BEV next time buying a car
  - 670 (13%) Might consider a BEV
  - 4283 (81%) Not considering a BEV.

Interviews in Austria:

- 105 persons from Klagenfurt region answered a telephone survey, in which 228 persons were contacted
- 396 persons answered a nationwide online survey, among:
  - 34 BEV owners
  - 6 owners of other alternative fuel vehicles
  - 356 Ordinary vehicle owners.

1.3.3 User groups by vehicle ownership

In the COMPETT analyses the answers to various questions are analysed by many socio-demographic variables. A commonly used categorization in the COMPETT analyses is user groups defined by type of vehicle and the number of vehicles the household that the person interviewed belongs to, owns:

- Single-vehicle EV households with one BEV only
- Multivehicle EV households with two or more BEVs
- Multivehicle EV households with at least one BEV and one ICE vehicle in combination
- Single-vehicle ICE household
- Multivehicle ICE household.

1.4 Modelling electromobility (WP5)

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 various incentives for e-vehicles in COMPETT. SERAPIS is a dynamic car fleet and propulsion technology multi-nominal logit model, utilizing the methods and principles of System Dynamics.

SERAPIS (Fearnley, Pfaffenbichler, Figenbaum and Jellinek 2015) models:

- The development of the fleet of motorised individual vehicles (cars, 2-wheelers[1])
- The share of alternative propulsion technologies: ICE, PHEV and BEV vehicles
- The car fleet differentiated into first (primary) and second (+) cars
- Three vehicle categories: Compact (micro vehicles up to VW Polo), Family (from VW Golf up to BMW 3 series), Luxury (BMW 5 and 7, Mercedes S etc.)
- Impact on greenhouse gas emissions and energy consumption
- Effects of incentives on the number of E-vehicles taken into use
- Government budget costs.

1.5 Dissemination of results

COMPETT has used a variety of dissemination activities, see details in chapter 11.1:

- The COMPETT internet site
- 11 research reports published by the partners
- Practical guideline handbook of electromobility
- Academically reviewed papers/articles: two published (in: Research in Transportation Economics, European Transport Research Review), one submitted
- Presentations at scientific conferences
- Public dissemination in journals and in TØIs Environmental handbook
- Local COMPETT workshops and meetings with stakeholder groups in Austria and Norway
- Presentations at meetings and conferences with authorities and researchers from Iceland, Sweden, Finland, Austria, Germany, Switzerland, Spain, Ecuador, Argentina, Columbia, Mexico and Norway
- Presentation at the final conference of Electromobility+ in Berlin, May 20th 2015.
- The COMPETT final international conference, *"Breakthrough for Electric vehicles"* in Oslo 11-12 June 2015, with 86 participants from Norway, the UK, Czech Republic, Finland, Germany, Denmark, Austria, Sweden and the Netherlands.

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

1.6 Scope and structure of the report

This main report from COMPETT contains an overview of all the relevant research activities and findings of the COMPETT project. In general, the results can be found in the reports and articles listed in chapter 10.1, but some additional analysis is carried out for this report.

The report is structured in ten chapters presenting basic facts on possibilities and challenges (main sources for each chapter in brackets):

1. The COMPETT project – objects, approach and diffusion
2. Introduction to electromobility – environmental background and market status
3. The electromobility proposition – assets and challenges of the EV technology and infrastructure (Krutak et al. 2014)
4. Electromobility in everyday life – users' travel needs, actual use and experiences (Hjorthol 2013, Hjorthol et al. 2014, Figenbaum, Kolbenstvedt and Elvebakk 2014)
5. Charging infrastructure and behaviour – i.e. ways of adapting to range limits (Figenbaum, Kolbenstvedt and Elvebakk 2014)
6. Embracing electromobility - attitudes to EVs and the motives, amongst different user groups, to purchase them (Figenbaum, Kolbenstvedt and Elvebakk 2014, Assum, Kolbenstvedt and Figenbaum 2015)
7. Societal processes leading to the diffusion of EVs - a socio-technical framework for diffusion and making EVs competitive (Figenbaum and Kolbenstvedt 2015)
8. Societal impacts of electromobility – environmental, rebound and economic effects (Fearnley, Pfaffenbichler, Figenbaum and Jellinek 2015, Figenbaum et al. 2015)
9. The road towards electromobility – scenario analyses and market potential in Europe (Fearnley, Pfaffenbichler, Figenbaum and Jellinek 2015, Figenbaum et al., 2015)
10. How e-vehicles can proliferate
11. References.

References to COMPETT reports are made at the start of their relevance and not in every paragraph in the same section using material from the actual report. Some places entire paragraphs may have been quoted with small modifications from these COMPETT reports.

Data on status for the electromobility market and incentives in different European countries has been collected from many different statistical sources. This information is collected in appendix I.

2 Introduction to electromobility

Electromobility was relaunched as an opportunity in 2010 when advances in battery technology allowed vehicle manufacturers to place a new generation of EVs on the market, spurred by the increased focus on the need to reduce climate gas emission from the transport sector.

Independent start-ups had experimented with BEVs in the period 1990-2010 with little success. French manufacturers launched some models around the year 2000, but they were also unsuccessful in creating a sustainable market. Li-Ion batteries now available provide BEVs with 2-3 times the range of Lead Acid and Ni-Cd batteries employed earlier, making modern BEVs much more useful for consumers, although still with limitations in range and charge times.

Policies and incentives have been introduced by many countries to support the marketability of this new generation of vehicles. The motive is that this kind of vehicles is needed to be able to meet future societal goals for climate gas emission reduction.

2.1 Climate challenges in transport

Global warming due to GHG emissions is a common global challenge. To reach the 2°C target for global warming put forward by the UNFCC in 2014, a decrease of 40-70% of the greenhouse gas emissions in 2010 (IPCC 2014) is estimated to be required by 2050.

While emissions from industry and buildings are decreasing, emissions from the transport sector have continually increased. Transport is a necessary activity in all societies, as it connects countries and regions, giving people access to various activities and aspects of social welfare, as well as making goods and services from businesses and public institutions available to users. Gains from technical development and other strategies have not been large enough to compensate for the growth in traffic.

Road transportation greenhouse gas emissions were 20% of total EU 15 emissions in 2012 according to the European Environment Agency (EEA, 2014). In Norway, road transport accounted for 19% of emissions according to the Norwegian Environment Agency (2015). Policies that reduce transport, shift transport into more efficient modes and improve the energy efficiency of each mode, will be required in order to contribute to reaching the targets for the reduction of greenhouse gas emissions from transportation.

If petrol and diesel cars are replaced by electric vehicles (EVs), there can be substantial savings in energy consumption and emission of greenhouse gases. There is no emission of exhaust gases from BEVs and PHEVs (in electric mode), as these are run on electricity stored in the batteries. COMPETT is not researching the different aspects of electricity production, but some points are discussed in chapter 8; Impacts of electromobility.

Electromobility at the EU level is anchored in the 2011 EU White Paper on Transport (EU 2011) which sets ambitious goals for phasing out conventionally fuelled cars in cities. The diffusion of electric vehicles is one way of achieving this goal, as proposed by the European Green Cars Initiative (EU 2009a), the EU Action Plan on Urban Mobility (EU 2009b) and the European alternative fuels strategy (EU 2014). Concrete goals are: 40% reduction in 2030 compared to 1990 and an average CO_2 emission from new vehicles of less than 95 g CO_2 per km in 2020. The Norwegian parliament's goal is to achieve 85 g per km in 2020 (Climate Policy agreement 2012).

Figure 2.1 shows the EU goals, the Norwegian goals and the actual development in CO_2 emissions for new vehicles. In order to reach the 85 g per km goal in 2020, emissions must reduce at a faster rate. During the latest years there has been a tendency for emissions from ICE vehicles to flatten out, and there is an increasing dependency on electric vehicles to further reduce emissions (Figenbaum et al. 2013).

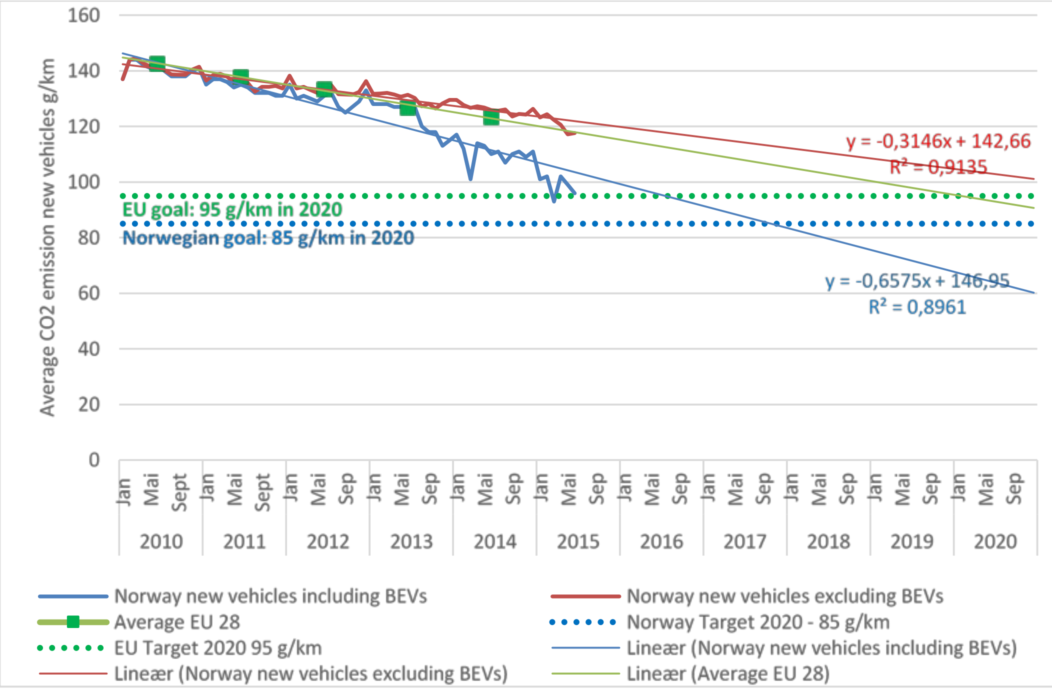


Figure 2.1 Status of monthly CO_2 emissions (actual and estimated) for new vehicles in Norway with and without battery electric vehicles from 2010-2020, in relation to different goals and average EU 28 emissions (year average value). Signature lineær =linear. Sources: Updated from Figenbaum et al. 2013, OFVAS 2015, ICCT 2014.

The environmental benefits of EVs are subject to discussion. It is not easy for consumers nor policy makers to get the full overview of how various factors and methods of estimating them, may produce seemingly different results. Researchers do not agree on which perspective to use in these calculations and how to take established policies such as the EU Emission Trading Scheme (EU ETS) into account. COMPETT is not researching these aspects, but some points are discussed in chapter 8; Impacts of electromobility.

2.2 Status of the market for electric vehicles

The development in market shares for BEVs and PHEVs in countries in Europe, the USA and Japan is shown in figure 2.2. Data on PHEV sales is not readily available and is therefore shown for fewer countries. The USA BEV sales share was calculated only from the sales of passenger vehicles (consumers also buy light duty trucks).

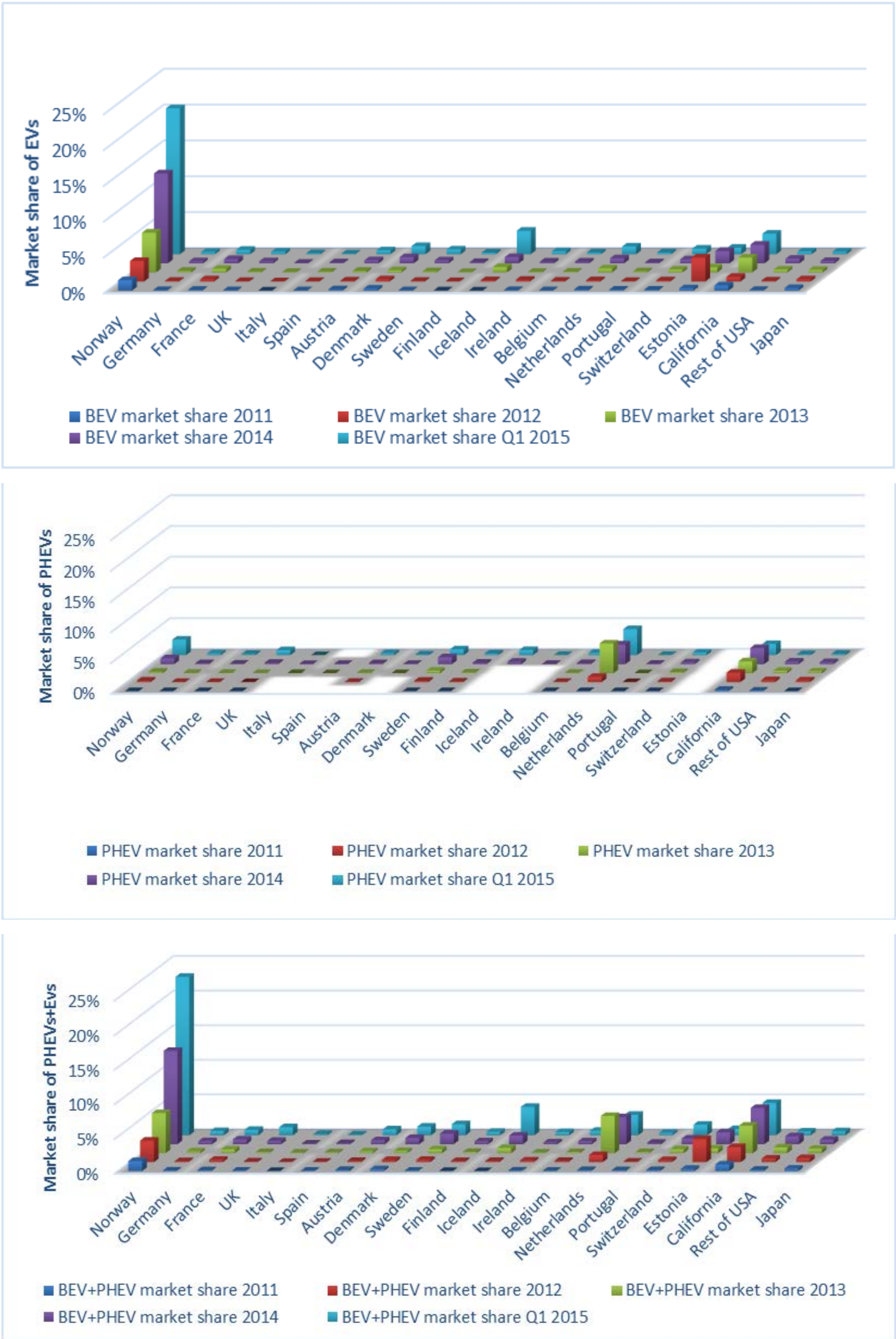


Figure 2.2 BEV and PHEV market shares in some European countries, Japan, California and the rest of the USA. (USA Passenger cars only) Sources: See appendix III.

The main BEV and PHEV markets are in the USA, Europe and Japan. Many BEVs and PHEVs are available in all these markets and the volumes in each market influence the total global volumes and thus the development of prices. Figure 2.3

compares the total sales and the growth of BEVs and PHEVs in these three regions. The BEV market in Europe has been growing about as fast as in the USA, whereas the Japanese market has been stagnant at about 0.35% market share. There is no statistics available in Japan on the sales of PHEVs. The PHEV markets in Europe is much lower than in the USA where the GM Volt and Toyota Prius PHEVs have been fairly successful. This may change the coming years. European manufactures such as VW, Audi, Mercedes and BMW started launching PHEVs in various segments in 2015.

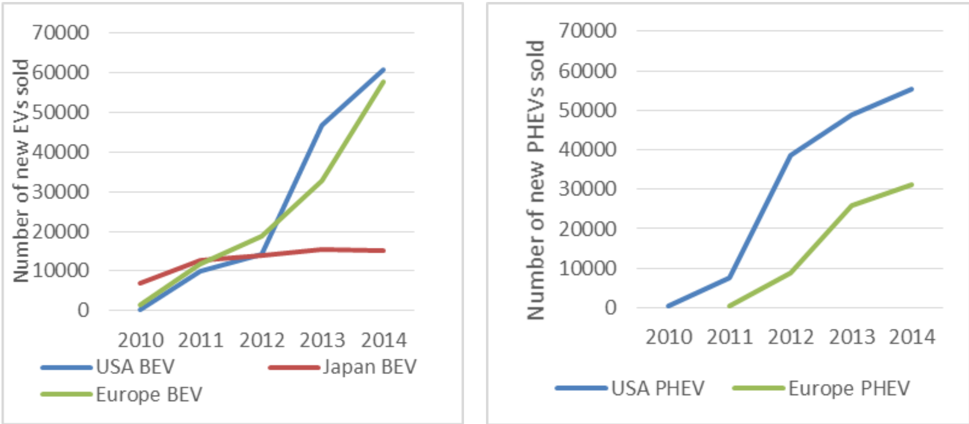


Figure 2.3 Sales of BEVs and PHEVs in Europe, USA and Japan 2010 to 2020. Source: See appendix III.

No countries come close to the BEV market shares that Norway has. Denmark, the Netherlands and Iceland are the other European countries that had market shares above 1% in quarter 1 in 2015. Iceland and Estonia had market shares above 1% some years. The only other region in the world with market shares above 1% was California. It should, however, be noted that the development in the USA is polarized with many cities having market shares well above 1%, most of them in California.

The market in China is also substantial but most of the market is controlled by national producers and suppliers not selling vehicles elsewhere. The market volumes in China therefore has little impact on the developments possible in Europe and is not investigated in the COMPETT project.

The Nissan Leaf is the bestselling BEV globally, see figure 2.4.

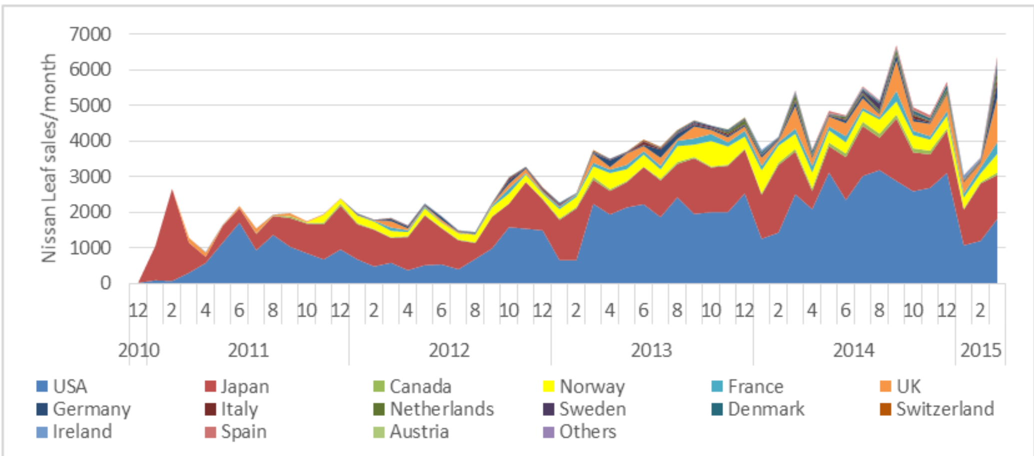


Figure 2.4 Sales of Nissan Leaf BEV in global markets. Source: See appendix III.

2.3 Electromobility status in European countries

Incentives for EV sales and other parameters are shown for various countries in Europe in figure 2.5. Data on sales, on infrastructure and on parking availability and the number of vehicles in the households as well as the share of sales to consumers, are in many countries difficult to obtain or even does not exist. The European markets are, as can be seen in the figure, diverse when it comes to the application of EV policies and incentives. The diversity is also reflected in the sales volumes. The countries with most incentives are Norway and the Netherlands followed by Denmark, France, UK and Sweden, see figure 2.5. It is obvious that the countries with the largest incentives also have the largest market shares and growth.

Various types of purchase incentives, reduced annual tax and incentives for infrastructure are most commonly applied. Some countries also apply preferential parking incentives. In some countries BEVs are exempted from congestion or road charges.

Purchase incentives come in many forms. In some countries ICE vehicles are taxed when being registered the first time, whereas EVs are exempted from the tax. VAT is waived in Norway whereas the UK and Sweden have national grant schemes for EV buyers. These schemes involve government budgeting and may be temporarily unavailable when the yearly budget has been exhausted. The time period they apply may be limited. France use a bonus malus system, i.e. a tax (malus) on ICE vehicles finances a bonus on BEVs and PHEVs. In the Netherlands purchase incentives are directed at purchasers of company cars. Consumers using "company car" BEVs and PHEVs have much lower income tax on the benefit of owning the vehicle than ICE vehicle owners. Some countries have the same incentives for BEVs and PHEVs, others differentiate.

Many countries provide incentives through an exemption from or reduced rate for the annual tax of vehicle ownership. The reason is probably that this incentive is easy to implement. The value depend on how large the annual tax for ICE vehicles is.

Incentives for infrastructure are commonly employed for public charging stations, especially fast charge stations. Normal charging stations are most often financed by regional or local authorities. The UK also offers incentives for private charging stations. Typically, a grant covers part of the initial investment cost and private capital the rest. Running costs are not supported. In some cases national networks are targeted.

Incentives may apply locally, regionally, nationally or even transnationally (The European Investment Bank provides loans for EV infrastructure). Incentives may apply to consumers or fleets or both groups. In some cases specific fleets such as municipal fleets are targeted.

In chapter 6 the importance and effects of various incentives will be presented, and this information will be used in chapters 9 and 10 to provide advice on how efficient policies can be shaped. Appendix I gives a detailed description of various market characteristics of European countries collected by COMPETT.

Most countries have increasing market shares both for EVs and PHEVs. In Norway, Denmark, Estonia and France, the incentives are biased towards BEVs. In the Netherlands, the UK and Germany the incentives favour or are equal for PHEVs. The results in market shares of these technologies in those countries reflect the biases as seen in figure 2.5.

The explanation for the Estonian market share in 2012 lies in an agreement with Mitsubishi trading EVs for CO_2-emission credits. In parallel a national network of fast charge stations, the first nationwide coverage in the world, was put in place. In 2013-2014 the market in Estonia contracted.

The incentives in the Netherlands are directed at company cars and do not distinguish between BEVs and PHEVs. The market is thus dominated by PHEVs. The incentives was reduced from January 2014 resulting in sales being moved forward to December 2013 and subsequent sales reduction in 2014.

Sweden has a purchase incentive, with funding from the national budget. When the budget is exhausted then the buyer risk not getting the incentive. In practice the government has allocated more resources when the budget has been exhausted.

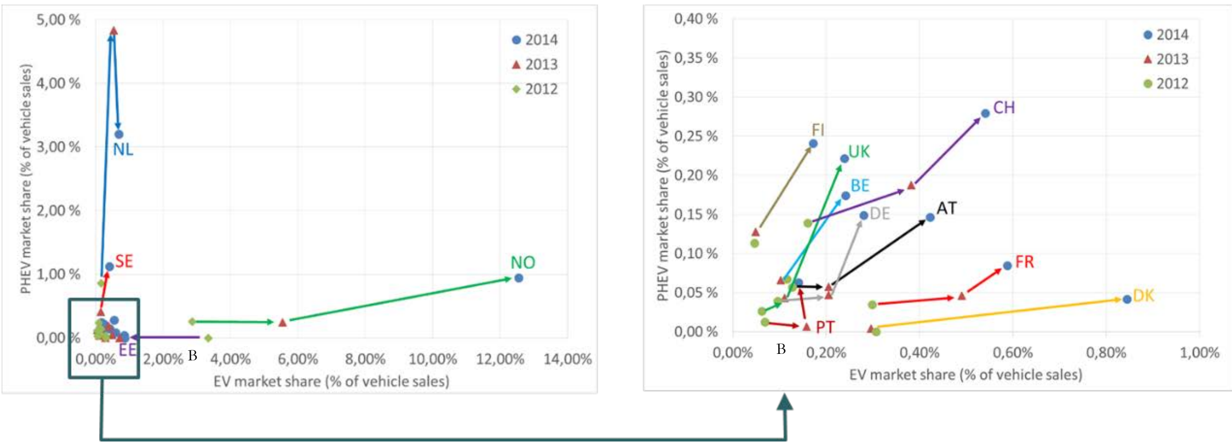


Figure 2.5 BEV and PHEV market development in selected European countries 2012-2014. Source: See appendix III.

The market shares for most countries seem rather unimpressive, but the total market is however growing steadily, see figure 2.6, partly because more models have come on the market. Care should be taken when comparing EV and PHEV sales figures as few countries have statistics for PHEVs.

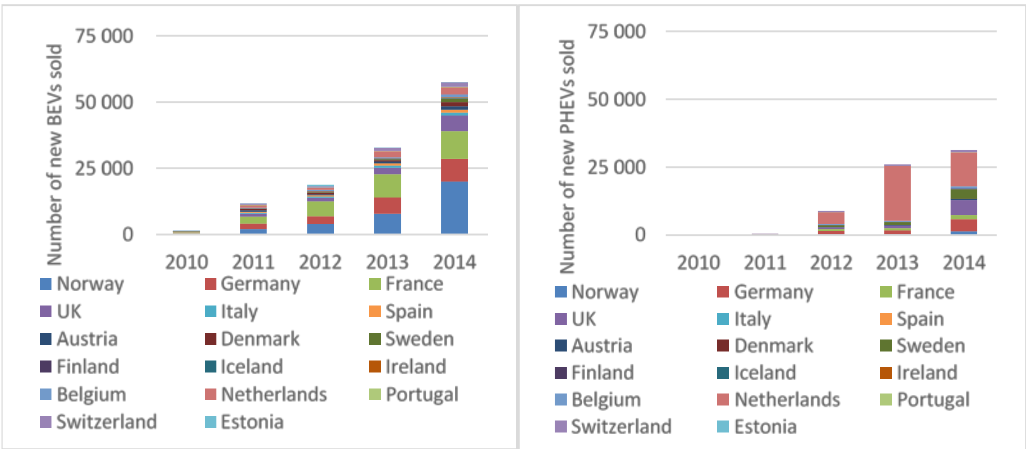


Figure 2.6 Total BEV and PHEV sales in Europe 2010 to 2014. Source: See appendix III.

2.4 Findings on the introduction to electromobility

Electromobility is seen as an important climate mitigation measure in most countries.

Incentives are introduced to a varying degree to support this societal target. The vehicles are too expensive to be able to compete with the incumbent ICE vehicle technology, infrastructure and established practises and regime. In addition BEVs have limited range and long charge times.

Incentives range from purchase incentives that can be directed at consumers, fleets or submarkets (passenger vehicles, company cars, VANs) and can be applied nationally, regionally or locally and be unlimited or limited in time. Many countries in addition or as an alternative reduce the annual tax for BEVs. User incentives such as free parking, exemption from road tolls and access to bus lanes are also available in some countries. Further activities include awareness raising, public procurement and various types of information activities as well as support for infrastructure deployment are also common.

In most countries the development is slow. It seems that purchase incentives are necessary to make the diffusion take off. Countries without such incentives have a very slow market development and incentives for instance for infrastructure in these countries may be wasted as there will not be enough vehicles to use them. Countries with national incentives seems to fare better than those with local or regional incentives.

Incentives are frequently changing in countries lacking a long term stable policy and incentive structure. Typically these countries may have grant based incentive schemes. These schemes are vulnerable to shifting governments priorities and funds have a tendency to run empty during the budget year. New funding may not become available until the next budget is presented. Some countries have funding available only in regions. For business developers such markets will be less attractive than those with stable national long term frameworks. Some countries improve on this situation by allowing grant funds to run over longer periods.

Countries with the largest incentives are modifying and reducing them over time, such as The Netherlands. Norway will gradually modify its economic incentives from 2018. Some countries such as Germany attempt a ramp-up of incentives, albeit slowly. Countries that only have supported infrastructure deployment, such as Portugal or Ireland, have hardly seen any market growth. France is a country with fairly large incentives, the "bonus ecologique" of 6300 Euro per BEV, but sales have been slow. They now attempt to increase these incentives and are also introducing restrictions on diesel vehicle usage that could have an indirect effect.

Few incentives are available in Eastern Europe, apart from in Estonia, and in Southern Europe.

The market statistics shows however that luxury BEVs may diffuse, although at a slow rate, also in countries with few incentives.

3 The electromobility proposition

The EV technology and EV characteristics have evolved over time. Range has increased, costs have been reduced, comfort and safety have seen vast improvements. Charging systems have evolved to become safer and much faster. The number of available makes and models have increased substantially, especially after 2010.

3.1 EV technology and characteristics

BEVs have definite advantages relative to internal combustion engine vehicles (ICE vehicles), both for society and the individual user. There are no direct Greenhouse Gas Emissions (GHG) or local pollution. They are at least twice as energy efficient as ICEs and they are more quiet than ICE vehicles at low speeds. Top speed, acceleration, safety and spaciousness do not differ substantially from gasoline or diesel vehicles. BEVs come in mini, small, compact and large vehicle sizes. The electricity is stored in the on-board batteries providing energy to the electric motor, which powers the wheels while driving. The regenerative braking system allows for one pedal driving, i.e. the vehicle brakes by running the motor as a generator when the foot is lifted off the accelerator pedal. Most battery electric vehicles (BEVs) have a theoretical range of 160-240 km between recharges, but the practical range is shorter. Tesla Model S is an exception with a range up to 500 km.

PHEVs have both an electric motor and one internal combustion engine. They can operate in a purely electric mode utilizing electricity recharged into the vehicles battery from grid power. They also have an extended range mode using the ICE fuelled by gasoline or diesel. Thus, owners will not experience range challenges. These vehicles generally come in the larger vehicle classes as the technical installation requires much space, due to the two motors, fuel tank as well as batteries, emission control equipment, charger and power electronics. The purely electric driving range is normally within 30-80 km to allow for most daily transport to be done in this mode. These vehicles can also operate as regular hybrid vehicles without recharging electricity from the grid.

Fuel cell electric vehicles (FCEV) have an on-board fuel cell that produces electricity from hydrogen stored in the vehicle's hydrogen tank. It operates much like a battery electric vehicle. The difference is that rather than recharging the vehicle with electricity it is filled up with hydrogen at a filling station. The range between hydrogen fillings can be comparable to ICE vehicles. It only takes a few minutes to fill. Hydrogen can be produced from fossil and non-fossil energy sources, including electricity. The latter will however be less energy efficient than using the electricity in a BEV due to energy conversion losses.

3.1.1 Technical development of vehicles

The BEV technology has changed substantially over the latest 15 years as seen in table 3.1. BEVs from the latest five years are thus not comparable with the less advanced vehicles available earlier:

- Range has doubled and BEVs are capable of fast charging
- Warranty on battery has quadrupled to 8 years
- BEVs have become as reliable, safe and comfortable as gasoline vehicles
- The acceleration performance of BEVs is in 2015 comparable to or surpass ICE vehicles whereas earlier BEVs were rather sluggish, top speed is adequate for motorway driving
- BEVs can be fast charged providing a safety for users when they run out of electricity or approach maximum range.

Research on EVs done before 2010 is therefore not very relevant today, although methods and modelling frameworks may be applicable.

Table 3.1 Technical facts for BEVs in different segments from 2000 – 2015. Sources: Manufacturer and importers web pages, historical price lists and brochures.

Segment	Unit	Mini				Small		Compact		MPV	Large
Year		2000	2009	2011	2015	2014	2015	2011	2015	2015	2015
Typical vehicle		Think City 1 	Think City 2 	Mitsubishi I-Miev 	VW E-up 	Renault Zoe 	Renault Zoe 	Nissan Leaf 	VW E-Golf 	Nissan E-NV200 	Tesla Model S 85, 70D 
Range	Km	80	160	150	160	210	240	175	190	170	442-502
Top speed	Km per h	90	100	130	130	135	135	144	140	120	225
Acceleration 0-100 kph	Seconds	(0-50 kph) 7 sec	(0-50 kph) 6.5 sec	15.9	12.4	13.5	13.5	11.5	10.4	14.0	5.4-5.6
Seats		2	2	4	4	5	5	5	5	5-7	5 (+2)
Luggage	Litres	350	350	227	250	338	338	330	341	2300	895
Length	Millimeter	2990	3120	3480	3540	4080	4084	4450	4270	4560	4970
Curb weight	Kg	940	940	1110	1139	1428	1503	1600	1510	1751	2191
Safety	EuroNcap	NA	NA	****	As ICE?	*****	*****	*****	As ICE?	***	*****
Battery		Ni-Cd	Na-NiCl2	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion
Battery size	kWh	11	16	16	18.7	22	23.3	24	24.2	24.2	70-85
Available battery	kWh	10	14.4	14.4	16.8	18.8		21.6	21.2	21.2	
Battery warranty	Year/ 1000 km/ remaining capacity %	2/-/-	2/-/-	5/100/80	8/160/70	5/100/70	5/100/70	5/100/75	8/160/70	5/100/75	8/unlim/
Battery maintenance		Watering every 6000 km	No	No	No	No	No	No	No	No	No
Fast charge		No	No	Yes	Yes	Yes	Semi-fast	Yes	Yes	Yes	Ultra-fast

3.1.2 Prices have been significantly reduced

The price of BEVs is the principal barrier to adoption. Figure 3.1 shows the situation in Norway where price statistics have been available since 1998. Gasoline vehicle price have remained stable over the period in real terms. The price decrease of BEVs in 2001 was the result of introduction of Zero rate VAT on BEVs that year. From 2003 BEVs more or less disappeared from the market, only 4 wheel mini BEVs were available. In this period there was also imports of second hand EVs produced before 2003. In 2009 Think City reappeared on the market. Prices have gone down rapidly after the introduction of BEVs from the major car manufacturers from 2010.

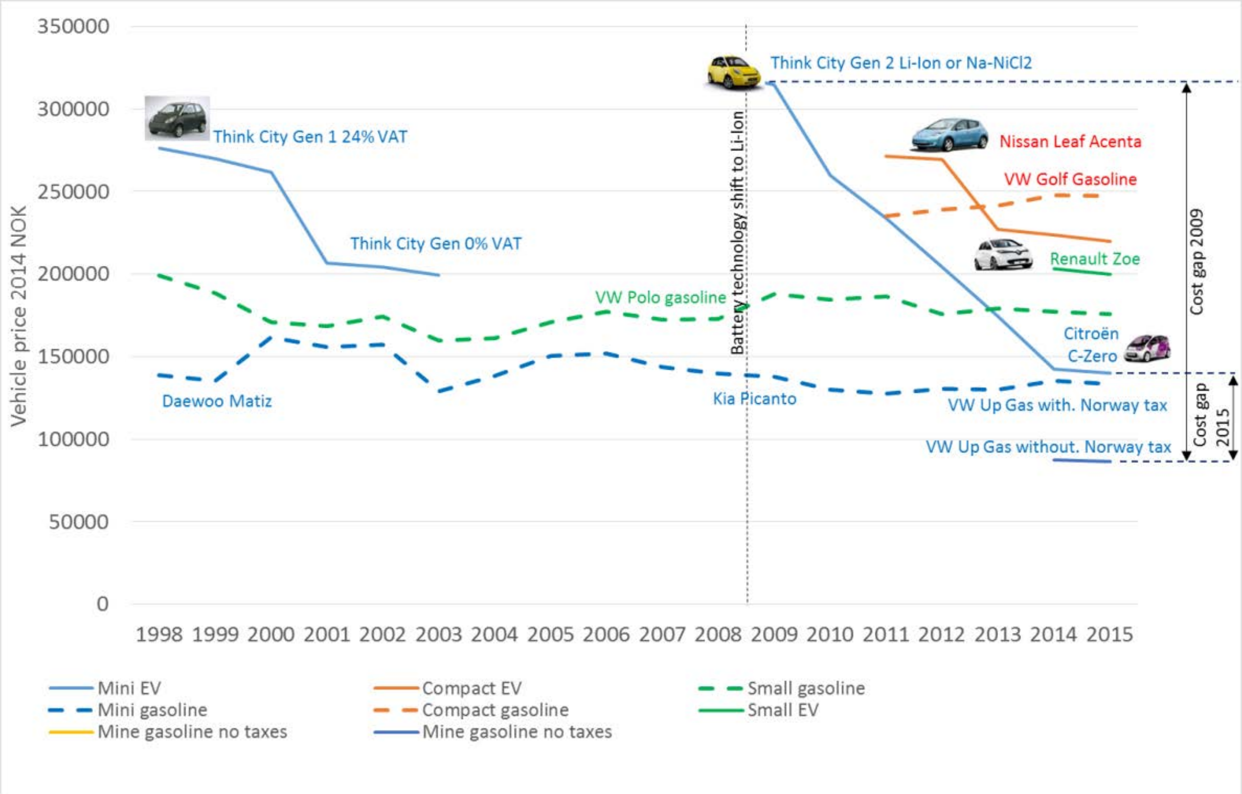


Figure 3.1 Historical sales prices of BEVs in 2015 NOK (without all taxes according to the Norwegian incentives) compared to ICE vehicles (including registration taxes and VAT). 2014 currency rate, 1€=8.35 NOK. Sources: Car prices 1998-2015, various webpages, news articles and historical sales material.

The PHEV price has remained high since the market introduction in 2012. Only two models were available in the market with very modest sales until the beginning of 2014. Then the more successful Mitsubishi Outlander was introduced in the market.

3.1.3 Available makes and models

The BEV market in Norway has been increasing not just due to lower prices and incentives but, also because a better selection of vehicles that matches more user needs has become available since 2010, see figure 3.2. In 2010 only two mini vehicles, of which only one was classified as a passenger vehicle, were generally available (a few other vehicles were imported in limited numbers). In 2015 these vehicles have been forced out of the market. However, a total of some 15 models was available in 2015, most in the very large and important compact vehicle segment, one large/luxury vehicle and some small vehicles as well as an increased mini-vehicle offering. This situation will continue with a SUV arriving in 2016 and medium sized "family" EVs from 2018. Further models are also expected in other segments.

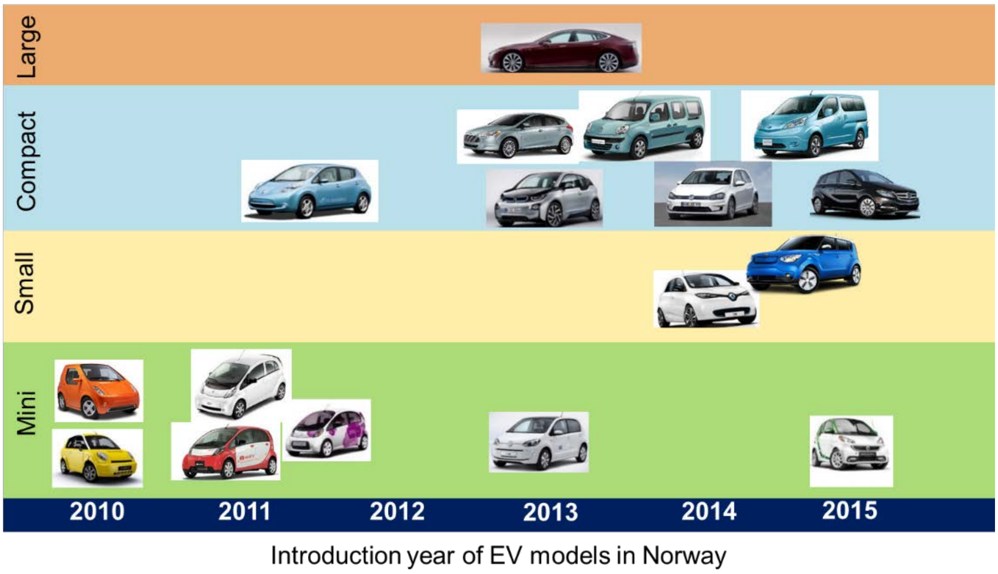


Figure 3.2 Increasing number of available makes and models in different segments in Norway. Sources: Manufacturers internet pages.

A large wave of PHEV models are coming on the market from 2015-2020, particularly from the German vehicle manufacturers. This may affect the sales of BEVs in the future. The prices of PHEVs will remain high in most cases as manufacturers are positioning them as sporty, powerful vehicles.

3.2 Charging concepts and equipment

3.2.1 Normal charging

Normal charging or slow charging is a term used when electric vehicles are charged from standard household sockets or dedicated wall-mounted charge stations, a “wallbox”. There are three types of slow charging, see figure 3.3. Mode 3 can also be used as inductive charging.

From the infrastructure side, mode 1 and mode 2 are equal, see table 3.2. The main socket that the charging cable is connected to is part of the building’s regular electrical system. Power sockets already installed in garages, outside buildings and in stands for power connection to engine block heaters can be used immediately allowing a great number of people to start using electric vehicles quickly.

Schuko household sockets Mode 1 and Mode 2 charging were thus used for home as well as public charge stations in the early days of BEV deployment in Norway. Standards were not agreed upon and they were cheap to install. These stations are still in use. They provided a low cost, low economic risk, basic infrastructure for electric vehicles, thus supporting early market activities. It is not recommended to follow this path when building infrastructure today as the sockets can become overheated. Public infrastructure needs to be mode 3 and this is also recommended for home charging. Yet most Norwegian BEV owners still use mode 2 charging. The charging cable has a switch which allows the user to set different power levels for the cable as the Schuko socket can be attached to a 10 or 16A fuse. The power rating is in the 2.3 to 3.2 kW range.

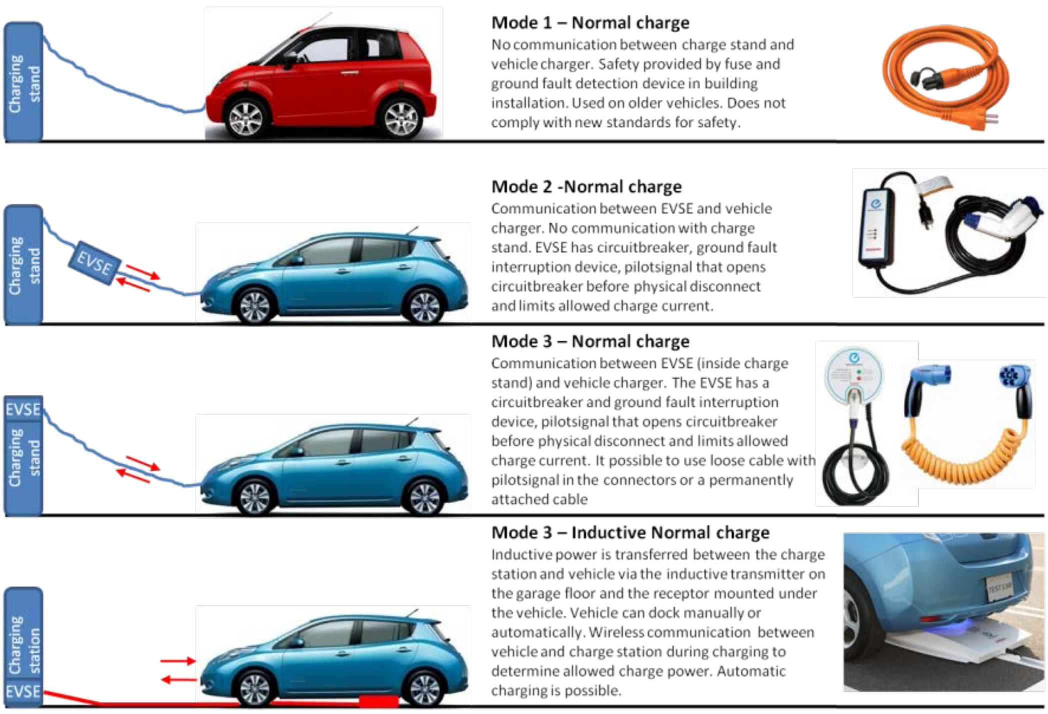


Figure 3.3 Various modes of normal BEV charging. EVSE = Electric Vehicle Supply Equipment. Source: Krutak et al. 2014.

Table 3.2 Installation requirements, theoretical max capacity achieved and costs in Euro (investment, electricity and user costs) for private and public normal chargers in 2015. Source: Krutak et al. 2014.

Charge type	**Building installation requirement**	**Charge power (reduced max)**	**Max km of driving per chargehour in summer**	**Investment cost excl. VAT EURO**	**Main-tenance cost per station**	**Electricity costs (incl. taxes)**	**User costs including taxes**
Normal charge	Mode 1.2, 10A household socket	2 kW	15 km	270-400		0.13 Euro per kWh	0.13 Euro per kWh
	Mode 1.2, 13A household socket	2.5 kW	20 km	270-400		0.13 Euro per kWh	0.13 Euro per kWh
	Mode 1.2, 16A household socket	3 kW	25 km	270-400		0.13 Euro per kWh	0.13 Euro per kWh
	Mode 3 20A Norway Mode 3 Austria	3.6 kW	30 km	1070-1740 Norway 200-5000 Austria		0.13 Euro per kWh	0.13 Euro per kWh
Public normal charge	Mode 1-2 Norway	3 kW	25 km	2700	25	0.13 Euro per kWh	Often free (gratis) for EVs
	Mode 3 Norway	3.6 kW	30 km			0.13 Euro per kWh	Often free (gratis) for EVs
	Mode 3 Austria	3.6-11 kW	30-90 km	4000-21000 Austria	500-1400		

3.2.2 Fast charging

There are two main types of fast charging, mode 3 AC with the charger inside the vehicle and mode 4 DC with the charger external to the vehicle, see figure 3.4 and table 3.3. Combo chargers can provide both types from one charger. The installation of fast chargers may lead to a need to reinforce the electrical distribution network. In Norway fast chargers have been reported to deliver only about half of the power to the vehicles when it is cold in the wintertime, as the cold batteries are not capable of handling the full 50 kW charge power. This comes in addition to the range being drastically reduced in the winter. The total kWh and thus number of km that can be recharged by fast charging, are limited by EVs not being capable of fast charging beyond 80% State of Charge (SOC). The user will fast charge when the remaining SOC is typically at 10-30% due to the spacing between fast charge stations.

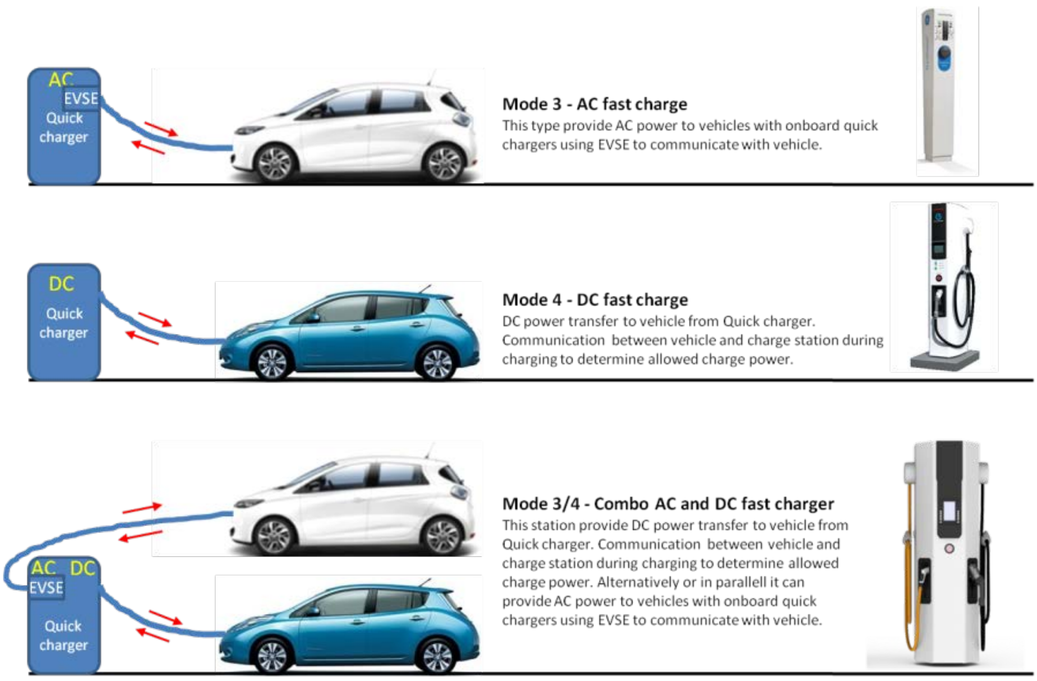


Figure 3.4 Fast charging systems, Source: Krutak et al. 2014.

Table 3.3 Fast charge station costs. Theoretical max km driving pr hour with charging, in Norway and Austria 2014. EURO. Source: Krutak et al., 2014.

Type of charge	Installation	Investment cost excl. VAT	Maintenance cost per station	Electricity costs (incl. taxes)	User costs including taxes	Theoretical maximum km of driving per hour of charge in the summer
Chademo DC 50 kW	400 V, three-phase 63A	Norway: 67.000–134.000 EUR	5.350 EUR	Special rates could apply	4–13.4 EUR per charge, many limit charge time to 15 min. One operator offer unlimited access for 40 EUR per month.	280 km
Chademo DC 50 kW	400 V, three-phase 63A	Austria: 20-40.000 EUR				280 km
AC 40 kW	400 V, three-phase 63A					220 km
Tesla Super charge 90-120 kW						500-650 km

Charging above 50 kW is termed *ultra-fast charging*. The vehicles need to be prepared for this charge level, like the Tesla Model S. This model will be capable of charging at a charge rate of 90 or 120 kW at dedicated charge stations.

3.2.3 22 kW semi fast charging

This charge mode is essentially the same as the regular AC fast charging mode 3 with half the available power. The reasoning behind this charge level is that AC power level of 22 kW is readily available in many places (32 Amp, three phase 230 V AC) and that some applications do not require a higher charge rate. This mode of charging is relevant for public charging stations for example outside shops, restaurants and other places where you would stay for an hour or two.

3.3 Findings on technology

Summing up chapter 3 we find the following traits on technological development:

- The vehicle technology has evolved over time. The BEV characteristics from the latest five years are not at all comparable with the much less advanced vehicles that were available earlier. Care should therefore be taken when comparing earlier research on old user and general population surveys with new surveys.
- BEV range has doubled over previous generation vehicles that used Ni-Cd batteries.
- BEVs have become reliable and safe with normal automotive standards for ride, handling, fit and finish. Top speed and acceleration are on par with ICEs allowing BEVs to blend in effortlessly in traffic.
- BEVs are now fast charge capable.
- Warranty on battery has quadrupled to eight years.
- BEVs are now available from the traditional auto-manufacturers and available at dealerships across Europe. The selection of vehicles has increased substantially. In 2000 they were only available in the mini segment, now BEVs are also available as small, compact, multi-purpose and large and luxury vehicles.
- BEVs have become cheaper, but remain more expensive than ICEs in countries without incentives. In some countries with incentives the price is comparable to ICE vehicles.
- PHEV development has been slower than for BEVs. This type of vehicle has only been available since 2011. Few models were available up to 2015 and prices were high.
- Charging has evolved from plugging the EV into a domestic wall socket, to introducing safety equipment on the cable, and in a further step into a home charger unit mounted on the wall.
- The cost of charging equipment has gone up as a result of these new safety features.
- Vehicles have become fast charge capable, typically able to charge at 50 kW providing 80% SOC in about 20 minutes in most BEVs.
- Still multiple standards exist for charge inlet, charge power and road side fast chargers. The latter being alleviated by multi standard units. Vehicles have two types of charge cables, to be able to use available infrastructure.

4 Electromobility in everyday life

A persevering myth about BEVs is that the range is too short for them to be useable for consumers. At the end of June 2015 almost 50 000 BEVs were in the hands of consumers in Norway, about 2% of the entire vehicle fleet. Apparently, the consumers manage to effortlessly put these vehicles into use in their households. The real-world experiences of Norwegian EV owners have been investigated to understand the reasons for this.

4.1 Real-world experience with range

The COMPETT project has not done experiments on range. COMPETT has however studied the owners' perception and experience of range, i.e. what range they believe their vehicle has under real-world travel conditions, what range they use when planning trips, how they cope when range is too low and whether they have experienced running out of power while driving.

The real world experienced range is a function of several factors:

1. The theoretical range, i.e. the type approval value
2. The weight of the vehicle
3. The number of passengers and weight of luggage
4. The topography
5. The temperature
6. Weather conditions
7. The use of climate controls in the vehicle
8. Type of precipitation
9. Road surface, type of asphalt, bare or covered with snow or ice
10. The number of stops (extra energy used to recondition cabin)
11. Types of tyres (summer, winter, all year, low resistance)
12. The speed of travel
13. The place of travel
14. The driving style
15. The traffic conditions (free flowing, congested etc.)

Figure 4.1 illustrates the most important factors. BEV owners attain the skills to calculate the expected real-real world range by experiencing their vehicles' range under different driving conditions with their own particular driving style.

88% of Norwegian BEV owners have managed to attain this skill without running out of power in the battery while driving. 9% have learned the hard way, running out once. 3% have run out of power several times. In Austria as many as 34% have experienced unexpected stops due to an empty battery (Jellinek, Emmerling and Pfaffenbichler 2015). One explanation of this difference might be that they have older BEVs. Older BEVs are overrepresented in statistics of vehicles that have run out of power in Norway, as they probably have less reliable range meters, and their range are shorter.

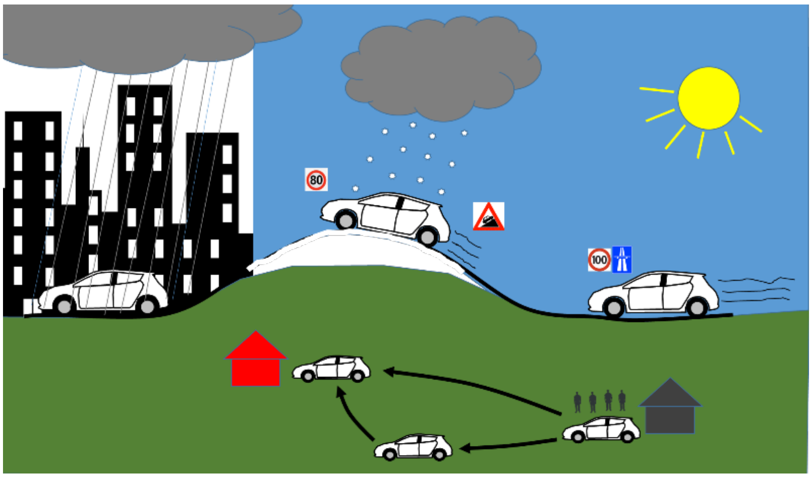


Figure 4.1 The range challenge. Factors influencing real world range.

The average user is confident in using 80% of the vehicle's range. Vehicle owners in Norway plan for an approximately 25% shorter range in the winter than in the summer. 130 km in summer and 100 km in winter for Nissan Leaf, see figure 4.2. For the smaller Mitsubishi/Citroën/Peugeot triplets it is about 110 km in the summer and 80 km in the winter (Figenbaum, Kolbenstvedt and Elvebakk 2014).

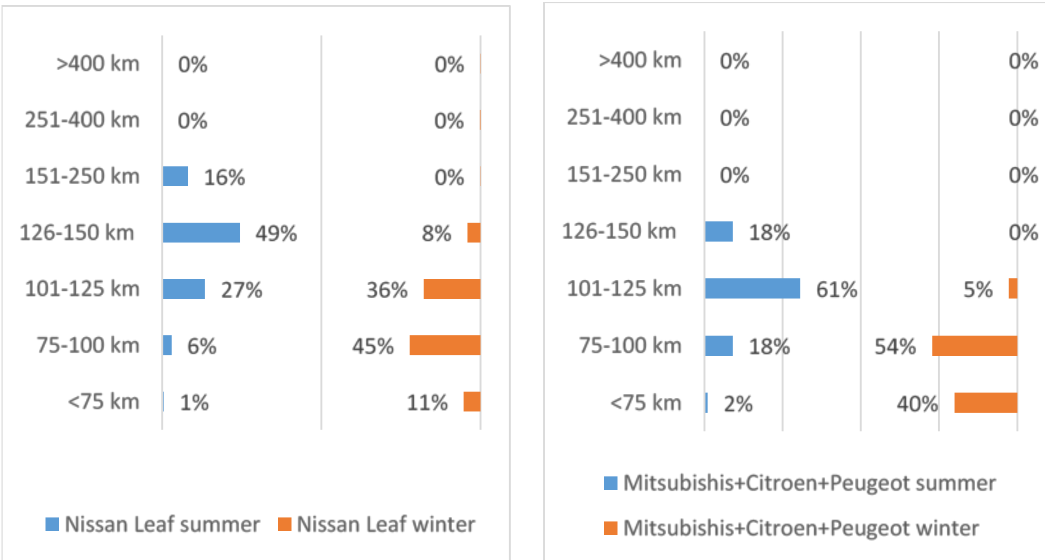


Figure 4.2 Share of owners of Nissan Leaf and Mitsubishi/Citroën/Peugeot feeling comfortable about using different lengths in summer and winter. Percent and km. Norway 2014. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

Based on this data the COMPETT project has estimated that current users in Norway employ an average range limit of about 120 km in the summer and 80 km in the winter when planning trips. These estimates include the 20% range margin when planning the day's travel and also take into account up to 10% degradation of range over time.

The Tesla Model S is not considered in these estimates, having few range limitations under Norwegian conditions. Tesla owners have access to the free Tesla supercharger network when range is too short. Only 14% of Tesla owners have stated that the experienced range was shorter than expected whereas 38-42% of owners of other types of BEVs state the same. For winter driving, the results are similar, although more drivers have experienced problems. Yet, it should be noted that 67% of Tesla owners also state that owning an BEV requires more planning. 61% to 80% of owners of other types of BEVs stated a need to plan more.

One should also note that the Norwegian speed limits are among Europe's lowest. The lower speed limits lead to BEVs using less power and having a longer range, compared to countries where speed limits are higher.

4.2 Potential for meeting daily travel needs

Travel surveys are used in order to acquire knowledge of how people travel. The surveys in Norway and Denmark are based on telephone interviews with a representative share of the population, see chapter 1.3. They show that 94-97% of trips, 83-96% of trip chains (from home to home) and 81-92% of full-day transport requirements, can be met by BEVs that have a range of 80 km in winter and 120 km in summer, see table 4.1. 63-72% of all travel needs can still be met even if range drops down to 50 km. Older BEVs, having lost some of their initial range, will thus still be capable of fulfilling a large share of daily travel needs.

Table 4.1 Share of daily car trips and trip chains by lengths and above the range limit. Number of days over range limit summer and winter. Travel data for car drivers, Norway 2009 and Denmark 2014, National travel surveys. Source: Hjorthol et al., 2014.

	Measured unit	Season	Mean dist-ance km	0-49 km %	50-79 km %	80-119 km %	120+ km %	Percentage of days with trips/tripchains over limit, %	Average no. of days over range limit Days pers eason	Total no. of days over range limit Days per year
Norway	Individual trips as car driver	Summer	13.7	94.9	2.5	1.3	1.3	3	6	16
		Winter	13.0	94.6	2.5	1.3	1.8	6	10	
	Trip chains as car driver	Summer	28	84	8	5	4	4	7	23
		Winter	27.6	86	6	4	4	9	17	
	Travel per day as car driver	Summer	48.5	70.1	12.0	8.5	9.3	8	15	43
		Winter	48.3	72.0	11.4	6.6	10.0	15	28	
Denmark	Individual trips as car driver	Summer		91.6	4.5	3.2	0.7	4	7	18
		Winter		93.0	3.8	2.8	0.4	6	11	
	Trip chains as car driver	Summer		74.0	11	6	8	11	20	50
		Winter		77	12	7	8	17	30	
	Travel per day as car driver	Summer		63.0	15.2	9.7	12.1	12	22	57
		Winter		66.2	14.7	9.1	10.0	19	35	

Driving length requirements per day are greater than the available range from a fully charged vehicle on 43 days per year in Norway and 57 days per year in Denmark. However, this challenge can be reduced by charging during stops, e.g. at work or when shopping, see chapter 5. In addition range challenge is not so relevant for multi-vehicle households, see section 4.6.

Almost all BEV owners park and charge their EV overnight at their home according to the survey of BEV owners in Norway (Figenbaum, Kolbenstvedt and Elvebakk 2014), see chapter 5.

4.3 Long-distance travel with electric vehicles

In the travel survey in Norway long-distance trips are a separate topic. A long-distance trip is defined as the distance from the start point to the destination being >100 km. Short stops on the way are considered to be part of the same trip to the destination. The spread of trip distances is used to calculate the number of days with long-distance trips and days over the range limit per distance interval, see table 4.2. Charging during the day and fast charging on longer trips can reduce the number of days above the range limit.

The range limit of Tesla Model S with 85 kWh battery would be over 300 km in winter and 400 km in summer. The average number of days above range limit for that vehicle would only be about two in summer and five in winter.

Table 4.2 Share of long-distance trips by length and average number of days over range limit summer and winter. Travel data for car drivers, Norway 2009, National travel survey. Source: Hjorthol et al., 2014.

	0-79 km	80-99 km	100-119 km	120-139 km	140-159 km	160-179 km	180-199 km	200-299 km	300-399 km	400-499 km	500+ km
Percentage of long trips		10 %	16 %	15 %	8 %	8 %	7 %	18 %	8 %	5 %	5 %
Accumulated long trips.		10 %	26 %	41 %	49 %	57 %	64 %	82 %	90 %	95 %	100 %
Spread of travel per day, summer	82.1%	3.3 %	5.2 %	1.9 %	1.0 %	1.0 %	0.9 %	2.3 %	1.0 %	0.6 %	0.6 %
Spread of travel per day, winter.	83.4%	2.5 %	4.1 %	2.0 %	1.1 %	1.1 %	0.9 %	2.4 %	1.1 %	0.7 %	.,7 %
Days over range summer				3.0	.6	1.6	1.4	3.,6	1.6	1.0	1.0
Days over range winter		2.8	4.5	4.2	2.2	2.2	2.0	5.0	2,.	1.4	1.4
Accumulated days summer				3.0	4.7	6.3	7.7	11.4	13.0	14.0	15.0
Accumulated days winter		2.8	7.3	1.,5	13.7	16.0	17.9	23.0	25.2	26.6	28.0
Accumulated share of days summer				20 %	31 %	42 %	51 %	76 %	86 %	93 %	100 %
Accumulated share of days winter		10 %	26 %	41 %	49 %	57 %	64 %	82 %	90 %	95 %	100 %

4.4 Types of owners

In Norway 80% of the buyers are consumers whereas in other countries in Europe this share varies from 10% to 40%, see figure 4.3. The share of consumers owning BEVs in other European countries will grow when early adopting fleet operators replace their BEVs and sell most of the old ones second hand.

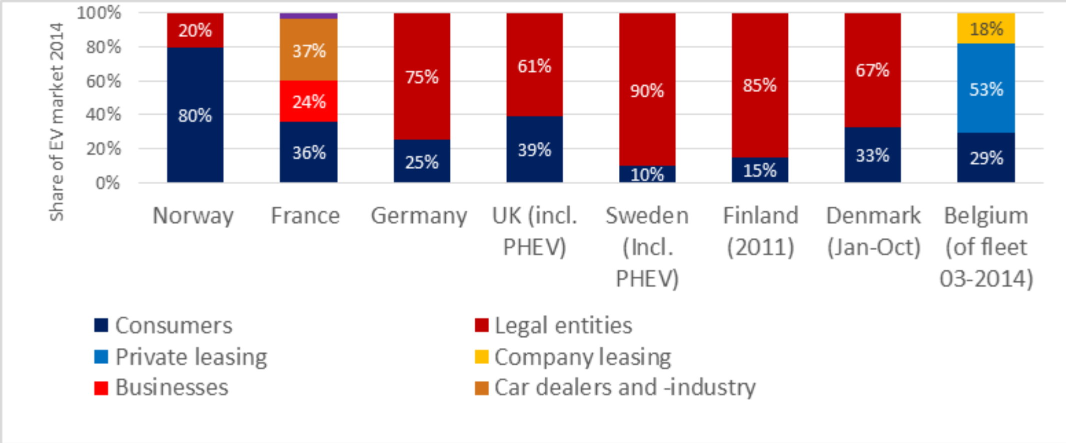


Figure 4.3 Share of BEVs with different types of ownership in some European countries in 2014. Percent. Sources: See appendix III.

The majority (74%) of Norwegian consumers owning BEVs belong to multivehicle households. This share is a much larger share than the nationwide average multivehicle ownership rate of 42% among all households and 50% among households with vehicles from NTS 2009 (Vågane, Brechan and Hjorthol 2011). An explanation for the difference is that multivehicle households can cope with EVs range limits more easily as they can swap vehicles, see chapter 4.6.

22% of the households owning BEVs are single-vehicle households. Of these, 23% own a Tesla Model S that has very small range limitations, 52% own a Nissan Leaf and the rest owns one of the smaller BEVs. The share of single BEV households in Norway will most likely increase. The next generation of BEVs will get longer ranges (Krutak et al. 2014) making it possible for a larger share of single-vehicle households to adopt electric vehicles.

75% of BEV owning households have a combination of BEVs and ICE vehicles. 3% have more than one BEV and no ICE vehicle and the rest have only one BEV.

4.5 Owners' actual travel pattern

The BEVs in Norway are driven more than the average vehicle in the car fleet, and at approximately the same level as other new vehicles. The average driving distance for EVs was reported to be 14 500 km per year (Figenbaum, Kolbenstvedt and Elvebakk 2014). Data from Nissan indicates that the number is underestimated as the average Leaf in Norway according to Nissan is driven 16 500 km per year (Nissan 2015) compared with the COMPETT surveys 14 900 km per year for Nissan Leaf. The average for passenger cars in Norway is approximately 13 000 km per year. Vehicles that are 0-4 years old (same age as most BEVs in the fleet and in the survey) are driven 15 500 km per year (OFV 2012).

BEVs are mostly used for daily travels, especially travelling to work, see figure 4.4, and are seldom used for holiday travelling. Owners of both ICE vehicles and BEVs tend to use their BEV more for everyday transport than their ICE vehicle. Part of the difference is related to BEV owners belonging to larger households with children, finding timesaving incentives especially interesting.

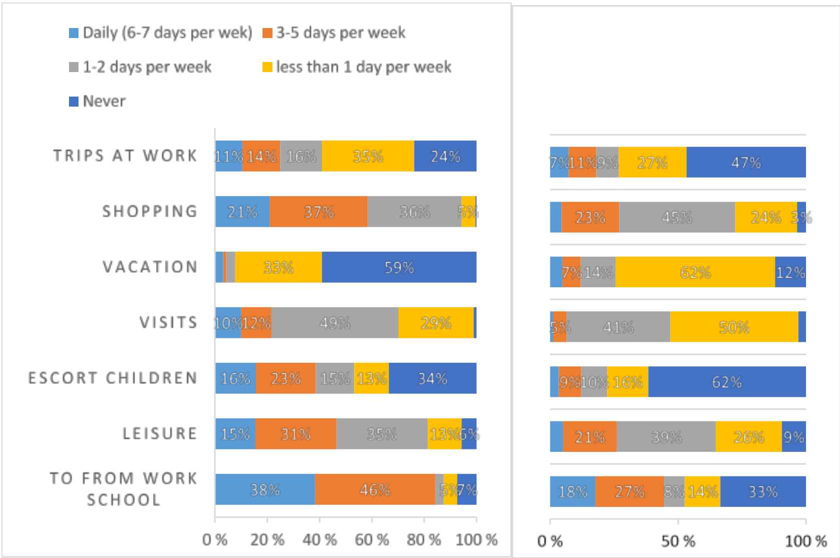


Figure 4.4 Travel purposes for BEVs (left) and ICE vehicles (right) in Norway 2014. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

The total insured travel length of the households' vehicles stayed the same for 2/3 of the owners after buying the BEV. The COMPETT findings indicate that the multi-vehicle households' usage of vehicles is redistributed so that the BEV has become the preferred vehicle for daily driving. Although it might have been purchased as a «secondary» vehicle, most daily travels are now made by the BEV. Total cost of ownership (TCO) calculations of BEVs vs ICE vehicles should take this change in usage into account.

4.6 Household types and ability to cope with actual range

The user survey in Norway included a question about the way BEV owners cope with trips to be undertaken when the range is not sufficient. The results are shown in figure 4.5 (Figenbaum, Kolbenstvedt and Elvebakk 2014). It is clearly seen that multicar households that also own an ICE vehicle, adapt far more easily than single BEV households. They can swap vehicles in the household and thus do not need to charge during the day. They could also plan so that both cars do not need to go on long trips on the same days. People also have other options in order to adapt, such as loaning or renting vehicles and planning trips better.

The share of single-vehicle BEV households that reports that they sometimes end up not taking the trip, due to insufficient range, is three times higher than that for multivehicle households. They also report a much more frequent use of cumbersome alternatives, such as loaning or renting vehicles. A few combine BEV ownership with a car sharing membership, or they might have purchased an BEV with a few days of ICE vehicle rental included (offered by some Nissan dealers). The users were not asked how often they needed to adapt.

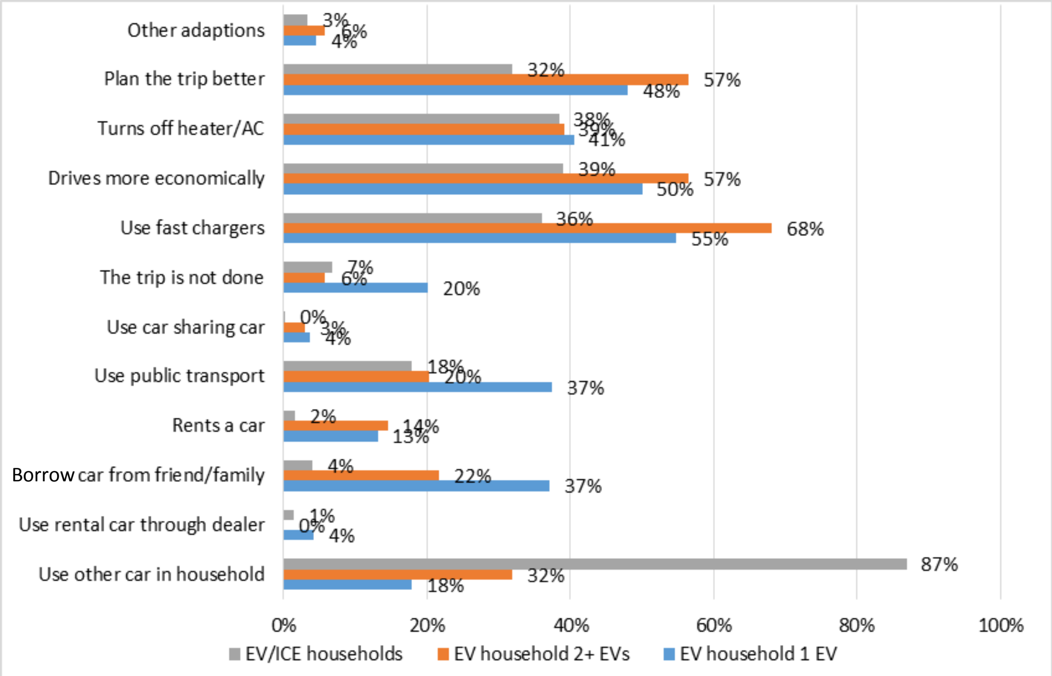


Figure 4.5 Ways of coping with trips longer than BEV range by type of BEV owners. Several methods could be mentioned. EV owners in Norway 2014. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

4.7 Findings on range versus travel needs

Main findings on BEVs range presented in this chapter are;

Range covers daily travel needs

- Most daily driving can be covered by today's BEVs having a summer/winter range of 120/80 km respectively
- BEVs are driven as much as other vehicles, about 15 000 km per year, and have become the primary vehicle for everyday travels of multivehicle households
- The challenge is longer trips. The BEV ranges are insufficient for 15 days in the summer and 28 days in the winter.

Users' comfort range has increased

- BEV owners are confident using 80% of the range and plan for a 25% shorter range in winter than in summer
- The estimated summer and winter ranges which the owners plan trips for, are for small and compact BEVs, 120 km and 80 km respectively
- 9% of BEV owners in Norway have experienced running out of power once, 3% several times, whereas 88% have never had that experience. In Austria, with older BEVs 34% have run out of power
- 2/3 of owners in Norway and Austria say that driving an BEV involves a need to plan trips better.

Relevance to other countries

The range difference from summer to winter will be smaller in countries with milder winters and warmer summers. The summer range will be shorter due to Air Condition (AC) and the winter range will be longer due to other requirements for climatization of the cabin. Higher speed limits on main roads and motorways may lead to shorter range in other countries. Potential buyers need reliable information about the real-world ranges, i.e. the ranges under varying conditions and driving styles.

5 Charging infrastructure and behaviour

The electromobility system is, as well as the ICE vehicle system, relying on infrastructure for getting energy to the vehicles. For BEVs a network of charging stations at various locations is needed. But how and where do EV owners charge and how can charging during the day contribute to an extension of the range?

5.1 Actual charging locations

User surveys in Norway and Austria show that BEV owners mainly charge their vehicles at home with electricity supplied from the house installation, see figure 5.1. Half of them charge their vehicles in a garage, the others in a parking lot. About 60% charge daily, 20% 3-5 times per week, 17% 1-2 times per week. Only 3% do not charge at home, potentially using on-street or workplace charging.

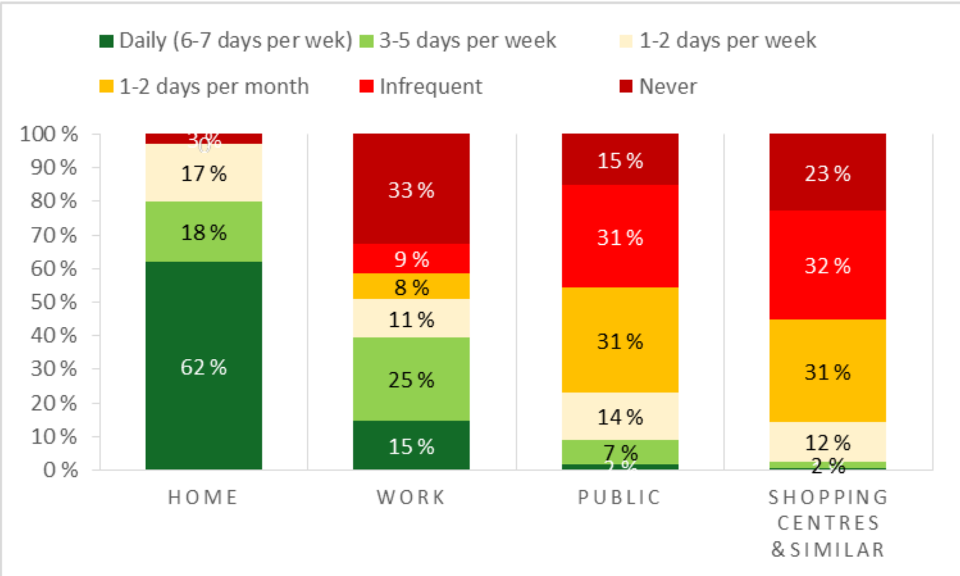


Figure 5.1 Frequency of home and external charging, BEV owners in Norway 2014. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

About 54% of the vehicles use a public charging station at least monthly, about 22% weekly. Shopping centre charging stations are used less frequently. About half of the respondents regularly (at least once a work) charge at work , i.e. many employers have installed charging stations.

The Norwegian EV association established a database (NOBIL) of charging stations by asking their members to enter stations into a national database. Gradually, the data quality improved, and with government support the NOBIL database has evolved into a national open source database. Anyone can make user applications from the data. This database also contains online information on when the stations are occupied or available.

The number of chargers is not keeping up with the rapid expansion of the BEV fleet. Currently, in 2015, Norway has about 5 900 normal charging points, 100 fast charging points and another 100 planned (NOBIL 2015). As shown in figure 5.2 the rapid diffusion of BEVs has led to a continuous increase in EVs per public charging point. There was 1 BEV per normal charge point in 2011, in 2015 this rate reached 9.

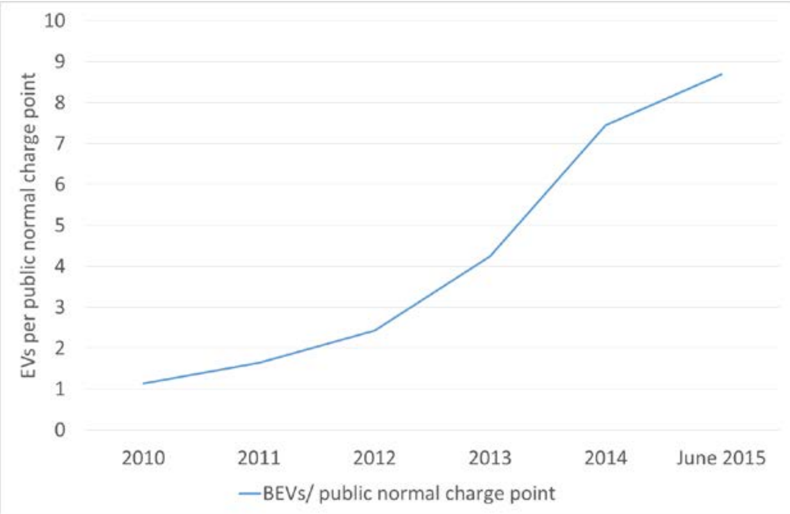


Figure 5.2 Development of public charging points in Norway 2010 - 2014. Number of BEVs per charging point. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

Tesla owners are already demanding faster home charging (7-11 kW) due to the large battery size in those vehicles. Buyers of second generation BEVs coming in 2017-2018 may also want faster charging at home as these vehicles will have much larger batteries. Grid owners should prepare for an increase in demand for charge power.

5.2 Fast charging for long-distance trips

The charts in figure 5.3 show a stylized long-distance trip with a BEV in Norway, compared to an ICE vehicle. Average speed is 80 km per hour. The batteries' state of charge is allowed to go down to 20% and fast charged to 80% SOC (State of Charge). The battery is fully charged before start. The range is 140/100 km summer/winter for the 2015 model and 200/140 km for the 2017 model. As the charging time is 20 minutes in summer and 40 minutes in winter for both models, the 2017 model will utilize 40% faster fast charging. Other assumptions are that the ICE vehicle owner takes a 15 minute break every two hours (Hjorthol et al. 2014) and that there is either zero or 20 minutes waiting time when charging the BEV.

Figure 5.3 clearly illustrates that, given these conditions, long-distance trips could already be feasible if waiting times are avoided. For the 2017 model the driving pattern can be almost as for the ICE vehicles. It is clear that it will not be very practical to undertake long winter trips with the 2015 model. The 2017 model has some improvements, and users may find winter trips up to 200 km feasible without too much time consumption. The risk of waiting time will be a serious obstacle for the willingness to undertake such long-distance trips. The bottom right chart shows that all benefits of 2017 models will be lost with waiting times of 20 minutes compared to the 2015 model without waiting times. It is therefore of utmost importance that the building of fast chargers follows the same pace as the fleet expansion. Strategies to free up capacity at fast chargers are important, and payment per kWh recharged should therefore be avoided in favor of payment per minute. Charging power is quickly reduced when battery SOC reaches 80%, the cost per minute, if usage is payed for per kWh, will then be low, leading to potential waiting times for others.

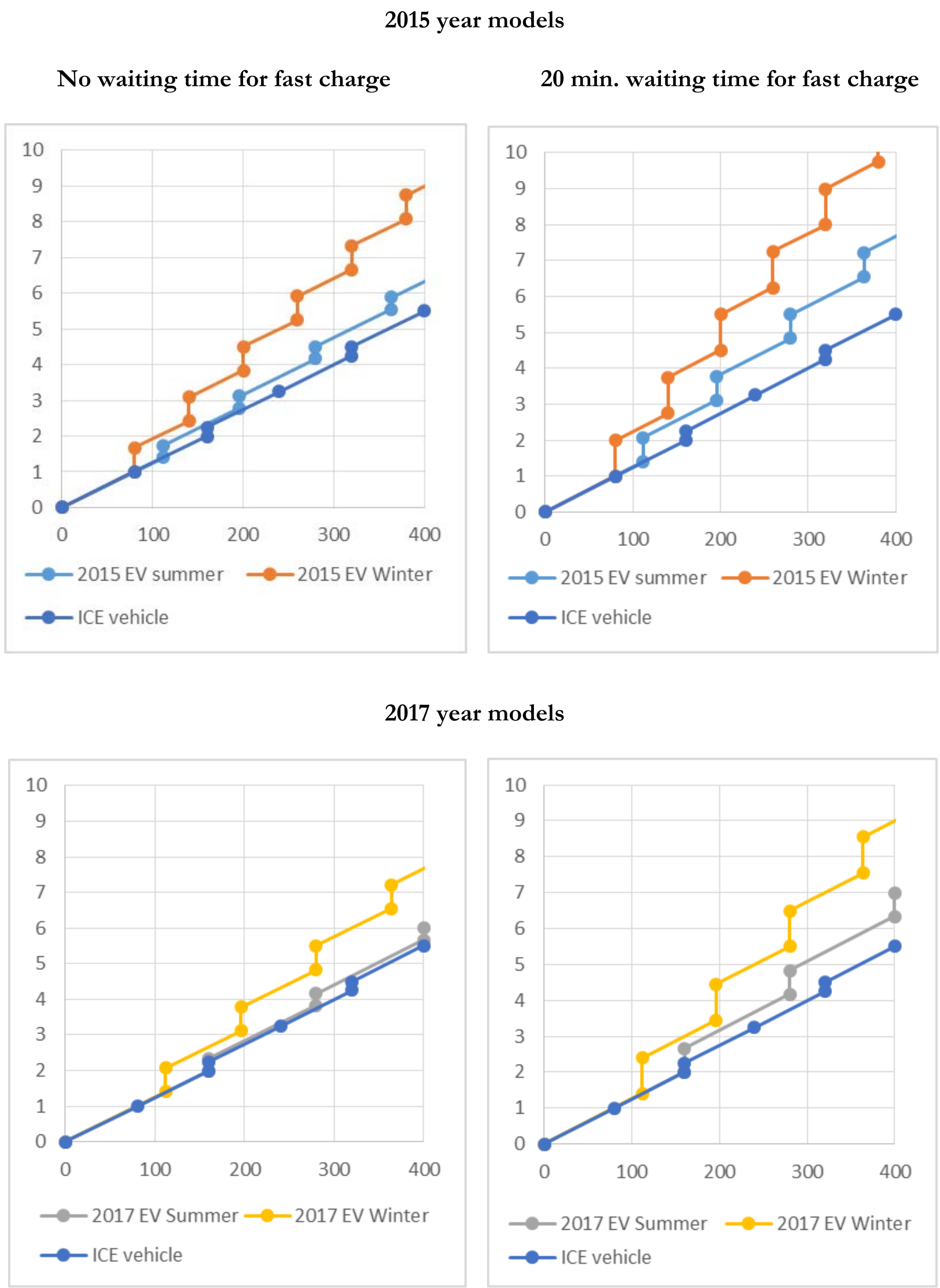


Figure 5.3 A stylized long-distance trip summer and winter with BEVs 2015 (upper part) and 2017 (lower part) models in Norway compared to an ICE vehicle without wait time for fast charger (left), with 20 minutes. waiting time (right). Premises: Average speed is 80 km per hour, ICE vehicle owners rest 15 minutes every two hours.

Fast chargers have been unreliable with down time and software problems in the initial deployment phase in Norway. Fast chargers were in the beginning free to use without payment as operators were gaining experience and establishing service.

Data on current Norwegian BEV owners' usage of fast chargers by vehicle model is shown in figure 5.4. The survey was done at a time when 54% of the respondents did not pay for fast charging. When payment was introduced, the usage of these chargers went down. Many chargers also had reliability problems leading to down time. These factors may have influenced the willingness to test and rely on fast chargers for longer distance trips. In 2015 all fast charging in Norway is subject to payment.

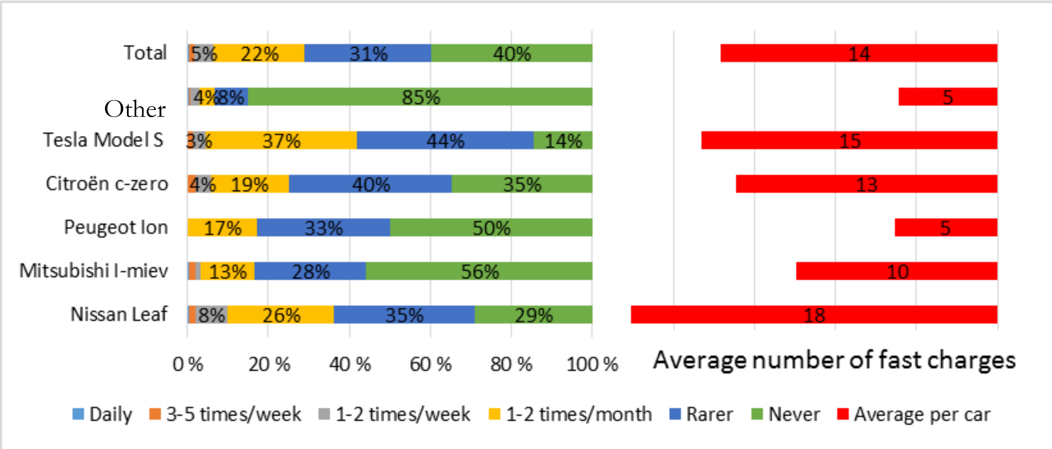


Figure 5.4 Frequency of use of fast charge stations (left section) and average number of fast charges (right section) per year by brand, among BEV owners in Norway 2014. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

The annual number of fast charges per vehicle is 14 per year, when excluding Tesla's. The smallest BEVs have the lowest number of fast charges. Nissan Leaf has the highest, indicating that Leaf owners utilize their vehicle better than other BEV owners. Contrary to intuition the use of fast chargers is the same in the winter as in the summer for most BEV owners (87%), see figure 5.5. With range being shorter, one would expect more fast charging in the winter.

Pure BEV households use fast chargers more than other BEV owners. The higher the share of range the owner is comfortable using, the more often they use a fast charger, see figure 5.5 (Figenbaum, Kolbenstvedt and Elvebakk 2014).

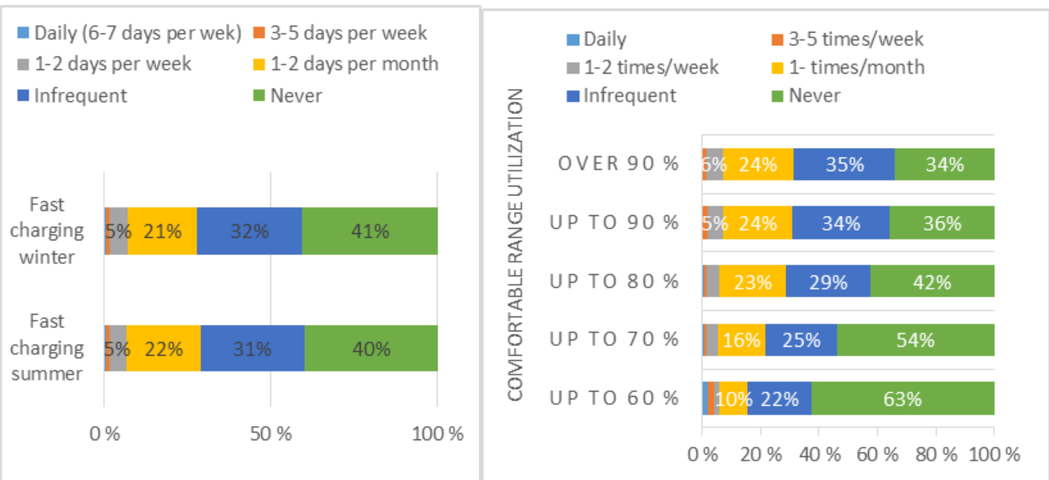


Figure 5.5 Frequency of using fast chargers by season (left part) and by degree of range necessary to be comfortable (right part). Norway 2014. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

The network of fast chargers has been put in place with the help of government and provincial support for parts of the investment costs. Support programs have used tendering and support schemes leading to a number of different fast charger providers with different payment systems. There were no requirements for common payment or specific payment systems as one did not want to limit creativity in the early phase, and no one knew what the business models would look like. Some opted for subscription services, others for pay as you go at a pay-desk (fuel station providers) or by RFID (Radio Frequency Identification) cards, credit cards, mobile phone payment etc. In the beginning, using other suppliers charging stations could only be done at pay as you go facilities. In 2015 the EV association initiated a common RFID card that can be used at multiple operators' fast chargers, although each will send separate bills.

The next generation vehicle with longer range, will likely appeal more to single-vehicle households and will be used on longer trips to a greater degree than the current generation EVs. The share of single-vehicle households among BEV owners is likely to increase. The result may be an increased need for fast chargers along main roads.

5.3 Increasing range by charging during the day

The days of travel over the BEV range limit, see table 4.2, can be reduced by using opportunities for charging during the day. The driver's stop pattern, and the short average distance of driving prior to charging, limits the energy that can be recharged on average, and thus limits the potential. The stop pattern in Norway and the energy recharged for 1.5 hour average charge time per location are shown in table 5.1. The estimated average charge time of 1.5 hours is derived from the average distance to work of 26 km that BEV owners have.

Table 5.1 Share of stops during the day (night time not included) at home, at work and other places with different length (hour), charge kWh pr charging and range increase summer and winter in Norway 2014. Sources: Calculation based on data from Hjorthol et al. 2014.

	Stops 1-5h,						Stops 5h+					
	Home		Work		Other places		Home		Work		Other places	
Kilometre	80-119	120+	80-119	120+	80-119	120+	80-119	120+	80-119	120+	80-119	120+
Stop pattern %	29 %	24 %	7 %	10 %	50 %	58 %	3 %	2 %	30 %	14 %	13 %	12 %
Charged kWh per 1.5 h charge at 220V/16 A	1.4	1.2	0.3	0.5	2.4	2.8	0.1	0,1	1.5	0,7	0.6	0.6
Range increase: *Summer Percent		8.3		3.5		20.1		0,7		4.9		4.2
*Winter Percent	6.4		1.5		11.0		0.7		6.6		2.9	

Charging 1.5 hours during the day at home could add 8-9% range and decrease days with insufficient range by two. The same charging at work could increase average range by 7-10% and give two more days without range problems. The corresponding figures for charging at other places are 8-20% and five days. The total effect is a range increase of 35% and 10 problem days less. The number of days over the range limit can thus be reduced to 23 when all charge options are utilized including one 20

minute fast charge for those that need that, see figure 5.6. Fast charge would then be used on about 3-3.5 % of travel days, i.e. 12 days per year on average per EV.

The average range increase and the decrease of the number of days above the range limit in Norway, when the opportunity for charging is utilized whenever the vehicle is stationary for more than one hour, is shown in table 5.2 and figure 5.6. The stopping pattern used for the 2015 BEV in winter was the 80-119 km pattern and for summer the 120+ pattern from table 5.1. For the 2017 BEV the 120 km+ pattern was used for both summer and winter. Other assumptions were: Fast charging when 10% remaining capacity, stop fast charging when 80% capacity, one 20-minute fast charge when range exceeded. Charge speed halved in winter. 2015 BEV fast charge summer range increase: 84 km, winter 28 km. 2017 BEV, fast charge summer range increase: 140 km, winter: 49 km.

Table 5.2 Range achieved by different charging modes summer and winter for BEVs of 2015 and 2017 models. Km, percent and number of days still being over range limit. Calculation based on data from Hjorthol et al., 2014.

		Season		Percentage range increase		Problem days remaining		
		Summer	Winter	Summer	Winter	Summer	Winter	Total
2015 BEV	Overnight at home	120	80			15	28	43
	Home during the day	129	87	8	9	14	27	41
	Work	128	88	7	10	14	27	41
	Home + work	137	95	14	19	12	26	38
	Other places	144	94	20	18	12	26	38
	Home+work+other	162	109	35	36	10	23	33
	Fast charge 20 minutes	204	108	70	35	7	23	30
	Home+work+other+fast 20 minutes	246	137	105	71	6	17	23
2017 BEV	Overnight at home	200	140			7	17	24
	Home during the day	209	147	4	5	7	15	21
	Work	208	148	4	6	7	15	21
	Home + work	217	155	9	11	6	14	20
	Other places	224	154	12	10	6	14	20
	Home+work+other	242	169	21	21	5	13	18
	Fast charge 20 minutes	340	189	70	35	4	11	15
	Home+work+other+fast 20 minutes	382	218	91	56	3	6	9

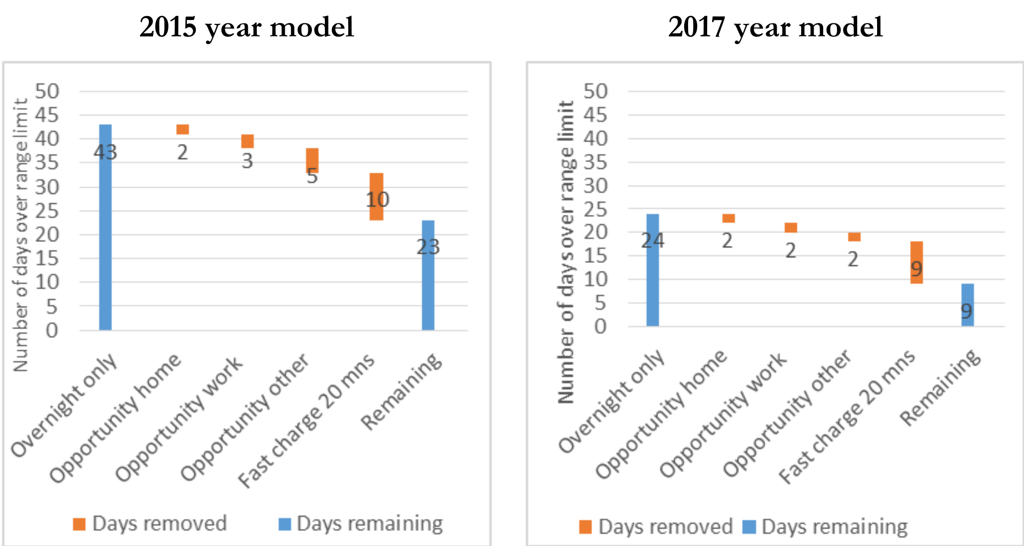


Figure 5.6 Number of days over range limit per year, reduced by different charging modes for 2015 year models (left), and 2017 year model (right)). Calculation based on data from Hjorthol et al., 2014.

The next generation of BEVs coming in 2017 is expected to have an increased range of 200 km in the summer and 140 km in the winter and the number of days with problems decreased by 19. When utilizing all charge options including 20 minutes of fast charge, the number of days with problems could then go down to 9. Fast chargers would then be used 2% of days on average, 7 times/days per year per vehicle.

The effectiveness of charging during the day is limited by the average amount of energy that has been used before coming to work, to home from work and to other places and on the stopping frequency at these locations. As most drivers only have 26 km to work, the energy that can be charged back at that location will on average be small. At home the same is true for the trip back from work. The stopping pattern indicates that relatively few owners drive out again after having parked at home after work. Fast charging 20 minutes once per day the range is insufficient, is more efficient in terms of extending the average range, than slow opportunity charging whenever possible. Fast charging in the winter has less effect as the charge speed is halved, and the range per charged kWh is lower. In the winter, opportunity charging is therefore equally effective.

Drivers in warmer countries would experience less variation from summer to winter, with a longer range in winter and a shorter range in summer due to more air conditioning. Drivers in countries with high speed limits on motorways and main roads will also achieve less range than what is calculated here.

5.4 Choosing a charging solution

BEVs can be recharged using domestic household outlets but, this practise is not recommended. At least not at power levels near the capacity limit of the socket and the installation in the building. The Schuko domestic socket, see section 3.3.1, was not designed to charge electric vehicles at continuous high power for the 6-12 hours required to charge an empty battery. 69% of respondents to the EV association's annual survey (Bu 2015), responded in 2014 that they used the Schuko domestic wall socket for charging at home. 20% used a home charger and 5% an industrial socket (to charge Tesla). 4% said it was not possible to charge at home. 2% used other types. All vehicles are delivered with a Schuko type charge cable. Manufacturers only recommend these to be used when occasionally charging away from home. In the home location a home charger is recommended, see chapter 3.

Home chargers with a separate fuse in the building's fuse box are the safest type of home charging and also the fastest. The National Research Council in the USA (NRC 2013) notes that the choice of infrastructure solution may be a complicated process for consumers. In Figenbaum, Kolbenstvedt and Elvebakk (2014) the question: "Constituted selecting the charging solution a challenge when taking the BEV into use?" was posed to Norwegian BEV buyers. 27% of Tesla buyers, in comparison to 11% of Nissan Leaf customers, faced challenges.

Dealers in Norway cooperate with infrastructure providers to offer the installation of home chargers. When sold as an option with the vehicle, the standard installation is exempted from VAT. The infrastructure provider gets the order through the dealer, and contacts the customer directly to arrange time for the installation. From the customer point of view the decision is reduced to: Do I need the faster and safer charging that the home charger offers? Renault has pushed it one step further, bundling the standard home charger installation with the car, i.e. the vehicle's price includes the home charger and standard installation.

5.5 Opinions on charging

EV owners have a far more positive attitude to charging facilities than potential EV buyers that are currently ICE vehicle owners. The ICE vehicle owners that are not interested in BEVs are the most negative, see figure 5.7. While 22 % of BEV owners consider access to charging stations a large disadvantage, this figure for ICE owners, who do not consider buying an EV, is 73%. The more experience one has and the more positive one is to BEVs, the less problematic one finds charging challenges.

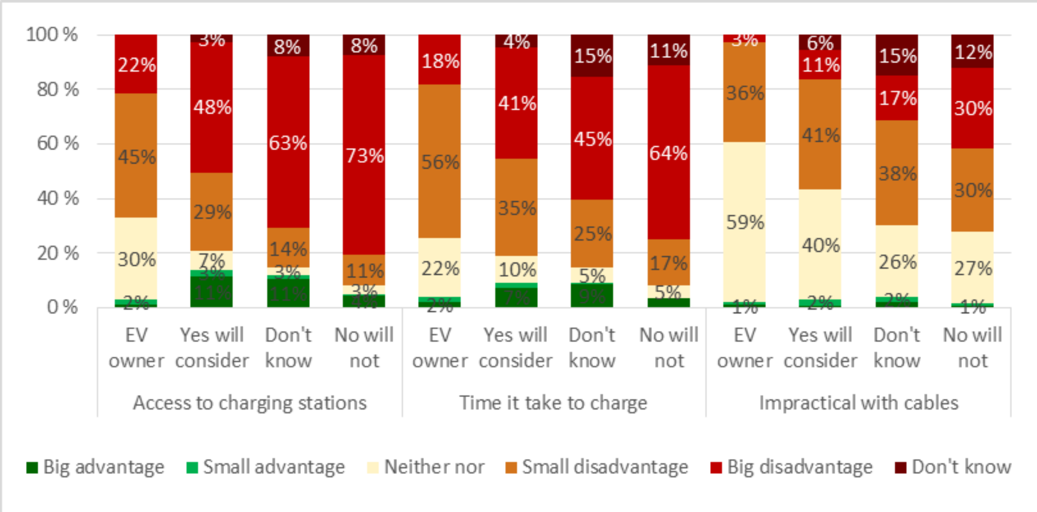


Figure 5.7 Attitudes to charging facilities among Norwegian BEV owners, potential BEV buyers among ICE vehicle owners and ICE owners not considering a BEV next time or not knowing. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

5.6 Findings on charging

Normal charging

- 97% of BEV owners charge their vehicles at home, 60% do it daily, 20% 3-5 times per week, 17% do it 1-2 times per week. Only 3% never charge at home
- 50% charge their vehicles in a garage (potentially warmer than the outside air)
- Work place charging is used regularly by half of the BEV owners
- Public charging, including shopping centre locations, is rarely used
- EV owners are much more positive to charging than those who merely consider buying an BEV. Those who are most negative to charging are the ones that will not consider buying an EV next time they purchase a car
- Some buyers had problems choosing the charging solution
- The dealers offer standard home charger installation packages as an option when buying the BEV
- 69% of BEV owners are using inferior home charging infrastructure, plugging the vehicle into domestic Schuko sockets

Long distance trips

- 40% never use fast charge (some may not have a fast charge capable vehicle)
- Fast charging is used on average 14 times per year, more so by Leaf owners
- Fast charging is used equally often in summer as in winter
- Fast charging is already making long-distance driving feasible in the summer and even more so with next generation vehicles. The distance between charge stops in the summer will be almost the distance between pauses that ICE owners take. Long-distance winter driving is and will still be a challenge
- The risk for and effects of waiting time to use the fast charger will, however, be a an issue that needs to be resolved
- Fast charging is not needed regularly today, but the demand may grow with next generation vehicles
- The lack of payment standards for charging allowed early experimenting, but systems must allow roaming between suppliers to make charging on the go more practical both within a country and between countries.

Charging during the day

- The full potential of charging on the go, at work, during stops at home and other places extends the daily travel possible with an BEV. The number of days above the achievable range can decrease by almost 50% to 23 days per year.
- The increase in possible daily travel by charging on the go is not limited by the available stopping time, but by the moderate energy spent on average before arriving at the stopping point.
- Using all available charging on the go will reduce the number of days above the achievable range with second generation BEVs coming from 2017, by 80% compared to current generation of vehicles only charged at home. The remaining days could go down to an average of only 9 days per year.
- The first generation BEVs would use fast chargers 3-3.5% of days on average, i.e. 12 times/days per year when assuming that fast charging is used once on all days when the user's driving needs exceed the range achievable.
- The second generation BEVs would use fast chargers 2% of days, 7 times/days per year on average. Only nine days with travel above achievable range would remain.

6 Embracing electromobility

This chapter deals with barriers and opportunities for BEVs, as well as factors and incentives that may reduce these barriers and entice consumers to buy BEV's.

6.1 Consumer adopter groups

Rogers' classic theory of diffusion of innovations (Rogers 1995) splits consumers into five distinct groups that represent successive adopters. These five groups, their positions on the adoption curve and their main characteristics are illustrated in figure 6.1. The step between early adopters and early majority is by some scholars called the "Chasm", constituting the gap between early adopters and early majority, which many innovations never pass. The market expectations of the technology changes when crossing the Chasm. The early majority accepts less risk of adoption than the early adopters do.

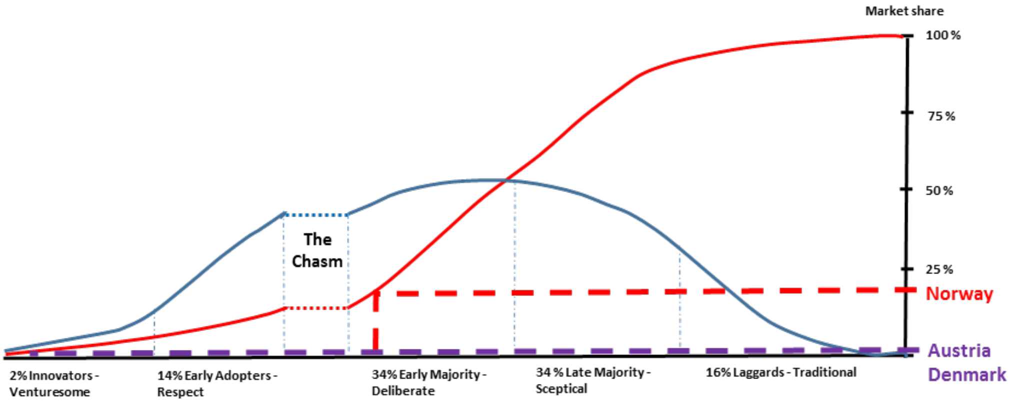


Figure 6.1 Adoption curve for innovations and the typical role of different user groups, adopted from Rogers (1995), indicating the actual position of Austria, Denmark and Norway. Source: Figenbaum and Kolbenstvedt (2015). Revised.

The five groups of users of innovations that appear in different phases of the process, having different significance in the spreading of new technology, are:

1. *Innovators*, the first to adopt or utilise an innovation, are young risk-takers with higher education, good finances, who are in contact with scientific environments, and other early users. Their risk tolerance allows them to try new technologies, and their finances can bear a possible loss.
2. *Early adopters* come directly after early users. They also have better finances, education and status, and are younger than those who adopt at a later date. Individuals in this group are often opinion leaders and are important for the further introduction process. They are somewhat more cautious than the innovators, which gives them credibility when communicating with others.
3. *The early majority* adopts an innovation significantly later than the two former groups. Their social status is above average for the population, and they are often

in touch with the early adopters. They themselves are not opinion leaders. They are less willing to accept risk than the earlier adopters.

4. *The late majority* comprises a group that adopts innovations later than the average population. They meet innovations with scepticism. Their social status is lower and their finances are worse than the average. They are not opinion leaders and mostly have contacts with others in the same group.
5. *Laggards* are the last ones to adopt an innovation. They are often older, negative to change agents and have low social status and a poor economy. Their contact is directed towards their family and close friends.

The different consumer groups adopt technologies in different ways and respond differently to policies and prices. The innovators want to be first and are willing to pay more and take the risk of the innovation potentially failing. The majority buyers do not accept such risks and the further the diffusion goes, the less willing people are to take risks. Innovators may accept some glitches in the technology performance as a price to pay to be first out with new technologies. Later in the adoption process the expectation will be that vehicles are as reliable as other vehicles.

Norway seems to have passed the Chasm, i.e. moved into the early majority group, in the 1st quarter of 2015 with an EV market share of 20%. Austria and Denmark are still in the earliest diffusion phase with innovators being the prime consumers purchasing BEVs.

6.2 Socio-demographics of owners and non-owners

The typical BEV owner in Norway in January 2014 was found to be male, 35-54 years old and working full-time. Compared to members of the Norwegian car association (NAF) and the general population (studied in the National Travel Survey, NTS 2009), they are more likely to hold a five-year university degree, belong to large, high-income multicar households located in and around big cities, having children below 18 years old. These characteristics fit well with early adopters. These are also the households who have the largest transportation needs. Working full time and having children is a combination that leads to high time costs, making incentives saving them time particularly valuable.

The Danish National Travel Survey 2014 also included some COMPETT questions related to electromobility (Hjorthol et al. 2014). 5 152 persons with driving licences were asked if they "*would consider buying an electric car.* " Only 6% answered yes and 13% maybe. As this situation is possibly similar in many European countries in the earlier stages of diffusion, it is interesting that the Danish analysis found two quite different groups among their potential byers, see table 6.1.

For details on socio-demographic characteristics of BEV and ICE vehicle owners see Figenbaum and Kolbenstvedt (2013), Hjorthol (2013), Figenbaum, Kolbenstvedt and Elvebakk (2014) and Hjorthol et al. (2014).

Table 6.1 Danish potential BEV buyer groups. Source: Hjorthol et al. 2014.

The Middle Aged	**Young(ish)**
o Middle aged	o Lives in a big city
o High income	o Relatively low income
o Well educated	o
o Good knowledge of EVs	o Little knowledge about EVs
o Access to more than one car	o No access to a car, or maybe just one car.
o Good home parking and charging facilities	o Bad parking/recharge facilities at home
o Some long trips	o Few long trips
o Concerned about the environment	o Concerned about the environment

The share of multi-vehicle households amongst EV owners in Norway is 74%, and it is larger than the nationwide average multivehicle ownership rate, see section 4.4. When comparing EV owners with other vehicle owners, who bought their last vehicle less than two years ago, large socio-demographic similarities between the two groups can be found. Figure 6.2 illustrates these similarities, comparing the economy of households with different vehicle ownerships. The economic incentives have lowered the EV purchasing price in Norway to a level that everyone buying a new vehicle can afford. These incentives may thus lead to BEV buyers' characteristics being more like the average car buyer earlier in the diffusion process than in countries with fewer incentives.

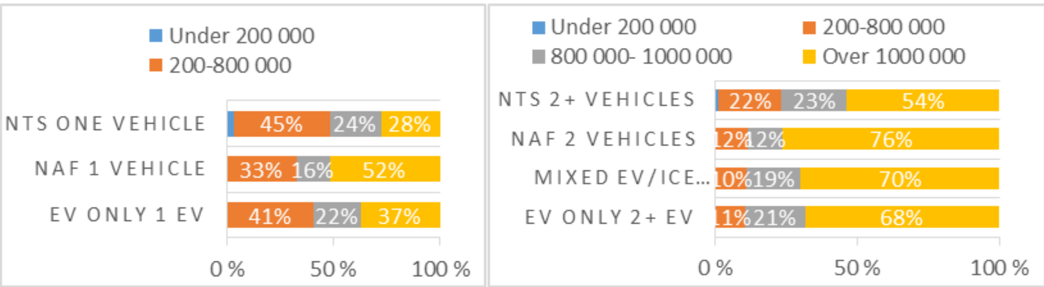


Figure 6.2 Single-vehicle household (left part) and Multi-vehicle household (right part) income for persons in Oslo-Kongsberg region with full-time jobs who have bought a new vehicle latest two years. Note: In NTS (National travel survey 2009) full time is defined as working more than 30 hours per week. NAF = members of the Norwegian Automobil Association. (Single-vehicle households: n NTS = 1 171, n EV = 83, n NAF = 134; Multi-vehicle households: n NTS = 801, n EV 2+ = 19, n Mixed EV/ICE = 192, n NAF = 145). NOK (and percent). Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

6.3 Reasons to buy electric vehicles

6.3.1 Advantages of BEVs

BEVs have clear advantages relative to ICE vehicles, both for society and the owner. The ride in BEVs is comfortable, with little noise, nimbleness in city traffic resulting from the high torques available from start from electric motors. Further advantages are an automatic gear function and the possibility of "one pedal" driving. The latter is a function where the gas pedal also acts as a soft breaker when easing off the pedal, when the electric motor shift to a generator mode recharging the battery creating a resistance to the cars movement. This resistance can be made powerful enough to drastically reduce the need to apply the brake pedal to use the vehicles mechanical brakes in city traffic. It is also possible to build EVs with very fast acceleration performance as demonstrated in the Tesla Model S beating so called Supercars using gasoline in this exercise.

BEVs are at least twice as energy efficient as ICEs, thus making lower operative costs a factor of great importance for BEV owners when buying their vehicle. Figure 6.3 shows that this is a typical relative advantage, mentioned by 81% of the BEV owners and only by 39% of ICE owners. The two owner groups also have different opinions when it comes to environment and safety. BEV owners emphasise environment, whereas ICE owners find safety very important when buying their vehicle. Actually, there is no real difference in the safety level of BEVs, PHEVs and ICE vehicles (EuroNcap 2015). Evidently, most ICE-vehicle owners have not grasped this fact. However, a factor of equal importance for both buyer groups is that the vehicle is the best-suited one for their needs.

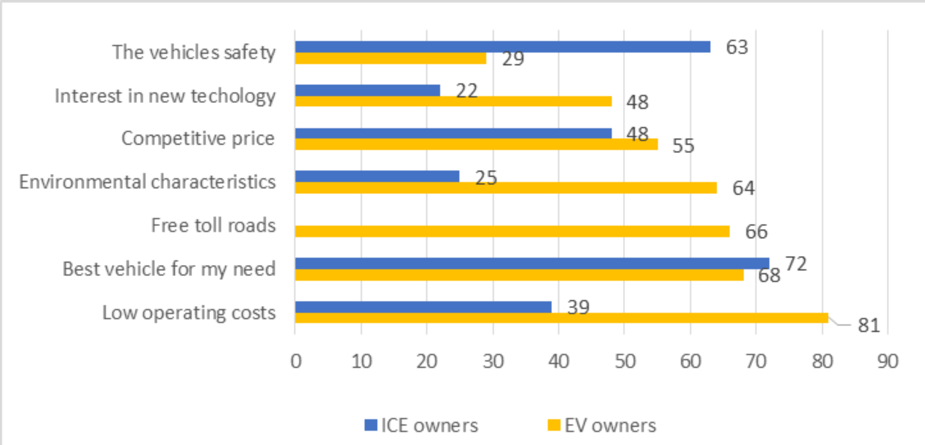


Figure 6.3 Owners reasons (important + very important) for buying BEVs vs ICE vehicles. Norway. Percent. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

The energy used by BEVs can be recharged at home or other places where the vehicle is parked. The owner can do other things while the vehicle is recharging such as working, eating or sleeping. No more detours to petrol stations to fill energy will be needed, saving the BEV owner time and effort on weekdays.

Most modern BEVs can preheat or precool the cabin remotely with electric power coming from the grid when plugged in, thereby preserving range and increasing comfort.

PHEVs exhibit these same advantages when driven in electric mode. Electric mode range is however much shorter than EV range leading to the vehicles partly operating in ICE drive mode. On the other hand, the electrical range is not limiting the operations of the vehicle. Long-distance trips can be undertaken with the ICE.

6.3.2 Disadvantages of BEVs

The limited range, the high cost of the vehicles and the long charge times are the main disadvantages that consumers face when considering buying BEVs.

The range available in a BEV is a function of the battery size. The higher cost of BEVs compared with ICE vehicles is also a function of the battery size. These two facts lead to manufacturers compromising when designing BEVs. The range is designed to be sufficient for everyday local transport to keep the price down, but the range will then often be too short for longer vacation or weekend trips, limiting the market to those that have matching driving patterns. Large consumer groups have driving patterns that match the all-year range of common EVs of 80-150 km, as seen in chapter 4.

PHEVs face many of the same problems with even higher cost compared to ICE vehicles and a very limited range in pure EV mode making it less worthwhile to plug the vehicle into the charge station. However, PHEVs change automatically to ICE mode when the electric range limit is reached.

Modern BEVs can be fast charged, but the battery life may suffer if the charge power is too high. Fast charge is not possible when the battery is approaching full charge. Again, these facts leads to a compromise where EVs can be fast charged in 20 minutes from 0% state of charge up to 80%.

Another disadvantage is the uncertain life of batteries. No modern EVs with Li-Ion batteries have been on the road long enough to shed light on this issue. If BEV batteries do not last the "normal" life of a vehicle, some 12-20 years and 150-230 000 km the consumer will face two alternatives, either to replace the battery or modules in the battery, or to scrap the vehicle early, both alternatives involving economic losses.

6.3.3 The significance of advantages and disadvantages

People's attitudes to new transport technology depend on their own social characteristics, experiences, values, travel needs and the assets and challenges of the technology at stake. The COMPETT surveys among BEV owners and general car owners in Norway and Austria included several questions on attitudes related to reasons for buying a BEV, see figures 6.4 and 6.8, and assets and challenges experienced when using BEVs, see chapters 4 and 5. This section deals with data concerning:

- Advantages and disadvantages of BEVs in general
- Willingness to buy a BEV next time
- BEV owners' willingness to recommend BEVs to their friends.

Knowledge on such factors is important in order to estimate competitiveness and future market development for BEVs.

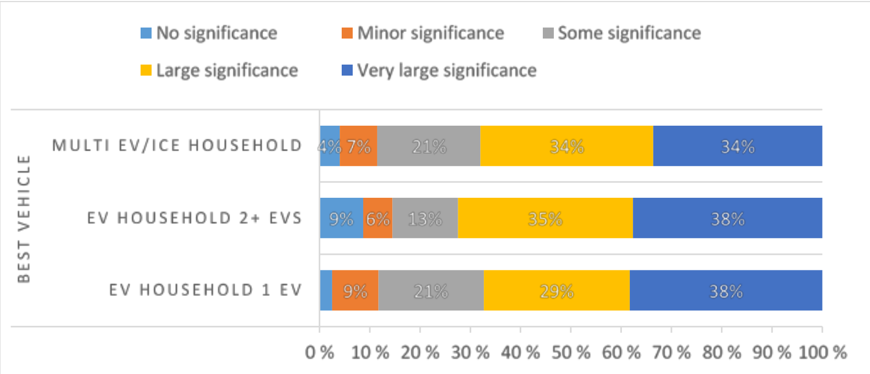


Figure 6.4 Share finding BEV the best car for their needs being of no, minor, some, large or very large significance when choosing a car by different type of BEV owner in Norway 2014 (n = 1 721). Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

Both BEV owners and ICE-vehicle owners considered the "practical aspect", i.e. that the vehicle is *the best one for their particular needs* as an important factor when they bought their latest vehicle (Figenbaum, Kolbenstvedt and Elvebakk 2014), see figure 6.4.

When asked to state the advantages and disadvantages of BEVs, a much larger share of the ICE owners than the BEV owners, i.e. people with real life experience of driving a BEV, perceived the challenges as large, see figure 6.5. Of the general vehicle owners, 74% find the range a big disadvantage, in contrast to 20% among BEV owners. Moreover, ICE-car owners and BEW owners do not perceive or comprehend the advantages of BEVs in the same way. Knowing that BEVs are energy efficient, 81% of the BEV owners think lower operative costs are a big advantage, whereas only 41% of the ICE car owners share this opinion.

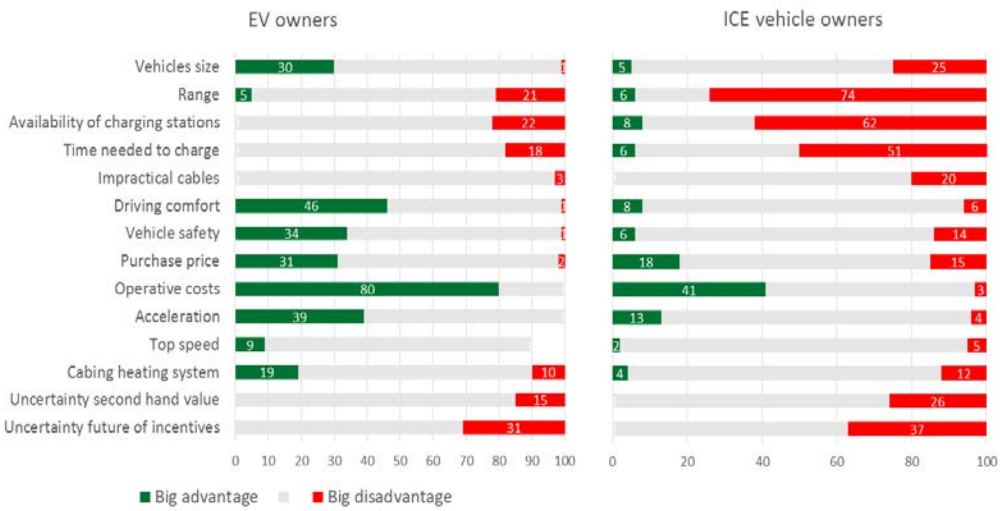


Figure 6.5 Big advantages (green) and disadvantages (red) of BEVs as seen by BEV owners and ICE-vehicle owners in Norway 2014. Percent. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

The answers from the two groups differ considerably, a fact illustrating a communicative challenge. Developing an effective information and communication strategy concerning the BEV assets, will be even more important in the next phases of BEV diffusion, when the people to be persuaded will be much less informed from the start.

Neither ICE-vehicle owners nor BEV owners are homogenous groups. The potential BEV buyers among the ICE-vehicle owners are rather similar to the BEV owners, rating the performance of BEVs higher than other ICE-vehicle owners do. The potential buyers are much less worried about range and charging than those ICE-vehicle owners who do not consider a BEV next time (Figenbaum et al., 2014).

There are also differences by brands. Tesla and Nissan Leaf owners rate safety highly, whereas owners of other brands rate it lower (Figenbaum, Kolbenstvedt and Elvebakk 2014). Tesla and Nissan owners are happy with their vehicles' comfort and acceleration, with the Tesla Model S in a league of its own with 94% rating these factors as an advantage. The heating system is a component that divides the BEV owners. Tesla owners are very satisfied, and Mitsubishi/Peugeot/Citroen owners are rather dissatisfied. For other factors, the results do not differ much between vehicle makes and models.

One can differentiate between three BEV owner groups – single BEV-only households, multi-vehicle BEV-only households and mixed BEV/ICE multi-vehicle households. When it comes to user needs, there are no major differences between BEV-only owners and others owning a mix of BEVs/ICEs, see an example in figure 6.4. People in BEV-only households are just as satisfied as mixed BEV/ICE owners with the match between their car and their needs.

BEV households with two BEVs have the highest share of members of environmental organizations (Figenbaum, Kolbenstvedt and Elvebakk 2015). This is a bit surprising, as one might expect that those living in BEV households with one BEV only, would be the most idealistic. The interest in vehicle technology and the technological competence in different BEV household types and regions varies. There are no clear trends, but it seems that members of BEV households with only one BEV are less interested than others, but a large share of these persons still rate their competence on BEVs as good.

Even if BEV owners experience challenges, these challenges are not large enough to make the BEV owners buy an ICE vehicle next time. Nearly all of them – both in Norway and Austria – show a very positive inclination to buying a BEV again. In Norway, 87% would buy a BEV again, and only 1 % would not, the rest being undecided. In Austria, where the incentives are few, all BEV owners want to stay electric (Jellinek, Emmerling and Pfaffenbichler 2015). Consequently, one conclusion could be that BEV owners in Norway and Austria love their vehicles.

6.4 Risks of adoption

There are risks involved when consumers adopt new technology. New vehicle technologies evolve quickly, making the vehicles better and cheaper over time, thus reducing the value of the first vehicles using the technology. Servicing may be more cumbersome, and the technology may be less reliable in the beginning. The technology could fail in the market, or the supplier could disappear. Then, the product could either be worthless, if it only has value when others also use the technology (Fuel cell vehicles rely 100% on public infrastructure, no one will over time supply hydrogen if the number of vehicles remains very small), or have a significantly reduced value, as few others will now be willing to buy it second hand.

A vehicle is the most advanced and costly “appliance” consumers buy. Designed for a 10-year, 230 000 km lifetime, the vehicle normally lives longer than these 10 years. It is also a big outlay for a consumer. The annual costs of owning and using one is also substantial.

6.4.1 Success or failure of innovation

Existing BEVs can continue to be used even if the technology should fail in the market for some reason in the future, for example if another technology takes over. The vast majority of owners can, however, still charge their vehicles at home in their own parking place, and thus get most of their daily driving done. The usefulness would most likely be somewhat reduced, as such a market failure is likely to lead to public charging stations gradually disappearing. The vehicles would then be difficult to sell or have little value, potentially leading to the owner being “stuck” with the vehicle.

For PHEVs, the risk of a failing market is lower. These vehicles can operate only on liquid fuels as regular hybrids without a need to charge. They can also continue to be charged at home. The risk of a reduced residual value should therefore be lower.

For FCEVs, the situation is the opposite. They rely solely on public infrastructure for their supply of energy. If this technology fails in the market, that infrastructure could disappear. These vehicles would then become useless without value.

The vehicle supplier is obliged to supply service and spare parts for vehicles throughout their lifetime. BEVs and PHEVs are now produced by large manufacturers that most probably will be in the market in the future. Consequently, the risk of not being able to repair a vehicle is low. If for some reason the automaker disappear, a risk could still be present, as independent spare part providers may not find the market of interest if the number of vehicles in the market is small.

The small independent manufacturers that supplied vehicles in the early phases were another story. After the Norwegian BEV producer Think went bankrupt in 2011, spare parts and repairs have been done by a few specialized workshops, by cannibalizing other vehicles or using parts that had been made for use in the production of new vehicles but not yet used. The falling numbers of such vehicles and parts will make it increasingly difficult to keep these vehicles operable and they are difficult to sell second hand.

6.4.2 Falling cost and fast improvement of new models

Early adopters also face a risk when the technology becomes a success. The technology will most likely improve substantially over time and at the fastest rate in the beginning. The cost of the technology will go down as it becomes more widely used.

New BEV models are likely to get significantly longer range, thus getting much more useful to the consumer. In addition, these newer models will potentially have the same or lower price than older models as production costs reduce over time. The second hand value is set according to the price of a new vehicle. If a new vehicle price for a similar model has fallen 30% since the purchase, there will be an extra loss of value on the vehicle of 30% added to losses from ageing, see section 6.4.6.

6.4.3 Life of vehicle and components

EVs now use Li-Ion batteries. The life of the battery is the principal risk of adopting an EV. No one knows for sure how long EV batteries will last. Failure mechanisms can be linked to usage, e.g. the number of charge and discharge cycles, fast charging, the climate the vehicle operates in and calendar ageing effects. The battery and vehicle industry places great emphasis on improving life expectancy. The main problem of modern batteries is the gradual loss of capacity over time leading to a decreasing range. The vehicle can still be used, but for shorter trips than when new. It is unlikely that users will invest in new batteries when the vehicles are old, if such a gradual decrease in range proves to be the common problem of EV batteries. These vehicles will rather be used for commuting and other short trips, or by users with less demanding transport needs, until the vehicle reaches the end of its life. The share of consumers, who can use the vehicle, will be smaller, a situation leading to less demand and lower prices.

The first vehicles sold regularly with the Li-Ion technology appeared in the market in 2008, the Tesla Roadster. The first Nissan Leafs with Li-Ion battery came into the market at the end of 2010, but the sales did not pick up until the second half of 2011.

This fact means there are about 4-6 years of experience with Li-Ion batteries among consumers. New vehicles are sold with a 5-8 year battery warranty. All EVs sold in Norway after 2010, the majority of the EV fleet, are thus still covered by warranties. So far, only a few vehicles have needed a battery replacement, partly because manufacturers build in spare battery capacity not visible for the user. Typically, about 21 kWh is used out of a compact BEV battery capacity of 24 kWh. The spare capacity could gradually be used up when the vehicles age, leading to a risk of older vehicles starting to lose range. Nissan (2015b) says they have only replaced batteries in three out of the 35 000 Leafs sold in Europe. BEV owners in Norway have not yet seen range losses on BEVs using Li-Ion batteries. A firm conclusion on this risk factor can, however, not be drawn until the vehicles have been used for a longer time.

Other components in BEVs are also new, such as the unit providing electric power to the motor (motor-controller) and the electric motor. Failures occurring in these components can be very expensive to repair. These components do, however, have a potential for being robust and achieve long life with few faults, so problems should be temporary as manufacturers solve teething problems.

6.4.4 Reliability and servicing

Spare parts of EV specific components such as the motor controller, can be very expensive while the technology is in its infancy. Manufacturers may have a strategy of replacing the entire component rather than repairing it. The risk of these components failing will also be higher in the early phases. There may be long lead times for repairing vehicles as faults occurring may be new to the service organisation, leading to a need to call in experts from the manufacturer to solve a particular issue. Spare parts may be stored in fewer and more remote locations leading to longer waiting times. The servicing of vehicles may also be limited to a few places. If the vehicle is sold in only a few countries, problems of repairing and servicing the vehicle in other countries may arise.

BEV owners in Norway have experienced all of these issues during the early diffusion phase of BEVs. Examples of failing components in Norway are motor controllers for the Think BEV and gearboxes for Tesla Model S. Kia's BEVs knocked out fast chargers in Norway, leading to them being banned from fast charging until the problem was solved.

6.4.5 Supplier risk

Previously, BEVs were predominantly delivered by small upstarts with uncertain futures. These companies needed a steady influx of funding in the early market expansion phase. When funding stopped, the company would go bankrupt, as happened with the Norwegian manufacturers Think and Buddy. Although the buyers' contract is with the dealer, bearing the warranty responsibility, a bankrupt producer may nevertheless lead to spare parts becoming unattainable and vehicles irreparable. The residual value of the vehicle could plummet.

6.4.6 Second hand value

The residual value of BEVs is the largest risk factor for private consumers adopting BEVs and the risks of adoption should be reflected in the second-hand value. Figure 6.6 shows the advertised asking price for second-hand Nissan Leafs, retrieved from Norway's largest classified online advertisement service in the 4^{th} quarter of 2014. The price of the vehicle when new (mid equipment line with 15 000 NOK added for metallic paint and winter tyres) is also shown in the figure. Buyers in 2011 and 2012 have suffered an extra loss of 47 100 NOK due to the reduction in new vehicle price. From the constant in the linear curve fit, the annual loss per year is about 15 700 NOK in addition to the initial loss plus losses due to the odometer status. A 2011 vehicle driven 45 000 km should have a value of about 152 000 NOK, a value loss of 46%. The curve fit for the 2011 and 2012 models is very poor, indicating that age is the most important factor.

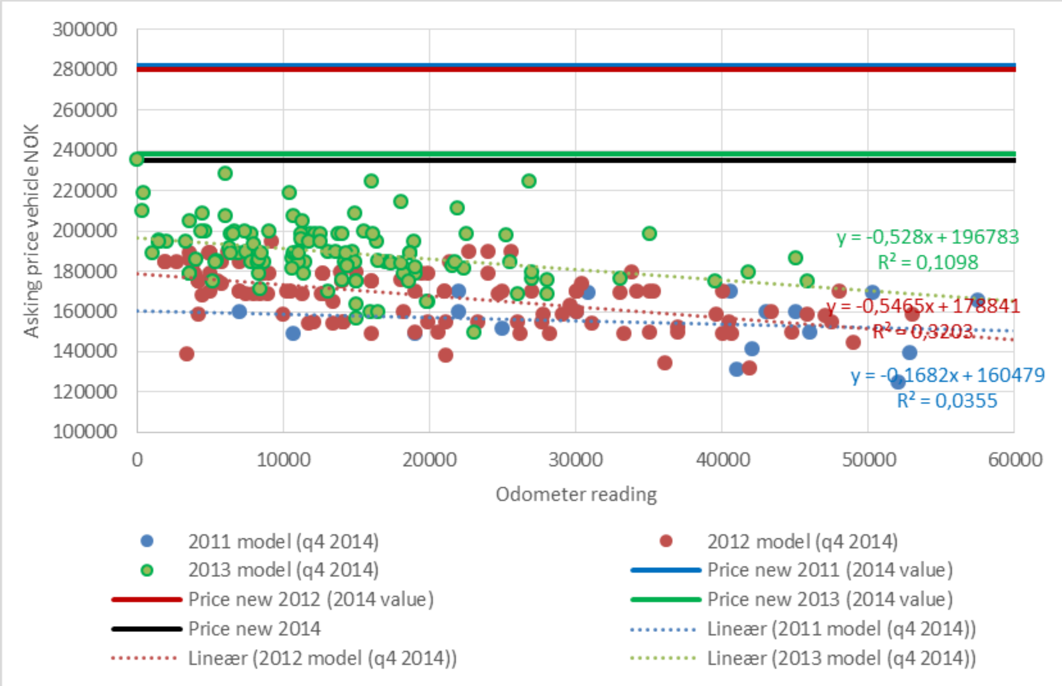


Figure 6.6 Asking price for second-hand Nissan Leaf in Norway, retrieved from www.finn.no Oct-Des 2014. 2014 NOK. 2014 currency rate: 1€=8.35 NOK. Own calculation.

A similar picture is seen in figure 6.7 for the "triplets", the Mitsubishi I-Miev, Citroen C-Zero and Peugeot Ion. Fewer vehicles have been advertised for sale, a situation leading to uncertainties. The new vehicle prices have dropped every year, leading to a larger value loss than for Nissan Leaf. A 2011 model has lost about 104 100 NOK just from the falling prices of new vehicles. Some of the models in 2011 were sold new at even higher prices. The 3-year loss of value for a 2011 model driven 45 000 km was 156 000 NOK, a retention of value of 39%, i.e. a value loss of 61%.

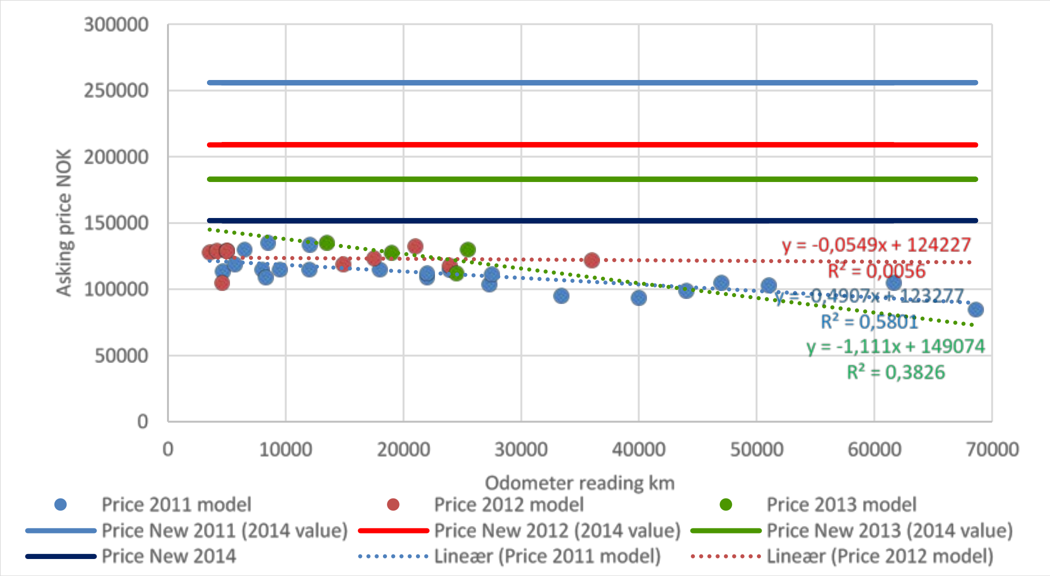


Figure 6.7 Asking price second-hand Mitsubishi I-Miev/Peugeot Ion/Citroën C-zero in Norway, retrieved from www.finn.no Oct-Des 2014. 2014 NOK. 2014 currency rate: 1€=8.35 NOK. Own calculation.

The Norwegian leasing company Autolease (VG 2015) has estimated the total value loss over the first 3 years for different BEVs and PHEVs and competing ICEs in Norway, see table 6.2. The residual value of the Leaf EV is lower than for the asking price on Finn.no. The expected yearly losses in NOK for BEVs are comparable to those of ICE vehicles, which is explained by the fact that BEVs are cheaper to buy new than comparable ICE vehicles thanks to Norway's purchase incentives.

Table 6.2 Autolease evaluation of EVs second-hand value after 3 years compared to ICE vehicles. Vehicle new price from vehicle importers. New price incl. destination/delivery charge, winter tyres, metallic paint. Source: VG (2015). 2014 currency rate: 1€=8.35 NOK.

Vehicles	New price NOK	Value after 3 years %	Value after 3 year NOK	Loss of value over 3 years NOK	Loss of value per year NOK
Nissan Leaf BEV	227 707	45%	102 468	125 239	41 746
BMW i3 BEV	323 400	50%	161 700	161 700	53 900
VW Golf GTE PHEV	355 200	60%	213 120	142 080	47 360
Audi A3 e-tron PHEV	368 960	60%	221 376	147 584	49 195
Nissan Qashqai 2WD Gasoline	300 850	64%	192 544	108 306	36 102
Toyota Auris Hybrid estate	314 200	60%	188 520	125 680	41 893
Ford Focus 125hp Gasoline Estate	316 000	60%	189 600	126 400	42 133
Volvo V40	369 100	60%	221 460	147 640	49 213
Tesla Model S85D BEV	707 000	55%	388 850	318 150	106 050
Volvo XC60	701 000	62%	434 620	266 380	88 793
VW Passat	393 900	62%	243 846	149 454	49 918

Residual value is heavily influenced by the life expectancy of the traction battery. A second-hand buyer cannot know the state of the battery and may not be protected by battery warranties. This issue may be temporary, as better data on the life of batteries will become available.

In the USA, where incentives are fewer, the value loss for Nissan Leaf has been much larger. A three-year old vehicle retains only 25% of original MSRP (Medium

Suggested Retail Price) not including the tax incentives offered, see table 6.3. In addition, the dealer may have offered a discount at the time of purchase. If 10 000 US$ are removed for the MSRP, then the average retention of the Nissan Leaf goes up to 35% after three years. For the Mitsubishi I-Miev the retention goes up to 31%. Both vehicles' value retention is substantially lower than in Norway.

Table 6.3 EV retention of value USA. US$. Source: NADA (2015).

2012 Model Year Units, Mar. - May 2015.

Make	Model	Average Trade-In	Average TE MSRP	Retention %
Tesla	Model S	$50,650	$88,550	57.2%
Toyota	RAV4 EV	$24,100	$50,645	47.6%
Ford	Focus Electric	$12,708	$39,995	31.8%
Chevrolet	Volt	$12,525	$39,995	31.3%
Nissan	LEAF	$9,300	$36,733	25.3%
Mitsubishi	i-MiEV	$6,166	$29,975	20.6%

Source: NADA Used Car Guide/ALG

The second-hand value of EVs in Norway will be influenced by the user incentives. The incentives follow the vehicle. All owners of BEVs with EL number plates have access to bus lanes, can drive at no cost on toll roads, pay reduced rates on ferries and park for free, resulting in a higher second hand value than without incentives.

6.4.7 Dealers and importers risks and costs

Importers of vehicles and their dealer networks face costs when introducing new vehicles with new technologies into national markets. There is a need to train the personal who handles and sells these vehicles and special equipment may be needed for the servicing. One of the vehicle importers stated an investment cost per dealer (including workshop) of some 300 000 NOK, to enable them to sell and do maintenance on BEVs according to Assum, Kolbenstvedt and Figenbaum (2014).

Nissan's strategy is to require dealers to install fast chargers for their clients. Potentially, the investment cost of this requirement could be up to 500 000 NOK per dealer. To recover such investments the dealer needs to be able to sell many vehicles. In countries with few incentives, these costs and risks may thus make it a challenge to persuade dealers and sales personnel to introduce and pursue sales of BEVs.

6.5 Economics of electric vehicle in household types

Most BEV owners belong to multi-vehicle households. These households have higher household incomes than single-vehicle households, making them more capable of absorbing the extra cost of buying an electrified vehicle, as shown in the BEV-owner survey, see figure 6.4 (Figenbaum, Kolbenstvedt and Elvebakk 2014). They are, however, unlikely to replace both vehicles in the household with EVs or PHEVs due to the risks of adoption and the high costs of these vehicles in countries with few incentives. However, in countries with large incentives, some households may do so. In Norway, 3% of the BEV owners in 2014 owned more than one BEV (Figenbaum et al., 2014). Multi-vehicle households will be better off economically with a BEV than a PHEV. More vehicle km can be replaced with electric drive with a BEV, as it has a much longer range than PHEVs have in pure electric mode. The operative costs of BEVs will be substantially lower than for PHEVs since driving in electric mode is much cheaper than using liquid fluids in ICE's. EVs are also cheaper to produce than PHEVs. When comparing similar models such as the E-Golf and the Golf GTE PHEV, the latter is 2000 Euro more expensive in Germany.

The risk of limited battery life may be perceived differently for PHEVs than for BEVs. BEVs have had a history of battery life challenges. People see that regular hybrid vehicles that have been on the market for 15 years now, have batteries that last the life of the vehicle. They may expect the same to be true of the batteries in PHEVs. PHEV usage characteristics will be more appealing to single-vehicle households with the PHEV's ability to go on longer trips effortlessly. The parking and charging availability is lower in single-vehicle households, a situation reducing the potential market much more than is the case for BEVs used in multi-vehicle households. The high cost of PHEVs compared with ICE vehicles, will be an obstacle for single-vehicle households.

Traditionally, the vehicle used for long-distance trips in multi-vehicle households has been the largest, the newest and most expensive vehicle. Many of these are company cars. Multi vehicle households may therefore opt for a PHEV, which are available in larger sizes, in spite of the fact that EVs are more economic to own and use for everyday usage. Manufacturers also position PHEVs as more luxurious and sporty vehicles. The electric drivetrain adds performance, not just the ability to drive part of the time in electric mode. This strategy is clearly seen at VW, where they use GTE as the model name for the PHEV, closely resembling the sporty GTIs of earlier days.

6.6 The influence of incentives

Studies on diffusion of environmental technologies clearly show that they need support from society at the early stages, partly due to high production costs. Hence, it is often necessary for society to put in to place compensatory measures to help the diffusion process and meet barriers (van den Bergh, Truffer and Kallis 2011, Jacobsson and Bergek 2011). Propfe et al. (2013) in their analysis of market penetration of passenger BEVs in Germany, also find that incentives related to purchase price and energy costs are needed.

Rogers (1995) finds that the rate of diffusion is influenced by how it is perceived with respect to relative advantage, comparability, complexity, trialability and observability. Incentives to speed up EV adoption should address the above factors, especially the relative advantage, as this is the most influential one. Prospective EV buyers will weigh in the benefits and costs of purchasing and using an EV when considering buying one. The options for incentives in relation to some crucial factors are shown in table 6.4. See chapter 7.3 for more details on these dimensions.

Table 6.4 Factors influencing relative advantage of BEVs.

Factors	Without incentives	What incentives and policies could do
Economic profitability	BEVs are more expensive and expected second-hand value after 3-5 years is low. Total cost of ownership over lifetime may be positive as a result of lower energy costs in countries with high fuel tax.	Purchase incentives reducing purchase costs for BEVs make it easier for consumers to see economic profitability of EVs. A tax on competing vehicles will have the same effect. A bonus/malus system such as in France combines the two approaches and can be made so that the tax on competing vehicles (malus) pays for the bonus to BEV buyers.
Low initial cost	BEVs are more expensive than ICEs. Value added tax expands the gap.	Same as above.
A decrease in discomfort	Discomfort due to perceived range limitations will be present for most users, although most usage will be compatible with range limits. Less noise in car and ease of operation in cities will lead to less discomfort Changes in discomfort due to greenhouse gas emissions and energy use depends on how electricity is produced and perceived in each country or region, compared with gasoline and diesel. If electricity is perceived more positive to the environment than fossil fuels, then discomfort may decrease.	Clear signals from the government about the societal impacts of BEVs are needed and will change buyers' perception of BEVs. Disseminate information to the public about how BEVs function in real life for different user groups and the BEV comforts and advantages
Social prestige	Tesla Model S and BWM i3 are vehicles designed to give social prestige. The most basic BEVs might be considered to be inadequate vehicles with negative social prestige in some countries, also depending on how environmentally benign electricity is perceived and how the government and researchers communicate.	Clear government messages about the positioning and need of BEVs in the transport system
A saving of time and effort	More effort needed, i.e. for planning the transport, for handling range challenges, for plugging in the vehicle, borrowing vehicles when needed. Fast charge takes a long time compared to filling fuels. No stops at the fuel stations, overnight charging means the vehicle is always ready and available the next day, can do other things while charging	Access to bus lanes is a direct time saving Free parking leads to time savings and less effort spent on finding parking
Immediacy of reward.	Economical: Not possible for first owner, the vehicle is too expensive and the savings per year too low and the second-hand value uncertain. Comfort, easy operation and less noise immediately available	Local user incentives will give immediate rewards, buy today, drive in the bus lane tomorrow Economic incentives can make EV ownership as economic as owning an ICE vehicle already for the first owner
Environmental standing in the population	Depends on the populations perception of the environmental characteristics of using electricity to propel vehicles, compared with using liquid fossil fuels.	Clear messages from governments, why go for BEVs and what are the positive environmental impacts.

6.6.1 Incentives tested in Norway

The EV story in Norway goes back to the 1990's when the first incentives were established, for varying reasons, see chapter 7 for more details. Figenbaum and Kolbenstvedt (2013, 2015). Table 6.5 summarizes the effects for the users and the Norwegian government's plan for future adjustments.

Table 6.5 BEV incentives, policies and initiatives in Norway. Source: Figenbaum, Assum and Kolbenstvedt 2014 and Political Agreement 2015.

Incentives	Introduced	Benefits for users, changed relative advantage	Future of the incentive decided 06. May 2015
Fiscal incentives Reduction of purchase price/yearly cost gives competitive prices			
Exemption from registration tax	1990/1996	The tax is based on emission and weight. Example of ICE vehicles taxes: VW Up 3000 €. VW Golf: 6000-9000 €. The tax makes the vehicles competing with BEVs more expensive	Continued until 2020. Will be reviewed against the achievement towards the Norwegian climate goals for 2020 and 2030. For ICE vehicles the registration tax will be tuned further towards reducing the emissions from these vehicles The government will also evaluate if PHEVs with a long EV-only drive mode should be more supported in the tax system, and if so how.
VAT exemption	2001	Vehicles competing with BEVs are levied a VAT of 25% on sales price minus registration tax.	Unchanged through the end of 2017. Will consider replacing it with a subsidy scheme that will initially be at the level of the value of the VAT exemption. A maximum subsidy per car may be set, but without leading to large price increases for any BEV models. In the future this incentive may be ramped down
Reduced annual vehicle license fee	1996/2004	Three rates apply for private cars. BEVs and hydrogen vehicles 52 € (2014-figures). ICE vehicle rates: 360-420 €.	Half rate of ICE vehicles could be introduced from 01.01.2018 and full rate from 2020, i.e. the incentive will be removed from that year.
Reduced company car tax	2000	The company-car tax is lower for BEVs. Most BEVs are not company cars.	This incentive may be removed from 2018
Direct subsidies to users – reducing usage costs and range challenges			
Free toll roads	1997	Large impact when toll roads are expensive. In the Oslo-area the saved costs are 600-1 000 € per year for commuters. Some places have tolls exceeding 2 500 €/year	The government will appraise the environmental effects of introducing differentiated fees for toll roads (main roads and toll rings around cities) and ferries based on the environmental characteristics of vehicles as well as a low rate for zero-emission vehicles.
Reduced fares on ferries	2009	Similar to toll roads saving money for those using car ferries frequently. Can be important in some areas.	
Financial support for charging stations	2009	Reduce the economic risk for investors establishing charging stations. These stations contribute to reduced range anxiety, expand the BEV market and get more EV miles out of every BEV.	
Financial support for fast charge stations	2011	More fast-charging stations become available, increasing BEV miles driven and the total BEV market including fleets.	
Reduction of time costs and giving relative advantages			
Access to bus lanes	2003/2005	BEV users save time driving to work in the bus lane during rush hours. Very efficient, high value to user in regions with large rush-hour congestion. Only a limited number of vehicles can use the bus lane. Can lead to increased vehicle ownership.	A process will be initiated to give local authorities the possibility of introducing restrictions in their jurisdictional district if zero emission vehicles hinder busses' ability to navigate the bus lanes.
Free parking	1999	The benefit for users is to get a parking space where these are scarce or expensive and to save time looking for a space. Impact depends on the number of spaces available.	Local authorities will be given the authority to decide whether this incentive is to continue in their jurisdictional district
Free charging		Not regulated in national laws, but is often bundled with free parking	Local authorities will be given the authority to decide whether this incentive is to continue in their district

Lower operating costs is by far the most important factor for EV owners when buying a new vehicle, much more so than for the ICE-car owners, see figures 6.8 and 6.9. Lower energy cost per km is an essential part of this, but also free toll-roads and free parking could be part of this parameter. Free toll-roads stand out as the most important local EV incentive, followed by free parking and bus-lane access.

The purchase incentives are not shown in figure 6.8, but they are implicitly included in the factor "competitive price" which is also of considerable importance. A reason for not asking questions about the purchase incentives is that they are invisible for the buyers. They only see the purchase price. The share finding competitive price to be of a very large significance when buying a BEV, is much larger than for those buying an ICE vehicle.

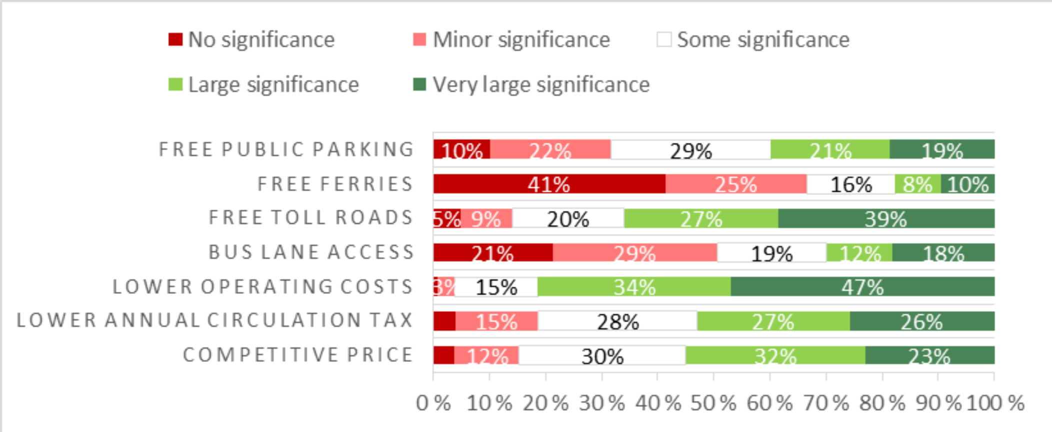


Figure 6.8 Degree of importance of factors and incentives related to buying EVs, as seen by EV owners in Norway (n = 1 721). Source: Figenbaum, Kolbenstvedt and Elvebakk 2014.

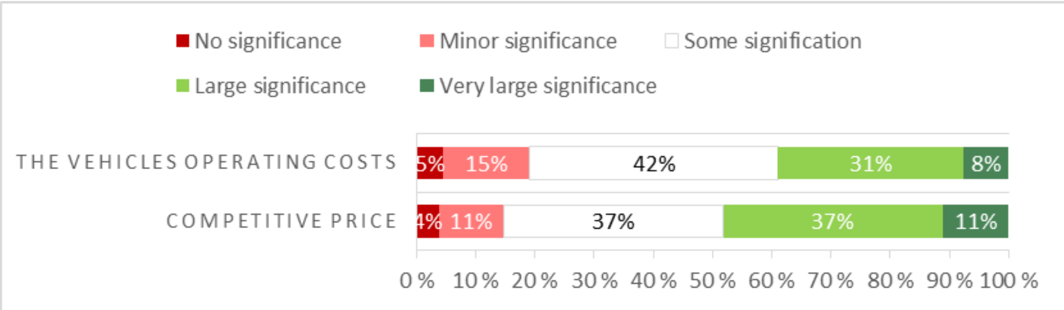


Figure 6.9 Degree of importance of factors and incentives related to buying a new vehicles, as seen by ICE vehicle owners (NAF-members) in Oslo-Kongsberg region (n = 2 241). Percent. Source: Figenbaum, Kolbenstvedt and Elvebakk 2014.

6.6.2 The economy of purchase incentives

The value added tax (VAT) has a flat rate of 25% in Norway and is imposed on all ICE vehicles including all types of hybrids, whereas BEVs and FCEVs are exempted.

The registration tax is progressive. It is the sum of the tax on four elements, weight, engine power, CO_2-emission and NO_X emission, as shown in figure 6.10. In addition, a scrap fee applies to all vehicles. The CO_2 tax is negative below 105 g per km, the others always positive. If the sum of the four elements is negative, the tax is set at the minimum level, the scrap fee of 2 400 NOK.

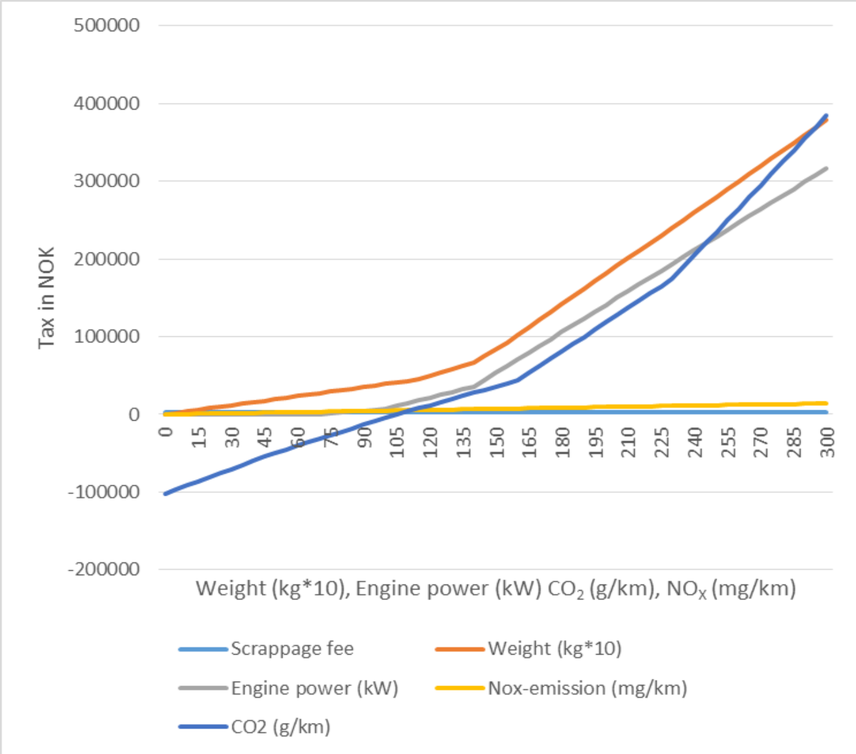


Figure 6.10 Registration tax system in Norway 2015: The total tax is the sum of the four partial taxes on curb weight (kg), CO_2-emission (g per km), NO_X-emission (mg per km), engine power (kW) and scrape fee. Sum of taxes cannot be negative. 2014 currency rate: 1€=8.35 NOK, Source: Fridstrøm and Alfsen 2014.

For a compact ICE vehicle competing with the Nissan Leaf compact BEV, the registration tax is typically around 5 000-10 000 Euros. For hybrid vehicles, the tax would also be close to zero. Hybrids are, however, more expensive at the outset leading to a higher VAT sum. The sum of the VAT and the registration tax can thus be 10 000-15 000 Euros for a compact ICE vehicle and 6 000-10 000 Euros for compact hybrid vehicle and zero for a BEV. Figure 6.11 shows the situation for mini vehicles.

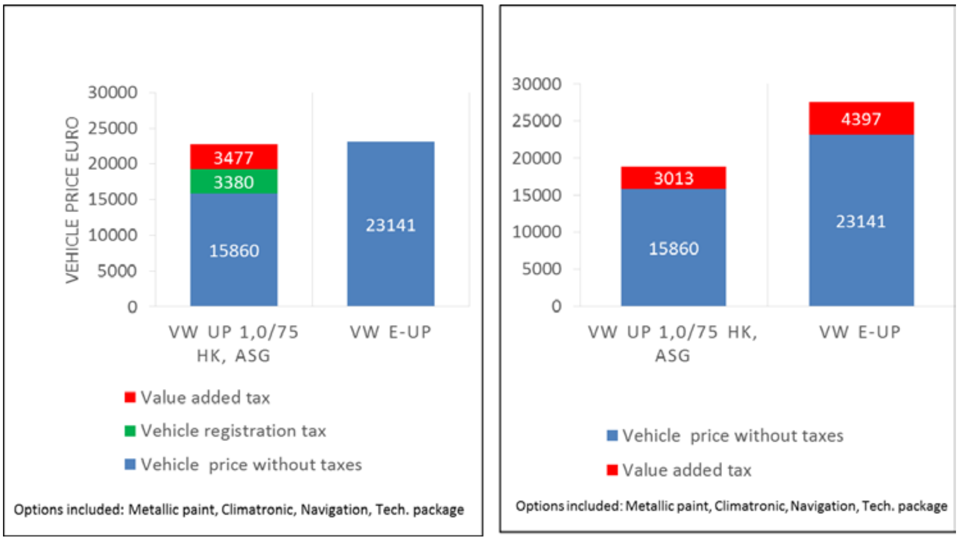


Figure 6.11 Cost of mini BEV (VW E-up vs mini gasoline ICE vehicle (VW Up), with and without taxes in Norway (reg. tax system and 25% VAT) 2014 and typical taxes for other European countries (19% VAT). Euro.

The combined effect of the purchase incentives can be summarized to:

- Small BEVs are about as expensive as ICE-vehicles
- Compact BEVs are slightly less expensive than comparable ICE-vehicles
- Large BEVs (Tesla Model S) are about as expensive as large ICEs
- Luxury (Tesla Model S) BEVs are much cheaper than luxury ICEs.

Tesla Model S is attracting customers both in the large vehicle and luxury vehicle segments, and hence used as example vehicle in both categories.

The Norwegian tax system may not be transferable to other countries. However, introducing a bonus/malus system that in essence could function in a similar fashion could be possible.

6.6.3 The economy of local incentives

Norwegian BEV owners have identified the value of the various local user benefits they enjoy when using their BEVs. The annual average economic value of the incentives for the average BEV driver sums up to about €1,900 per vehicle per year, see table 6.6. The calculation is based on the user survey of BEV owners in WP4. The responses to questions about the frequency of use of the incentives and their estimated value in money or time saving were used in the calculation (Figenbaum et al., 2014).

Table 6.6 BEV Users' average perceived value of incentives. Euro per year. Source: Figenbaum, Kolbenstvedt and Elvebakk 2014.

Incentive	Value per BEV, € per year
Bus lane access	940
Toll-road exemption	434
Free parking	398
Ferry rebate	145
Total	1 928

There are large regional differences in the advantages, and relatively few BEV owners enjoy many incentives, see figure 6.12 for a comparison of the Oslo-Kongsberg area with Bergen and surrounding areas on the west coast of Norway. Bus-lane access is, for example, only important in the larger urban areas, where resulting time savings are large. Reduced ferry fares are important on the west coast. The various BEV incentives thus address different contextual situations and needs (Figenbaum, Kolbenstvedt and Elvebakk 2014).

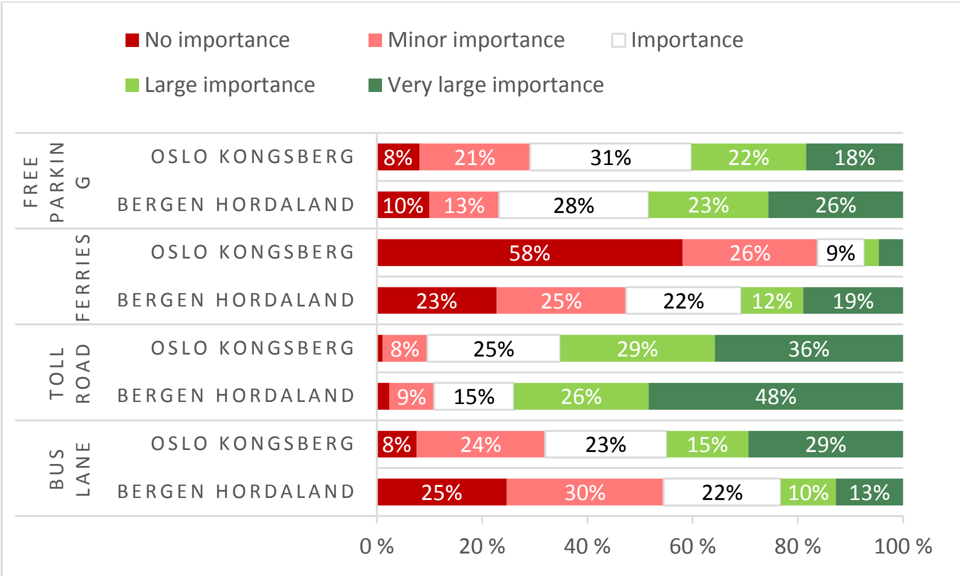


Figure 6.12 Degree of importance of incentives for EV owners in Oslo-Kongsberg region (n = 542) and Bergen-Hordaland region (n = 211) respectively. Source: Figenbaum, Kolbenstvedt and Elvebakk 2014.

6.6.4 Low operative cost

Low operative cost is the main asset of BEVs to private consumers in all European countries, especially in those without purchase incentives. The estimated savings per year of using a BEV are shown for European countries in figure 6.13. The savings are large for the countries with expensive liquid fuels and cheap electricity in the left side of the figure, and largest in Norway, the only country with savings above 1000 Euro per year. Germany has moderate fuel prices and high electricity prices leading to the lowest saving in Europe followed by Denmark and Spain, all three below 400 Euros per year. In most countries the savings are 500-700 Euros per year with EU average 600 being Euros per year.

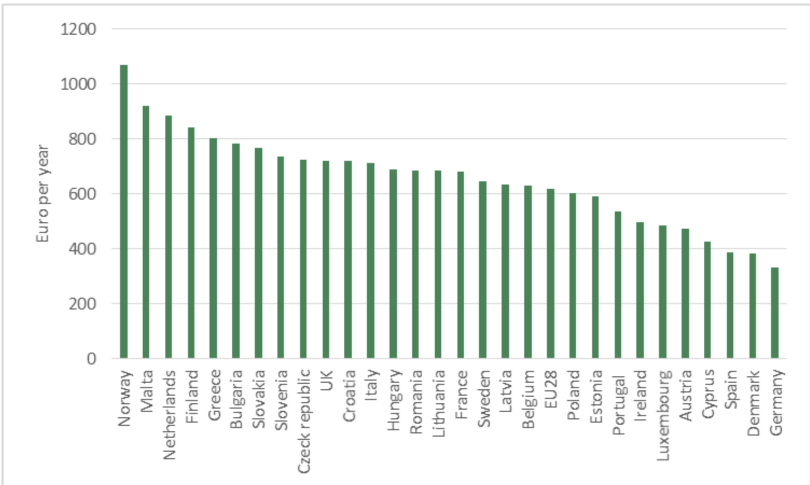


Figure 6.13 Savings per year of using a BEV instead of a gasoline vehicle. Euros. Assumptions: 0.2kWh per km, 0.06 l per km, 15000 km. Sources gasoline and electricity prices: Eurostat, Statistics Norway,

6.7 The buying process

6.7.1 The customer – dealer interaction

As mentioned, 80% of BEVs in Norway are bought and owned by consumers, see figure 4.3. Some of the remaining 20% are leased vehicles, which end up being used by consumers. In most other countries, the share of consumers buying and owning BEVs is low. The process of sales to consumers is different from that of sales to fleets. The latter would be a result of a tender process, the former the result of a negotiation between a sales person at a dealer and the consumer.

The purchase of a vehicle is a transaction where the salesperson and dealer earn more money if the deal is closed quickly, spending as little time as possible in the sales process. Being a new technology, requiring user practises to change, BEVs may require a larger effort from the seller. In addition, more time may be needed when writing the contract and handling over the vehicle.

In Norway, the sales process seems to run smoothly. On average, 85% of the buyers are satisfied with the information from the dealer fitting with the vehicle functions in practice. Tesla owners are the most satisfied, with 10% even reporting that the dealer undersold the vehicle, i.e. it being better than the dealer said (Figenbaum et al., 2014). Most of these owners said the acceleration and driving comfort were better than expected. The majority of the 15% that complained about the dealer information were dissatisfied with the information about range. The Norwegian EV and car owner associations (NEVA and NAF 2015) have produced a leaflet containing purchase information about the range the BEV buyers can expect in real traffic, to address this issue. Shown in figure 6.14, the information is consistent with the information that dealers give to their customers, as the car importers have guidelines containing about the same information on range. Some dealers even require the customer to sign a document explaining what range to expect when using the vehicle under different driving conditions.

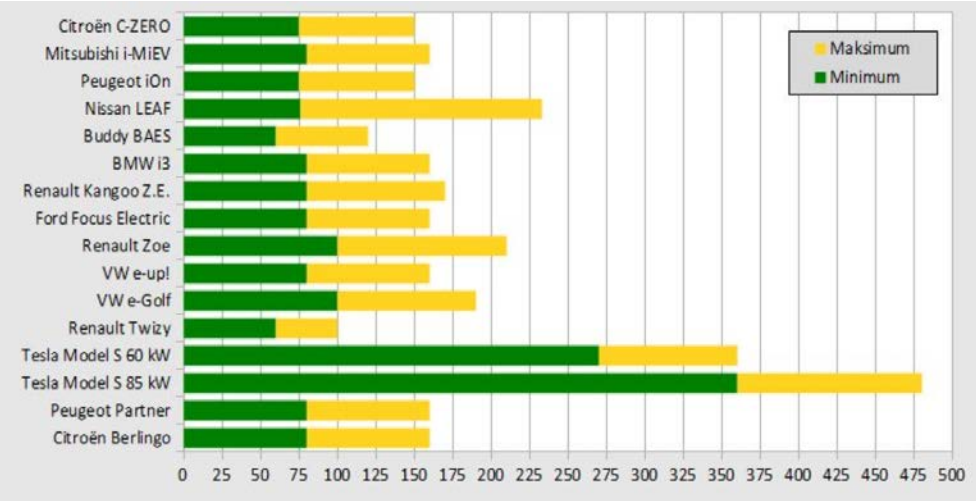


Figure 6.14 Range in km for EVs in Norway. Green colour is the minimum range in winter; yellow the maximum range in summer. Information in leaflet made by NEVA and NAF , Source NEVA (2015).

The BEV sales person's job has also been easy in Norway as 88% of the BEV buyers had their mind made up before going to the dealer (Figenbaum, Kolbenstvedt and Elvebakk 2014). Dealers report that it takes approximately the same time to sell a BEV as it does to sell an ICE vehicle (Assum, Kolbenstvedt and Figenbaum 2014).

However, the time spent handing the vehicle over to the customer can be slightly longer for EVs, due to the BEV functions that the customer is not used to. Choosing a charging solution and arranging the installation of proper charging equipment can also be a part of the buying process, see chapter 5.5.

In the US, sales representatives are reported to spend three times longer closing an EV sale (BEV or PHEV) than closing the sale of an ICE vehicle (NRC 2013). The willingness to market BEVs efficiently may be significantly influenced by this issue, making it a barrier to BEV adoption at least in countries with few incentives.

The effects of incentives could be threefold. Firstly, incentives will make more people interested in the new technology before going to the dealer. Secondly, the sales person at the dealer's will have more arguments for the sales pitch. Thirdly, enticing customers in the shop to look at EVs as an alternative, will be easier.

6.7.2 Other sources of information – social networks

The media have been the most important source of initial information about BEVs, see figure 6.15. Social networks, such as friends and family, are more important sources of information than dealers are. Responding to the question: Where did you first get the information that prompted you to buy a BEV? (more than one alternative could be selected), 77% answered media, 28% friends and family, 13% the dealer, 6% organisations and 13% other (Figenbaum, Kolbenstvedt and Elvebakk 2014). Information from friends and family have a much higher value in diffusion processes as people treat such information as much more trustworthy than information from other sources.

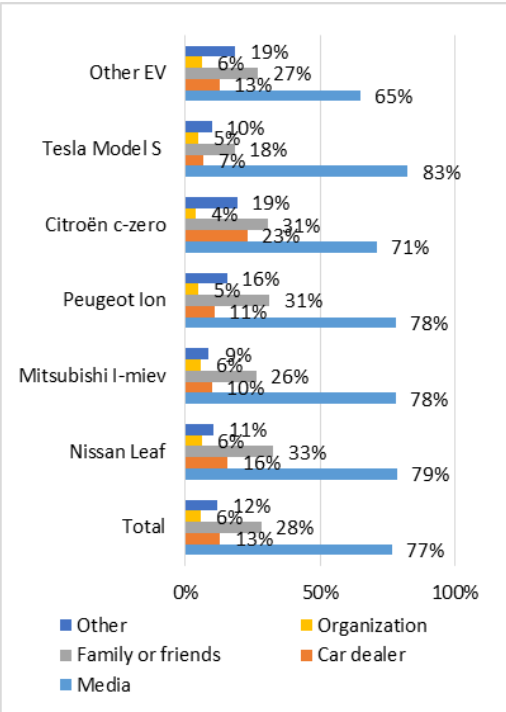


Figure 6.15 Where BEV owners got information before they bought their vehicle by brand. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

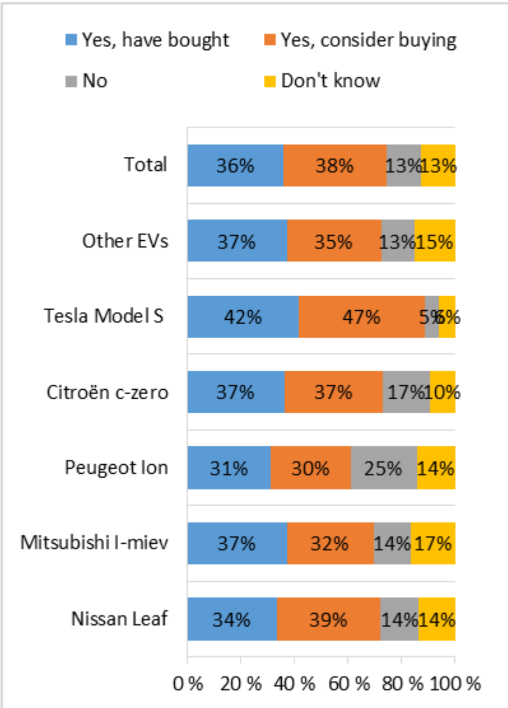


Figure 6.16 Share of BEV owners having friends who have bought or consider buying an EV after them by brand. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

When asked if they have friends who have bought BEVs after they had told them about their EV experience, 36% said yes and further 38% said that they now had friends considering buying an EV. The share of ICE vehicle owners considering a BEV next time is higher among those who have friends with EVs than among average car owners (44% vs 30%). The results are similar for all BEV types with Tesla buyers influencing more friends, see figure 6.16.

The same is found in Austria where 40% of the EV owners would recommend purchasing a BEV to their friends. (Jellinek, Emmerling and Pfaffenbichler 2015). EV owners are thus ambassadors for electromobility. This "neighbourhood effect" is likely to be important when consumers are buyers, and the technology is new (Assum et al., 2014). However, the share of consumers owning BEVs in other European countries will grow, when the early adopting fleet operators replace their EVs, and sell the old ones.

6.7.3 Why BEV owners buy a BEV again

Of the BEV owners in Norway 87% say they will buy a BEV again (Figenbaum, Kolbenstvedt and Elvebakk 2014). Only 1% say they will not, with the rest undecided. The most important motives for buying a BEV again are economy followed by the environment and that it is the best type of car for the owner's needs, see figure 6.17.

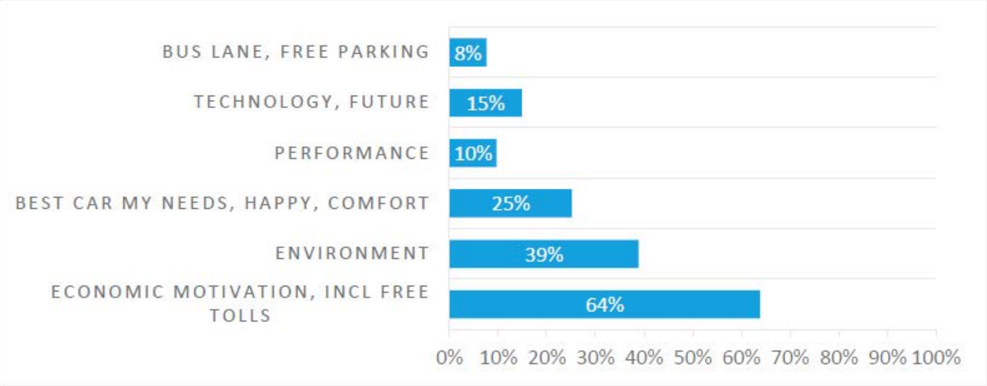


Figure 6.17 The most important factors for buying a BEV again. BEV owners in Norway 2014. Source: Figenbaum, Elvebakk and Kolbenstvedt (2014).

6.8 Findings on buying and using electric vehicles

Motives for buying

- Of the BEV buyers in Norway 80% are consumers. The share of consumers buying BEVs is increasing in other European countries
- Of the BEV owners 81% find low operating costs to be the most important reason for buying an EV
- Both BEV (68%) and ICE (72%) owners bought their car because it was "*The best car for their needs*"
- The vehicle's environmental characteristics are important for BEV owners (64%), but not for ICE owners (25%)
- Of the BEV buyers in Norway 85% are satisfied with the information provided by the dealer, and dealers provide an honest picture of the vehicle's range.

Residual values

- Residual value of BEVs and PHEVs have been established in Norway
- The biggest part of the value loss is associated with falling new BEV prices
- The residual value of BEVs in percentage of new vehicle price is 10-15% lower after 3 years than for ICEs
- The actual loss in NOK over 3 years of the lower priced compact BEVs is comparable to that of ICEs in Norway thanks to the purchase incentives.

Differences between households

- Multi-vehicle households will be better off economically with a BEV than with a PHEV
- Multi-vehicle households have higher incomes and can more easily absorb the extra cost of plug-in vehicles than single-vehicle households can.

Importance of incentives

- Incentives are needed to speed up diffusion, but they must be tailored to meet user needs, making the product competitive and/or provide buyers with relative advantages over ICE vehicles
- Purchase incentives are more important than user incentives in stimulating sales.

7 Societal processes supporting diffusion

Electromobility consists of a complete socio-technical system (regime) consisting of vehicles, infrastructure, energy supply, regulations, standards and the actors involved in developing, distributing, installing, selling and servicing these items as well as the users driving them and the practices being established.

COMPETT has investigated the societal processes leading to the diffusion of BEVs in Norway using two different approaches. The first approach, the Multi-Level Perspective (MLP) framework developed by Geels, Dudley and Kemp (2012), aims at understanding the processes that leads to efficient BEV policies and the way incentives are introduced. The other approach uses the theory of diffusion of innovations developed by Rogers (1962, 1995), to investigate how, why and how fast BEVs diffuse in the population.

The diffusion of BEVs in Norway has advanced further than in any other country in the world, a fact making these analyses particularly interesting. Denmark and Austria are early in the diffusion process. Denmark has incentives in place, but their future is debated. Austria does not have many incentives, and the policies are directed at early testing, experiments and awareness raising in "model regions" receiving government funding for the activities.

7.1 Processes at three interactive levels

The MLP framework (Geels 2012) is based on the premise that transitions in society are a result of the interplay of various developments at three analytical levels: 1) Niches of usage where innovations can be tested, 2) The regime of established practices and rules and 3) An exogenous framing landscape. The levels coexist in a hierarchy of stability, where the niches attempt to infiltrate the more stable regime, which in turn is embedded in the landscape. Due to the MLP's non-linear form and its heuristic nature, it requires the analyst to use their cognitive faculty in order to appreciate the multifaceted issues and questions that arise from the MLP.

Figure 7.1 provides an ideal-typical representation of the way the three levels interact dynamically in the unfolding of socio-technical transitions. Although each transition is unique, the general dynamic is that transitions come about through the interaction between processes at different levels:

1. Niche-innovations build up internal momentum,
2. Changes at the landscape level create pressure on the regime, and
3. Destabilisation of the regime *creates windows of opportunity* for niche-innovations (Geels 2012).

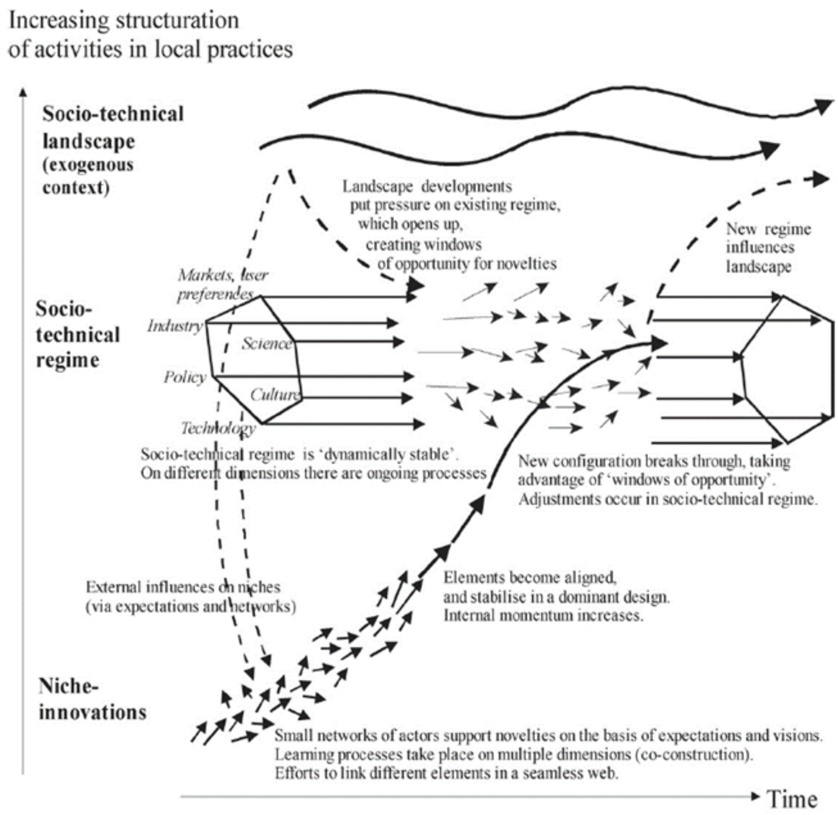


Figure 7.1 Multi-level perspective on transitions. Source: Geels 2012.

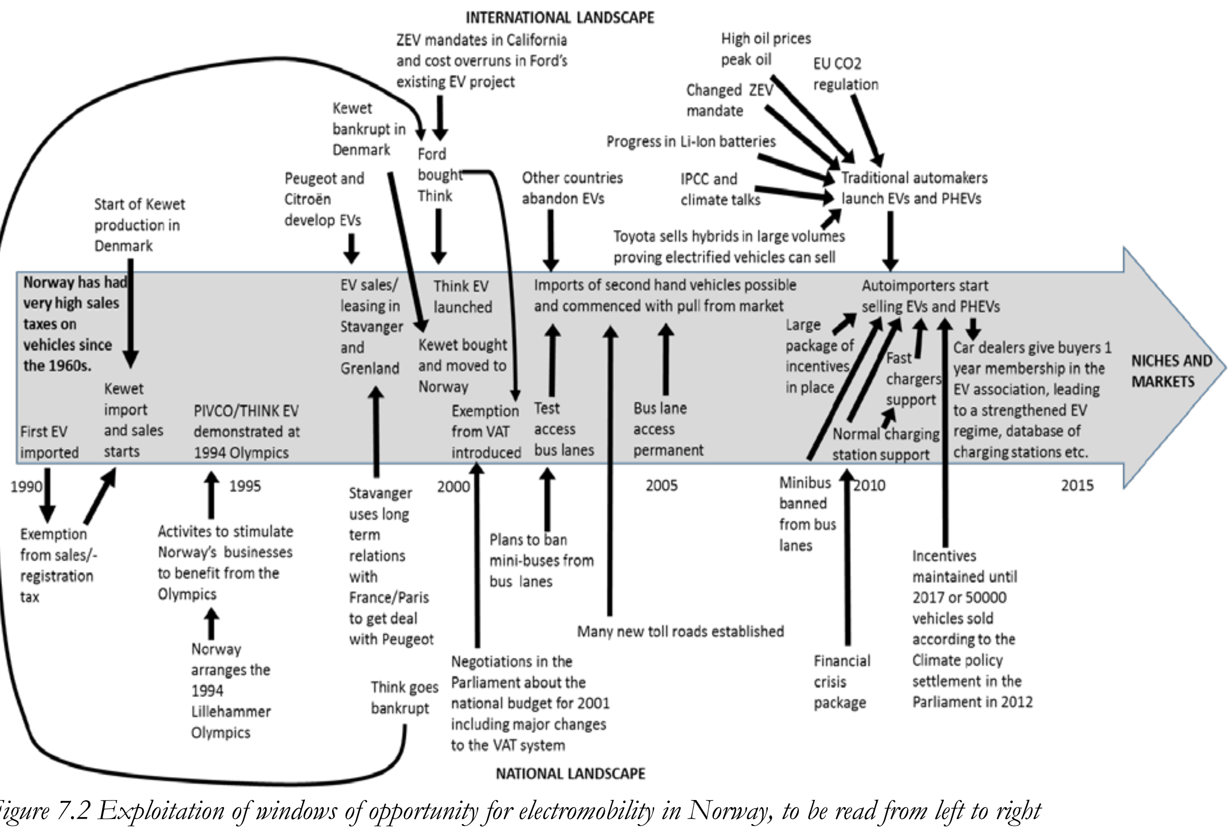


Figure 7.2 Exploitation of windows of opportunity for electromobility in Norway, to be read from left to right as a chain of events. Arrows indicating opportunities arising from previous events. Source: Figenbaum and Kolbenstvedt 2015.

The success of BEVs in Norway seems to be a result of the long-term, stable political framework built up piece by piece by many actors and stakeholders (Figenbaum and Kolbenstvedt 2015). The BEV policies were found to become strong because of outspokenly positive politicians, a weak ICE regime, the early establishment and endurance of a BEV regime, efforts to establish a Norwegian BEV industry and a lack of counterforces. In addition, many windows of opportunity opened up, enabling stakeholders to lobby for large incentives over the years as seen in figure 7.2. Heavy vehicle taxes have given room for tax reduction incentives rather than direct subsidies. The incentives remained in place over a very long period with low BEV sales, a situation keeping the cost of incentives low. Over the years, this situation has grown into a stable framework.

The framing of the policies has evolved from first allowing the testing of BEVs, then to support industrial development, and finally the BEV policy was framed as a climate mitigation measure, a situation leading to higher acceptability for the policies, in line with Geels, Dudley and Kemp (2012). The lack of vehicle production in Norway means that the ICE regime actors are not affected much by which vehicle type they sell, although the dealers' workshops may have less work as BEVs have less maintenance requirements. The car manufacturers in the international landscape (in the Norwegian case) may however fear losing sales of their existing products, as the consumers buy BEVs instead of ICEs.

Vehicles were supplied by small independent actors in limited numbers and only in some areas up to 2010. These vehicles were expensive and rather basic. In 2010/11, the traditional auto-importers could take advantage of the large package of incentives fought for during two decades by the independent EV regime actors. They applied all their experiences, resources and competences into launching a number of BEV models into the Norwegian market. Suddenly BEVs became available all over Norway in unlimited numbers, with a very attractive package of incentives to stimulate the sales process. Sales took off as new models came into the market, reaching an unprecedented 20% market share in quarter 1 2015.

A proposed general multi-level perspective (MLP) model for the BEV market development in Norway is shown in figure 7.3. The relevant activities at the landscape, regime and market levels are summed up. Further details are found in Figenbaum and Kolbenstvedt (2015). The BEV activities in the Norwegian market must also be seen in relation to attempts to establish biofuel, PHEV and FCEV regimes in the same period (Figenbaum and Kolbenstvedt 2015). From 2010, a BEV regime emerged inside the ICE regime, but merging with the independent BEV regime actors presented earlier. The result is a substantially strengthened BEV regime. PHEVs have suffered from lack of incentives, but also from few models being available. Since 2014, the sales of PHEVs have been progressing steadily, and a more stable PHEV regime is now being established supported by larger incentives and more models that are attractive. The hydrogen and biofuels regimes have suffered setbacks during the latest years in Norway. Large industrial actors have given up their hydrogen efforts, and a tax on biofuels has been introduced.

The MLP model has been proven useful in explaining the dynamics of the policy framework and the introduction of incentives, the actors responding to or influencing this framework, and consumers gradually picking up BEVs at the dealers. It also demonstrates the way the long BEV history in Norway gave the traditional car manufacturers a head start in the Norwegian market as they established a new BEV regime within the ICE regime system. This new regime could utilize the effects of all the results built up by the independent BEV regime over a period of two decades. The success of BEVs in Norway is thus the result of a long chain of events and opportunities that could be exploited. Other countries can be inspired by Norway, but may need to follow other paths as different windows of opportunity open up.

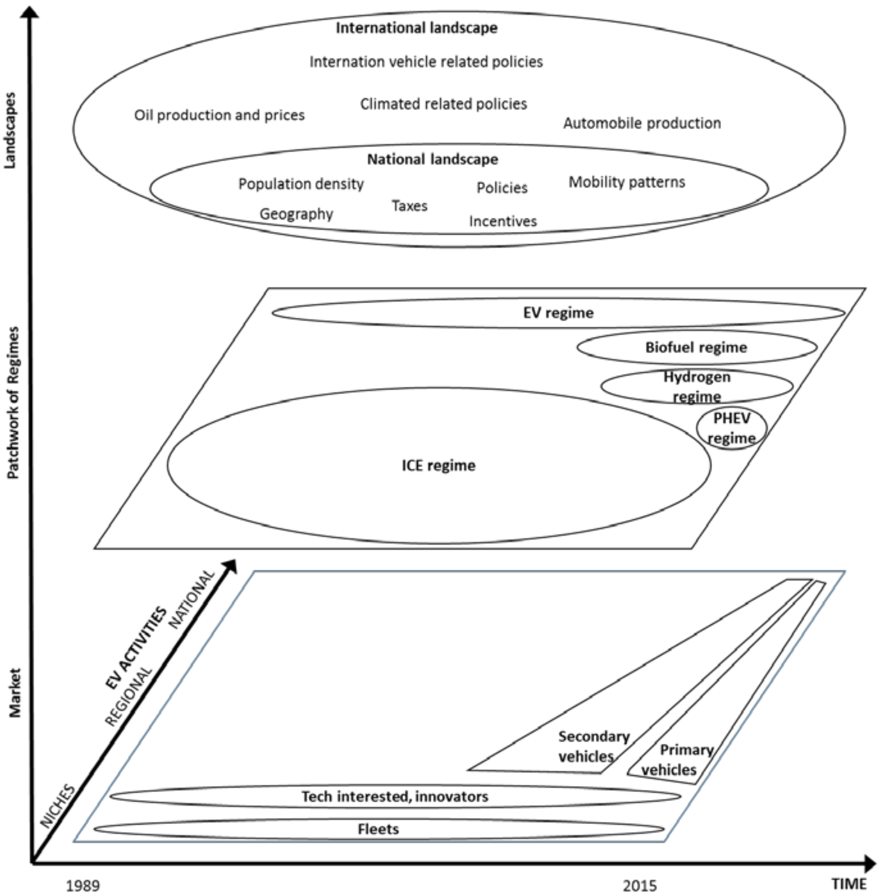


Figure 7.3 Multi-level perspective framework for analysing electromobility in Norway. Source: Figenbaum and Kolbenstvedt 2015 (Adapted from Geels 2012).

The BEV privileges in the Norwegian policy framework may have suboptimal effects. The future may consist of fragmented markets with multiple dominant designs, i.e. BEVs for short-distance travels, for cities, and FCEVs and PHEVs for longer distance travel, and biofuels for heavy-duty vehicles. Too much focus on BEVs could lead to a risk that other options are not developed. It should however be noted that all BEV incentives also apply to FCEVs, and that PHEVs are taxed less than ICE vehicles.

Using the classification of Geels and Schot (2007), the BEV diffusion seems to be on a *transformation path* internationally, where moderate pressure on the ICE regime from CO_2 regulations and incentives in some countries lead to a gradual establishment of a BEV regime. The BEV regime grows out of the old regime through a reorientation of the propulsion system of automobiles while keeping other basic vehicle features unchanged. In Norway, the policies and pressure from the landscape have been much larger, leading towards a "*technological substitution path*".

The competitiveness of other technologies and the ability to provide incentives for these technologies have been hampered by the strong BEV regime in Norway. An example is the limited incentives available to PHEVs. The difference between the technologies can be considered a result of the strength of the perennial BEV regime and its ability to influence politicians, but also the political uncertainty about how technologies that can be used in more or less environmentally friendly manners will be used in practice. A PHEV can operate either with a large percentage of driving in electric mode using electricity recharged from the grid, or as a hybrid vehicle using gasoline or diesel.

7.2 The diffusion in the population

The theory of diffusion of innovations developed by Rogers (1962, 1995), seeing diffusion as a social process, has been used as the main theoretical baseline for explaining the development of the market and the rate of diffusion of BEVs in Norway. In addition, newer theorists like Axsen and Kurani (2012, 2013) emphasise that technology diffusion processes take place within a social system. They add important aspects concerning the importance of interpersonal relationships. Crucial factors involved in the way the new technology can meet the user needs, are shown in figure 7.4. The users must be seen in a wider sense, from individuals to decision makers at different levels and sectors.

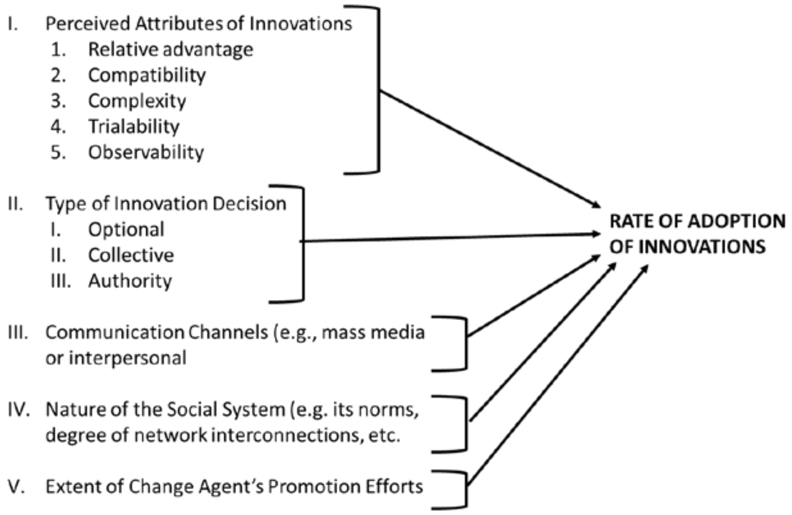


Figure 7.4 Factors in the diffusion process that influence the rate of adoption. Source: Rogers 1995.

The technology itself, its characteristics and ability to meet user needs, and the ability to change the technology during the process to avoid possible weaknesses, are the key elements of diffusion. The rate of diffusion (Rogers 1995) is influenced by the perception of technology with respect to:

- The *relative advantages* of the innovation related to other technologies, can be financial, practical, environmental and personal, giving social status or satisfaction. Examples are economic profitability, low initial cost, and improved comfort, saving time or effort, immediacy of reward.
- The *compatibility* with the users' needs, basic values and norms in the social system. The more radical and disruptive the technology and the less its compatibility with existing practises, norms and values, the slower will its rate of adoption be.

- The *complexity* conceives how easy it is to understand and put the technology to use, and its ability and flexibility to accommodate more opportunities. The more complex the innovation, the lower the adoption rate is.
- The *trialability* applies to the opportunity for trial. Innovations that can be tried out in a small scale are perceived as less uncertain and easier to implement than those requiring full implementation immediately. Trialability is more important for early than for later adopters. The latter will be helped by information from adopting peers.
- The *observability/visibility* for new users can increase the speed of implementation. This factor stresses the importance of network communication and the strategy for launching the product.

Incentives to speed up BEV adoption should address these factors, especially the first one, relative advantage. This factor is the most influential in the diffusion process when prospective BEV buyers consider the benefits and costs of taking BEVs into use. Some factors influencing relative advantage and the importance of incentives are shown in table 7.1. See also table 6.4. The incentives turn BEV ownership into an advantage already for the first owner of the vehicle, thus being the key to the BEV success story in Norway.

Table 7.1 Elements of relative advantage. Assessment of first owners' evaluation of the potential of each element without and with the Norwegian BEV incentives. Source: Figenbaum and Kolbenstvedt (2015)

Factors in assessing relative advantage	**Without incentives**	**With Norwegian incentives**
Economic profitability	Vehicles are too expensive and expected second-hand value after 3-5 years is low. Total cost of ownership over lifetime may be positive through lower energy costs.	Profitable for first owner, but the risk of second-hand value still relevant. Vehicles bought 2010-11 have potentially been unprofitable due to the rapid falling new-vehicle prices depending on usage of incentives.
Low initial cost	BEVs are more expensive than ICEs. Value added tax on top expands the cost gap.	Equalize the price in smaller vehicle segments. BEVs are cheaper than ICE vehicles for larger vehicles
A decrease in discomfort	Discomfort due to range limitations although many users' driving needs are compatible with range limits. Need to plan better Not available with 4-wheel drive	User advantages result in increased comfort. BEVs are in accordance with societal environmental goals. People can afford buying them. Concerns of second-hand value are reduced as the owner potentially saves more each year by low operative costs and incentives than what is risked. Not available with 4-wheel drive. Need more planning.
A saving of time and effort	More efforts needed, i.e. planning the transport, range challenges, time to plug in the vehicle, borrowing vehicles when needed.	The effort of planning is reduced by time saved using bus lanes and less time to finding parking. Vehicles are cheap enough to be used by multi-vehicle households being capable of handling range challenges.
Immediacy of reward	Not possible for first owner, the vehicle is too expensive and the savings per year too low, and the second hand value uncertain.	Time and cost savings from day one are achieved with low energy costs, low annual tax and free of charge toll roads, reduced ferry fares, free parking and access to bus lanes
Social Prestige	Teslas and BWM i3s give prestige, but basic BEVs may have such poor value proposition that prestige could be negative?	Possible for everyone to buy a BEV, democratizing BEV diffusion, but also reducing social prestige.
Environmental standing in the population	Not a dominating motive initially in Norway, but important for some. May be an important motive in countries earlier in the diffusion phase.	Increasing as a motive after buying BEVs. A possible negative factor is that it becomes easier (morally) to justify buying a second household car.

7.3 Regional diffusion

Technologies are expected to diffuse out radially from initial user areas that are not interconnected. Eventually the areas grow together into larger zones and finally the whole country, see figure 7.5. In addition to the diffusion in the market, there must also be a parallel diffusion in the vehicle industry leading to a larger selection of vehicles in more segments.

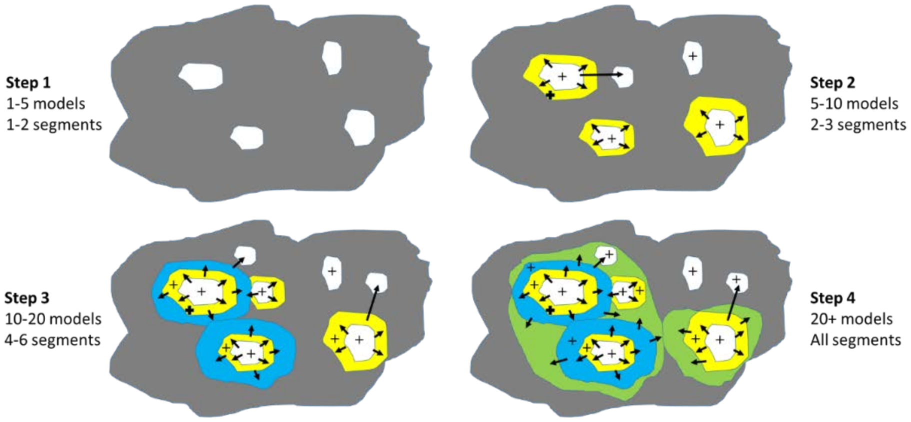


Figure 7.5 Expected pattern of market diffusion, the first four steps taken into account. White are initial areas, + signs illustrate a deeper diffusion within areas where BEVs have been taken into use. Arrows mark diffusion to new areas with increasing distance to the original areas with yellow, blue and green colour. Source: Figenbaum and Kolbenstvedt 2015.

After 2010, the diffusion of BEVs started in cities and their neighbouring municipalities, and spread further out radially. An increase in the adoption rate has also occurred within each municipality, see figures 7.6. and 7.7. Municipalities with expensive toll roads, such as Finnøy, the first municipality with more than 10% adoption and where owners save up to 30 000 NOK per year, were a second group of early adopters.

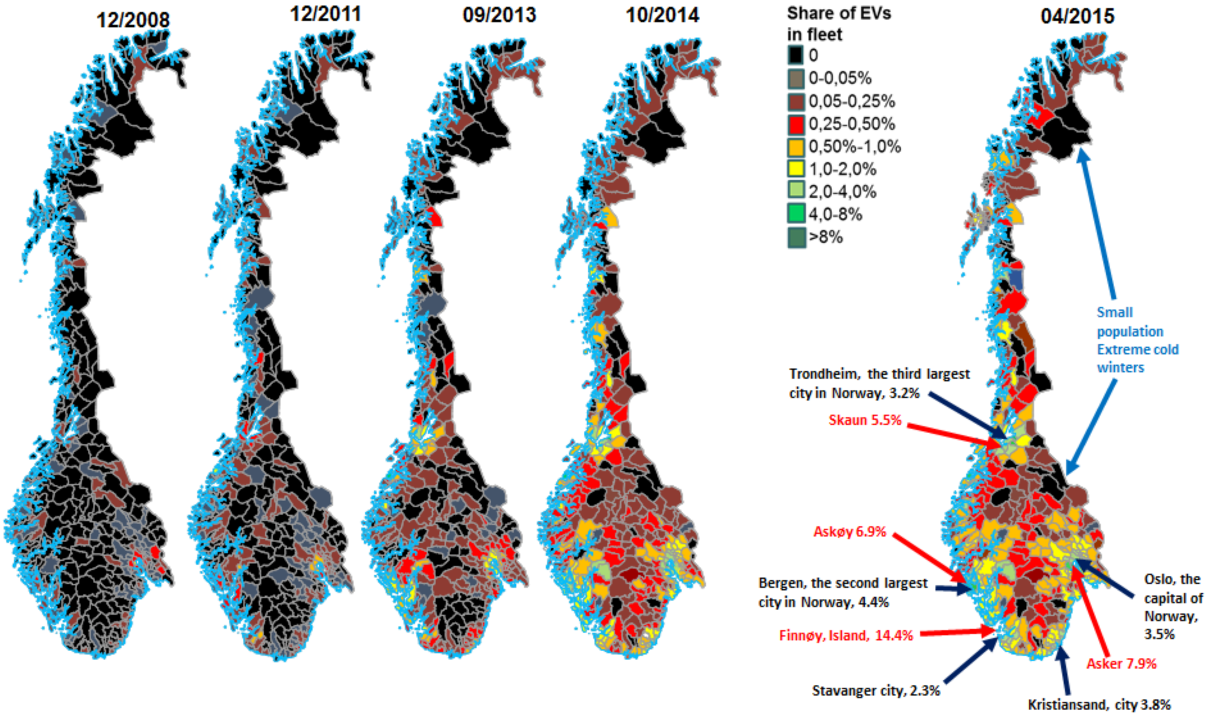


Figure 7.6 Geographical diffusion of BEVs in Norway's 428 municipalities 2008-2015. Share of BEV in total fleet in different points in time. BEV and total fleet data from the Norwegian Public Roads Administration and the EV association, OFVAS 2015, Statistics Norway 2015.

The number of municipalities without BEVs has gone down dramatically over the years. Only 10% of the municipalities had no BEV registered in April 2015, see figure 7.6 (municipalities in black colour). In 2008, no municipalities had more than 2% BEVs in the fleet. In April 2015, this share was 15%. The largest adoption rate is typically not within the city, but in a neighbouring municipality where owners have better parking availability at home and more benefit from incentives, see figure 7.7.

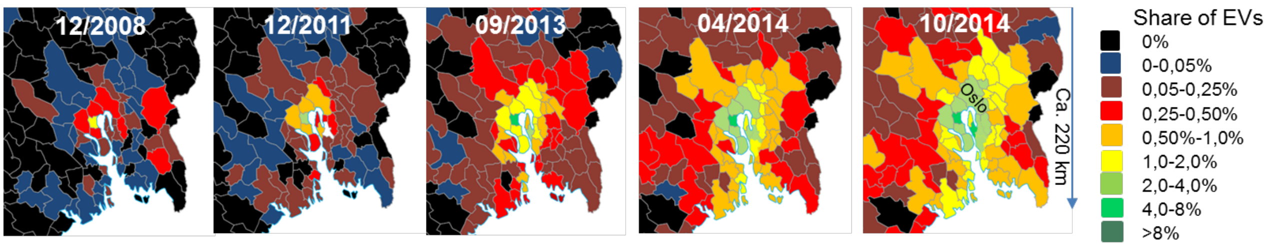


Figure 7.7 The change in BEV density (share of BEVs of total fleet) of the municipalities in the greater Oslo region in different points in time. Percent of total fleet. BEV and total fleet data from the Norwegian Public Roads Administration and the EV association, OFVAS 2015, Statistics Norway 2015.

The expansion in the fleet between 2011 and 2015 must be seen in relation to the substantial decrease in the purchase price of BEVs, see figure 3.1 and the expansion of the number of available BEV models in the market as well as the "neighbour effect" becoming stronger.

The general tendency is, contrary to intuition, that the sales volume of the existing models remains the same when new models enter the market, significantly contributing to the rapid diffusion of EVs in Norway. Nissan has (Assum, Kolbenstvedt and Figenbaum 2015) a high percentage of conquest vehicle sales (customers who previously had vehicles from other brands) that seem to hold even when competitors enter the market, see figure 7.8.

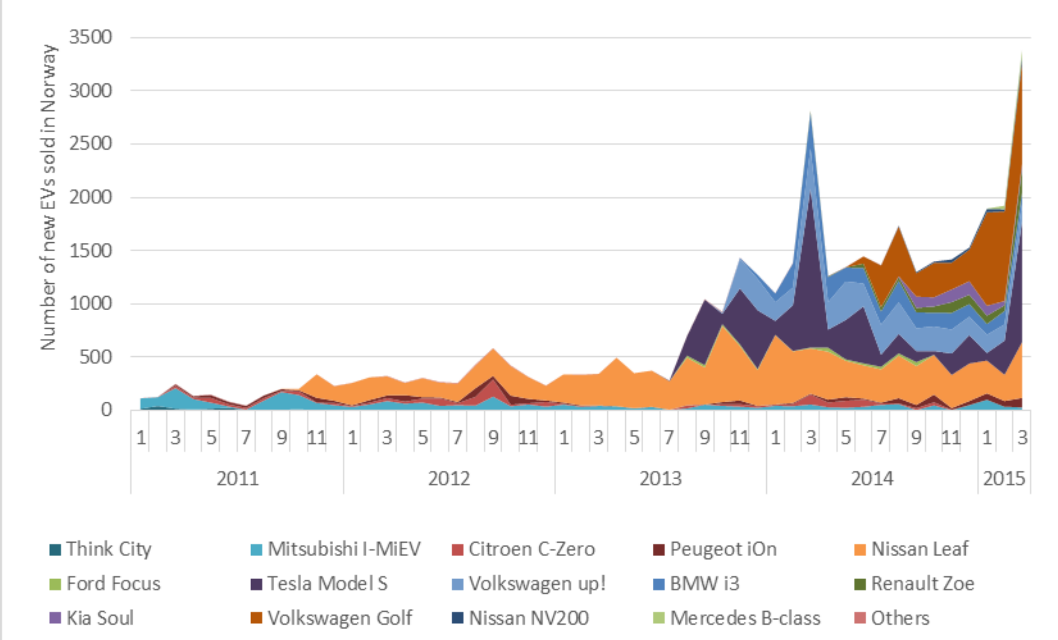


Figure 7.8 EV sales of models sold per year and month. Source: Figenbaum and Kolbenstvedt (2015), OFVAS (2012-2015).

7.4 Possible unintended consequences

Large incentives are efficient in making the diffusion speed up, but there is the risk that the market will not be sustainable once they are removed. When the technology itself becomes cheaper and more competitive over time, a gradual decrease in incentives should be possible. In the automotive sector, technological steps are typically related to changing model generations every five years, whereas prices are adjusted continuously to adapt to market conditions. These factors combined tell us that incentives need to be in place for a long time in order to achieve full effectiveness. Replacing all vehicles of the existing fleet will in addition take some 20 years.

It is important to have a strategy to meet unintended consequences. Electromobility can be seen as a type of support to vehicle based transportation competing with public transport, cycling and walking. To get the diffusion of BEVs started, cities should be targeted due to higher visibility, higher share of innovators and reduced cost and more environmental benefits (less local pollution). However, they should not be targeted out of concern for a risk of increase in vehicle-based traffic causing more congestion in the cities. Although this is a dilemma, the diffusion pattern shows that BEVs spread to rural areas from the cities, where these conflicts are less apparent, suggesting that the issue is temporary.

The improved technology and reduced costs, combined with the incentives, have resulted in Norwegian BEV buyers experiencing that BEVs have many relative advantages over ICE vehicles. The limited range does not seem to be an obstacle to adoption. The rewards are immediate as BEVs cost the same or less than ICEs. Their operative costs are lower due to their energy efficiency, an advantage that is available from day 1. Hence, one may claim that BEVs are both climate friendly and low variable cost vehicles, suitable for daily travel needs.

There is potential for future growth supported by diffusion through interpersonal networks and the increased availability of longer-range models attracting new customer groups. Further expansion probably requires the availability of BEVs in the SUV and medium-sized vehicle segments as well as a broader selection of models in the other segments.

In 2015 to 2016, a large number of PHEV models will be launched into the same segments as some of the BEV models[2], possibly causing some potential buyers to opt for PHEVs despite the incentives for PHEVs being few. The company and public-body fleet markets are underdeveloped. These markets should grow more quickly in the future as fleet owners get used to BEVs being available and able to meet transportation needs. From July 2015, leased EVs will be exempted from VAT further supporting an expansion of the fleet market (Ministry of Finance: National budget 2015).

The diffusion of BEVs in Norway closely resembles what is expected from diffusion theory. An achievement of the BEV policy is that national, regional and local governments, businesses and NGOs have been motivated to move in the same direction through a long-term stable framework. The risks facing buyers and actors have been compensated for by incentives.

The future rate of diffusion will be heavily influenced by possible modifications to the societal and economic framework and cooperation. The Norwegian BEV market is, however, dependent on other automotive markets. If diffusion does not catch on globally or in Europe, the diffusion of BEVs in Norway may slow down, because the expected reduction is prices and increase in models will be slow or not happen at all.

7.5 Findings on societal processes

The two diffusion research perspectives presented complement each other. They provide a good understanding of the way the BEV policies in Norway came into being and the way they have influenced the market actors and the vehicle buyers.

The BEV policy has consistently been pro BEV in Norway, indicating to users that the technology is compatible with societal needs, although the reasoning has changed. Other competing options such as biofuels have been more debated. The positive BEV communication in Norway may have inspired a greater share of vehicle owners to consider buying a BEV, compared to other countries where the communication seems to be more ambivalent. Even the media in Norway are mostly neutral or have a positive attitude to BEVs, presenting the BEVs based on what they can be used for rather than what they cannot do.

From the experience of BEVs in Norway, it is evident that incentives are needed to speed up diffusion because BEVs are more expensive than ICEs without these incentives. These incentives came about through a series of unique events where stakeholders took advantage of windows of opportunity. Other countries will need to find their own way of supporting BEVs, as other windows of opportunity may

[2] Compact vehicles: Golf GTE, Audi A3 E-tron; Large vehicles: VW Passat GTE, Mercedes C; Large SUVs: BMW X5, Mercedes GLE, Volvo XC90; and several others in these and other segments

appear. They will have their own framework of previous vehicle policies from which they can start.

Incentives that address and improve on the perceived relative advantage of BEVs, from the perspective of the potential buyers, will be the most effective in speeding up the adoption of BEVs. In Norway, the purchase incentives have been particularly effective in speeding up adoption when used in combination with user incentives giving BEV owners a relative advantage that is not available to others. When the price is right, the vehicle buyers see the advantages of BEVs, and BEVs are available in sufficient varieties of makes and models, the diffusion pattern will be similar to that of other innovations. Independent actors and large incentives may have been sufficient to start the diffusion process in Norway, but diffusion did not speed up until the established vehicle manufacturers started selling BEVs, see figure 7.9, and the cost of the vehicles were going down, see figure 3.1.

Globally, electromobility develops rather slowly compared to the rapid changes seen in Norway. This slow development may lead to the costs of vehicles remaining higher for a longer time, as the total volume of BEVs produced will increase at a slower rate than if all countries progressed at Norway's rate. This development could also lead to a slower improvement in technology and a narrower selection of models, as the automakers might delay the introduction of new models. The risk of international setbacks in BEV development is thus the main uncertainty for the future of electromobility in Norway. The other major uncertainty, revision of the incentives, will also have an inevitable impact on sales.

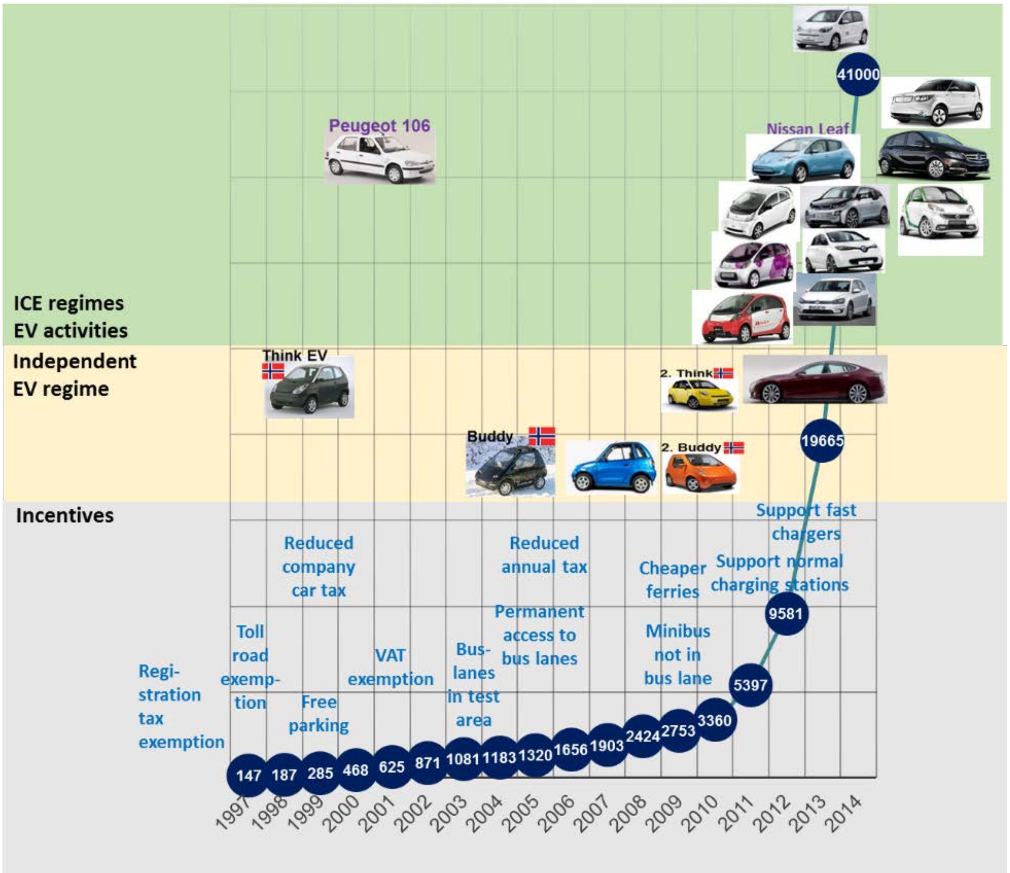


Figure 7.9 The expansion of the BEV fleet in Norway, the timing of introduction of incentives as well as makes and models.

The Norwegian Government White Papers on climate present Norway as a test site, with a global responsibility to test incentives and learn from experiences that can be useful in other countries. Norway may push electromobility even further, potentially succeeding in a transition from ICE domination to having passenger vehicles that predominantly run on electricity much earlier than other countries. As suggested by Geels, Dudley and Kemp (2012), the pressure on the ICE regime must be increased in order to support such a transformation path. This path is feasible now that the alternatives to ICEs exist and expand rapidly. Geels, Dudley and Kemp (2012) also state that a transition policy should be seen as a process lasting five, ten or up to 20 years, requiring leadership, persistence and the ability to deal with unexpected events. So far, there is evidence that Norwegian politicians have had this ability. However, the coming years, when the BEV incentives will have to be downsized gradually, may be more challenging.

8 Societal impacts of electromobility

BEVs are energy efficient, do not pollute or emit CO_2 while used, and are less noisy than ICE vehicles when travelling at low speeds. BEVs are much cheaper to operate than ICE vehicles even in countries such as Germany having a high electricity price, advantages that could potentially lead to increased vehicle usage by owners. The net effect on greenhouse gas emissions of replacing ICE vehicles with BEVs using various types of electricity is subject to discussion, and it is not easy for consumers and policy makers to get a clear picture of these benefits

The effect on greenhouse gas emissions of replacing ICE vehicles with BEVs have not been investigated in the COMPETT project. COMPETT has done research on noise from BEVs. Roadside measurements of noise from BEVs have been carried out, and the impact of noise in cities has been analysed.

Many different types of transnational, national, regional and local electromobility incentives and policies have been taken into use across Europe to support the market introduction of battery electric vehicles. The incentives may be based on taxes, tax exemptions, grants, regulations or organizational measures, leading to several societal impacts, such as burdening public budgets and creating distributional effects in the economy.

8.1 Environmental impacts

Many different methods are used to assess the effects of BEVs on greenhouse gas emissions. Some researchers use life cycle analysis and include the emissions from the production of the vehicles, and some use marginal electricity production as the source of electricity in the calculation. Others use the average EU, regional or national electricity mix, whereas others point to these elements as being unimportant as both the electricity production and vehicle production sectors are within the European Union's greenhouse gas emission trading scheme (EU ETS). Local pollution improvement is easier to estimate, being linked to the tailpipe emissions of ICE vehicles.

8.1.1 Greenhouse gas emissions and energy efficiency

BEVs are typically 2-3 times more energy efficient than ICEs when only looking at the energy consumption of the vehicles, as seen in figure 8.1. Electricity can be produced from all primary energy sources, thereby improving the security of supply of energy for transport. The energy efficiency and the greenhouse gas emissions in the total WTW (Well To Wheel) system will vary widely with electricity sources as can also be seen in figure 8.1.

The total energy efficiency and greenhouse gas emissions from the use of BEVs and PHEVs compared with ICE vehicles also depend on the type of energy used to produce the vehicles. Greenhouse gas emissions from different vehicles are therefore frequently analysed using life cycle analysis. The results will depend on the chosen boundary conditions. Most analyses include the energy consumption and emissions in the production of vehicles and energy carriers, the emissions from the vehicles in the usage phase, as well as the emissions and energy used when recycling vehicles. Normally, the construction of factories that produce the vehicles and energy carriers is left out in order to make the analysis feasible.

These life cycles indicate more emissions from the production of BEVs compared to the production of ICE-vehicles as seen in figure 8.2 comparing the electric Golf with diesel and gasoline versions (VW 2014, an ISO certified life cycle analysis). Life cycle studies from BMW and Mercedes present roughly the same picture (BMW 2013, Daimler AG 2014). However, the emission reduction during the usage phase more than compensates for this increase in emissions and energy consumption in the production phase, leading to a net reduction even when using the average EU electricity mix as also seen in figure 8.2.

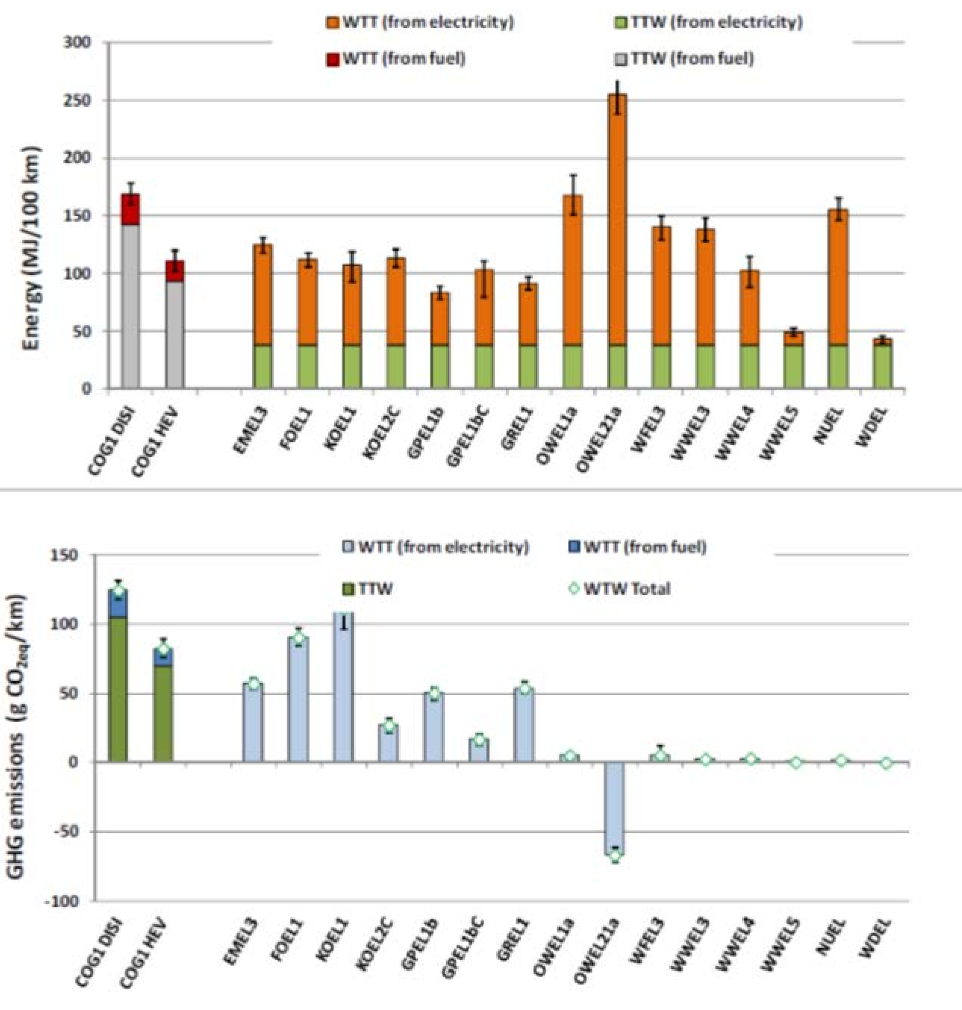


Figure 8.1 Energy use (top) and greenhouse gas emissions (bottom) of 2020 BEVs using electricity produced from different types of primary energy sources, compared with ICE vehicles. WTT = Well To Tank, TTW = Tank To Wheel. COG1=conventional gasoline, Electricity examples: EMEL3=EU-mix, FOEL1=Heavy fuel oil conventional power plant, KOEL=Coal conventional power plant, GPEL1b=piped natural gas combined cycle gas turbine, WDEL=Wind. Source: EU WTW analysis (2014).

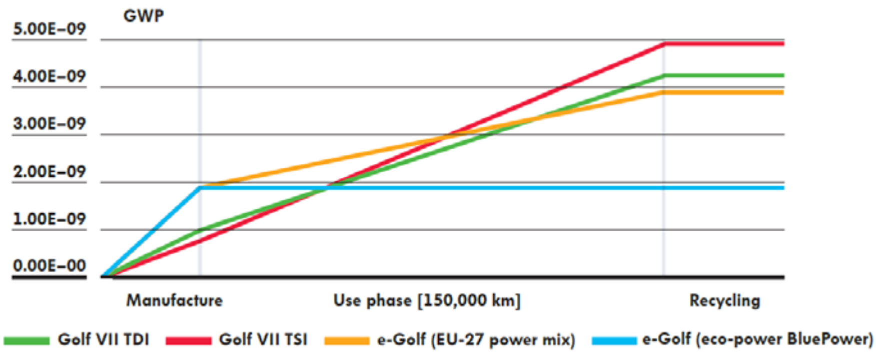


Figure 8.2 Life cycle analysis of VW E-Golf BEV greenhouse gas emissions (GWP-Global Warming Potential of total greenhouse gas emissions) compared with gasoline and diesel fuel variants of the same vehicle over 150 000 km, including recycling. BluePower = Fossil free electricity, Source: VW (2014).

Electricity can be produced from 100% renewable sources without emissions, and on the other end of the scale from highly emitting coal fired power plants. The effect of the different types of electricity is shown in figures 8.2 and 8.3.

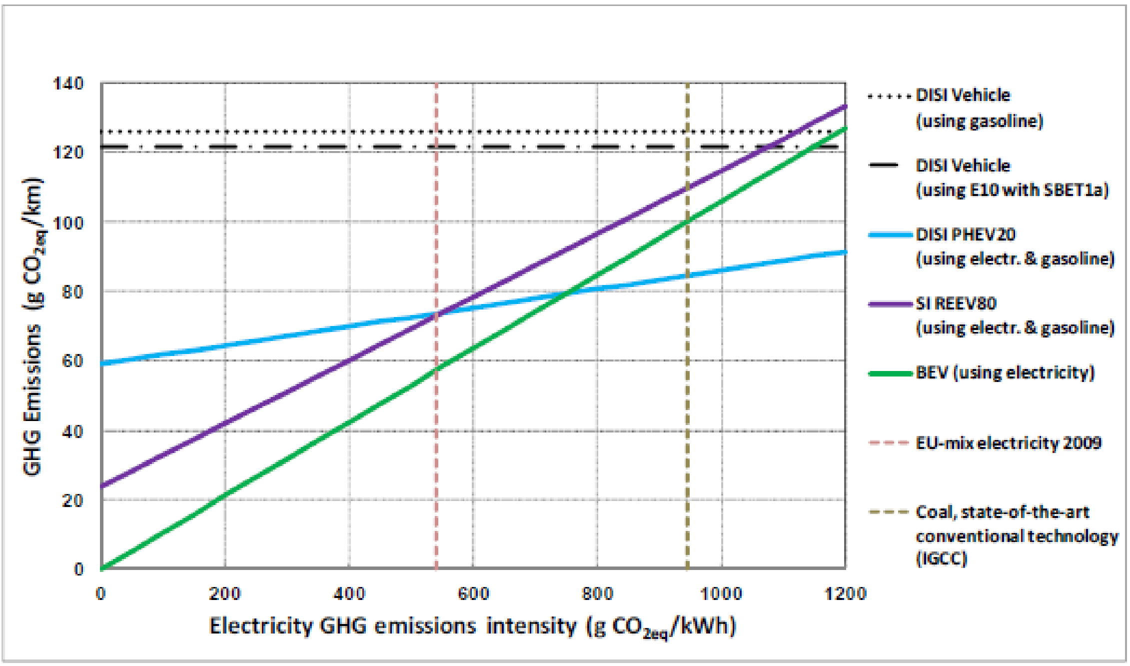


Figure 8.3 The effect of different types of electricity production on 2020 BEV greenhouse gas emissions. DISI = Gasoline vehicle, E10=10% etanol blend, SBET1a refers to WTW path, SI REEV20 =Plug in hybrid gasoline range extender vehicle with 20km pure electric drive mode; SI REEV80, same as SI REEV20 but with 80 km range. Emission from BEV as function of GHG intensity of electricity production. Source: EU WTW analysis (2014).

8.1.2 EU Emission Trading Scheme changes the assumptions

Usually, lifecycle analyses do not take into account policies that influence emissions. Both vehicle and electricity production are now included in the EU ETS[3], thereby changing the assumptions on emissions. The EU ETS includes electricity production and most industries, including the automotive industry. There is a cap on the total

[3] For more information about the EU ETS see: http://ec.europa.eu/clima/publications/docs/factsheet_ets_en.pdf

annual CO_2-emissions from the sectors inside EU ETS. All industry and electricity producers must buy greenhouse gas emission permits if they use fossil energy. The sum of the emission permits equals the total cap. The cap is reduced by 1.74% per year to ensure continued pressure to reduce emissions (EU ETS 2015).

Emissions from ICE-vehicles are outside the EU ETS, and will be eliminated when BEVs replace them. The potential increase in electricity production to provide electricity to these BEVs, does not lead to net CO_2-emissions, as the cap remains unchanged. BEVs thus lead to a 100% reduction in emissions when they replace ICE-vehicles. In fact, even if the BEV were an additional vehicle to the household, the emission resulting from the electricity used in the usage phase would still be zero with EU ETS. There is no longer a physical relation between the use of electricity and the total emission. When the vehicle recharges it may be that a coal power plant physically delivers the electricity to that vehicle. At the same time the coal power plant uses up CO_2-emission permits, leading to less permits being available later that day or another day or month or in another country or sector within the EU ETS. It is therefore irrelevant to claim that BEVs use polluting coal-powered electricity.

The emission in the vehicle production phase is more complex to assess. Vehicles are produced across the globe with parts being made in countries both inside and outside the EU ETS. Therefore, the net effect varies, and will be specific to the vehicle model. Potentially, the increase could be 4-5 tons for a BEV with a 24 kWh battery (see figure 8.2). If the vehicle is produced inside the EU, parts of this increase will be cancelled out by emission reductions elsewhere in industry and power production inside the EU ETS.

8.1.3 Local pollution

BEVs do not contribute to local pollution, as they have no tailpipe emissions. Local pollution is directly proportional to the number of kilometres driven with polluting vehicles. The effect on local air quality will however not be large until BEVs make up a substantial part of the vehicle fleet and the effect may vary with local conditions.

The best effect is seen when BEVs replace older diesel vehicles, which have high missions. New research (Hagman, Weber and Amundsen 2015, Mock et al. 2014) points to diesel-vehicle emissions as being much higher in real traffic than in the official type approval test for new vehicles. This newly clarified fact is not taken into account in many analyses. It means that even the replacement of newer diesel vehicles with BEVs will have a larger effect on pollution in cities than earlier studies have shown.

8.1.4 Noise

COMPETT has studied and measured the noise impact of BEVs (Iversen and Holck Skov 2015, 2015b). The overall conclusion of these studies is that although the noise is 2-5 dB lower than that of ICE vehicles at speeds below 30 km per hour, depending on traffic situation, see figure 8.4, it will not have a practical impact on noise levels in urban areas. The noise problem in cities is dominated by vehicles travelling at speeds above 30 km per hour. At these speed the noise reduction of BEV’s will be small. In residential zones, a small improvement may be noticed, but these areas are not even mapped in noise action plans. The adoption of BEVs will therefore not have an impact on policies to reduce noise in cities.

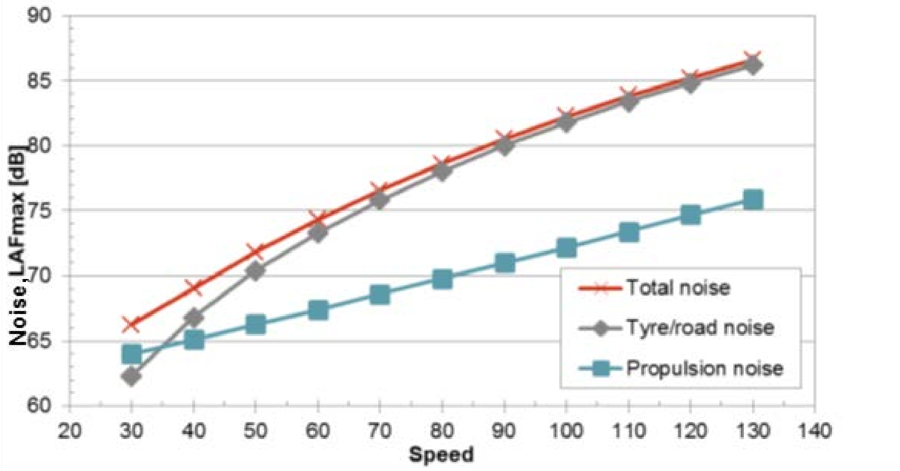


Figure 8.4 The propulsion noise, the tyre/road noise and the total noise from a passenger car by speed, calculated with the Nord2000 noise prediction model. LAF max[4] (dB) and kph. Source: Iversen and Holck Skov (2015, 2015b).

8.2 Possible rebound effects

BEVs have very low variable cost per km, i.e. low energy costs and reduced maintenance cost, and thus offer cheaper transport than ICE vehicles do, once the vehicle has been bought. One would therefore expect to see rebound effects, i.e. more vehicles on the road and more kilometres being driven per vehicle on average, when BEVs are introduced into the market.

The user survey in WP4 was designed to provide an insight into these potential effects by asking several questions regarding changes in driving behaviour after having bought the BEV compared to the situation before.

Of the respondents 6% stated that the total kilometres the household's vehicles were insured for, were reduced after buying the BEV, 18% said it had increased. The majority, 67%, did not change their daily travel patterns. 7% walked or cycled less, 16% used less public transport and 7% drove less. On the other hand, 5% walked or cycled more, and 23% drove more.

Previously, 80% had driven to work in an ICE vehicle, 2% in another BEV, 2% had been passengers in another car, 2% cycled, and 11% previously used public transport to get to work. 2% stated that the specific trip in question had not been done before. 28%, said the BEV was an additional vehicle in the household, 3% had not owned a vehicle before. In total, there are indications that the BEVs contribute to increase in travelling.

Deeper analysis reveals that there are three categories of BEV owners reporting that the BEV is an additional vehicle:

- *Category 1*, 10%, do not use the additional BEV to drive to work. These 10% additional vehicles constitutes about 2% of the total number of BEVs in the sample.
- *Category 2*, 53%, have children and use the vehicle to get to work. Some have short distances to work, but many also quite long, see figure 8.5. These people may need the extra vehicle because they are escorting children and public.

[4] LAFmax : A-weighted, Fast, Maximum, Sound Level.

transport is too time-consuming. As owning a vehicle is a huge investment for families, there is a high probability that these people really needed to purchase the additional vehicle. Had they not purchased a BEV, the likely necessity of an additional vehicle would have meant that an ICE vehicle would have been purchased instead.

- *Category 3*, 37% of the total, use the BEV to go to work but have no children. They should be able to manage more easily without the additional vehicle. A share of these also have short distances to work. 50% of them, however, have more than 19 km to work and 30% have more than 29 km. Removing these 30% of additional vehicles with the longest distances to work, the remaining additional vehicles are 27% of the reported additional vehicles. These 27% additional vehicles constitutes 8% of the total number of BEVs in the sample.

Adding those who bought an additional BEV but do not use it to go to work (Category 1), to those who have no children and whose distance to work using the BEV is below 30 km (Category 3), the total rebound effect on vehicle ownership can be estimated to be around 10%. The calculation is based on what the respondents say about their driving patterns. Changes in the travel pattern of other persons in the household may also have triggered the BEV purchase.

Figure 8.5 shows the spread of distances to work for the two categories who have stated that the vehicle was an additional vehicle and that they drive to work.

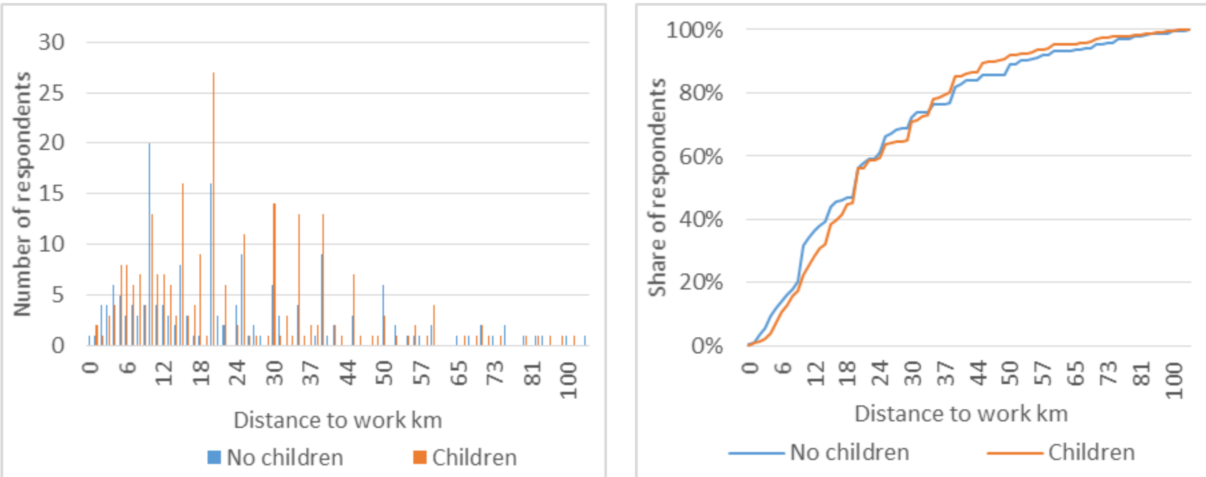


Figure 8.5 Distance to work, those buying additional vehicles, with or without children. Km and cumulative percentage. Calculation based on data from BEV owner survey. Source: Figenbaum (2015).

8.3 Economic impacts

Policies and incentives will not be effective and societal impacts small until the sales price of BEVs becomes competitive, either through large enough incentives or as a result of falling manufacturers cost over time. Large reductions in manufacturers prices have been seen in the Norwegian market since 2008, leading to BEVs becoming competitive with ICE vehicles with the help of the economic incentives in the tax system, see figure 8.6. BEVs however remain more expensive than ICE vehicles before the taxes are applied to ICE vehicles.

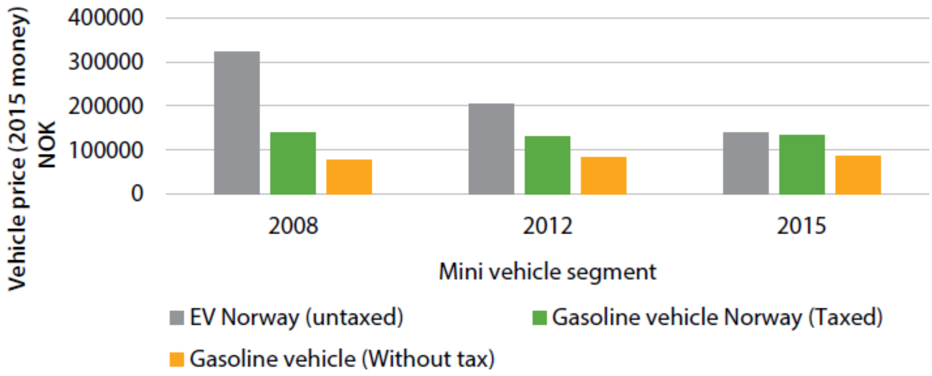


Figure 8.6 Development of BEV prices in Norway. Calculation based on data from section 3.1. 2014 currency rate: 1€=8.35 NOK. Source: COMPETT Team (2015).

Many types of transnational, national, regional and local electromobility incentives and policies have therefore been taken into use across Europe to support the market introduction of battery electric vehicles. The incentives may be based on taxes, tax exemptions, grants, regulations or can be organizational measures.

Transnational incentives and policies are mainly regulations or of the organizational type. In Europe, the EU regulation of CO_2 emissions of new vehicles is the most important transnational policy. This regulation, requiring that new vehicles shall emit less than 95 g per km in 2020, has led car manufacturers to develop and sell BEVs and PHEVs. National governments have introduced incentives and policies further supporting BEV and PHEV diffusion, once they became available in the market.

For the actors selling BEVs the national incentives may appear more attractive than local or regional incentives as they influence the entire market of a country. They also appear to be more stable as they are typically anchored in national policies.

The benefit of local or regional incentives lies in the way in which they may be tailored to local circumstances. Access to parking or bus lanes can have huge effects on BEV sales in some areas; in other places, the incentive of free toll roads is more important.

There will be large differences between countries concerning the incentives that can be taken into use. Each country has its own tax system, governance traditions and automotive market characteristics that form the background for developing incentives and policies.

The effectiveness of national and local incentives and their implications for public budgets have been investigated in Austria and Norway using the SERAPIS model (Fearnley et al. 2015), see section 1.4 and chapter 9. SERAPIS simulates markets for alternative propulsion technologies. It is 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 BEVs and PHEVs. The model allows the effectiveness of new incentives to be analysed when it has been calibrated using historical sales, incentives, costs, BEV models availability and fleet data. The results feed into calculations of energy use and other environmental indicators, public revenues and expenditures.

8.3.1 Effectiveness

Various BEV incentives have different effects on BEV market shares. Fiscal incentives directed at the use of BEVs have relatively little impact on BEV market shares in comparison to the larger effect of incentives that reduce the purchase costs, according to results from SERAPIS simulations for Norway. In between lies the annual circulation tax rebate, where the effect on BEV sales is significant (Fearnley et al. 2015).

The exogenous uptake of BEVs resulting from policies and incentives in other countries leading to improved technology and reduced cost, as shown in figure 8.7, is slow in the first years. Incentives speeds up the uptake of BEVs. The incentives reducing the purchase price (VAT and purchase tax or rebates) are the most effective ones. They generate the largest BEV market take-up in Norway, see figure 8.7. Convenience and time saving due to the access to bus lane also contribute to a large uptake of BEVs. The same time saving effects also apply to dedicated BEV parking, but to a much lesser extent (Fearnley et al. 2015). In another calculation using a tobit regression model, Fearnley et al. (2015) found a bigger impact in Norway of the toll road exemption.

The Norwegian incentives were also tested in the Austrian SERAPIS model on Austrian data. In general, the sales generated are much smaller than in Norway given that the total passenger vehicle fleet is almost twice as large as in Norway[5]. The slower sales seem to be a delayed diffusion compared with Norway. Bus lane access had little effect in the model simulations for Austria, but purchase incentives are effective, although less so than in Norway.

The difference between the two countries may partly be due to Austria being much earlier in the diffusion process than Norway. Austria may therefore also need incentives directed at speeding up the early diffusion, to catch up some of the market delay compared with Norway.

[5] 4.64 million in 2013 in Austria, 2.50 million in Norway, Sources: Statistics Austria, Statistics Norway.

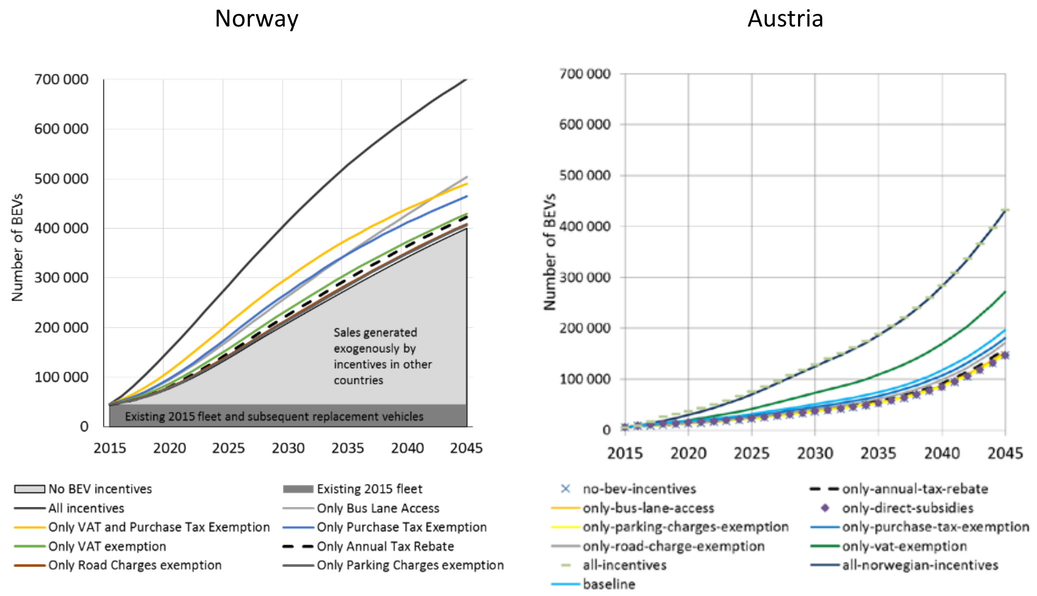


Figure 8.7 The number of extra BEVs sold with various incentives in Norway and Austria. All existing incentives were removed from the model (No BEV incentives run), then they were reintroduced individually to estimate the partial effect of each incentive. Source: Reformatted from Fearnley et al. (2015).

8.3.2 Fiscal cost effectiveness of incentives

The fiscal cost effectiveness of BEV incentives refers to the effect on market take-up relative to public budget costs. How many BEVs will an incentive generate per unit of public budget? The budget impacts can be direct (e.g. subsidy or tax exemption), or indirect (more BEVs reduce revenues from petrol taxes). 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, see figure 8.8. National incentives appear to outperform local and regional incentives and are, usually, appreciated by the market as more stable and predictable (Fearnley et al., 2015).

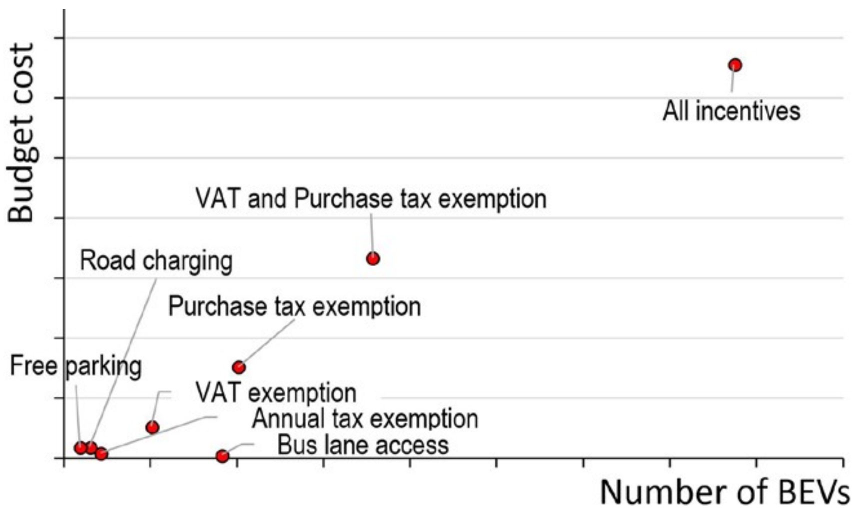


Figure 8.8 Partial relative effects of BEV incentives based on Norwegian SERAPIS model calibration. Road charging=Toll roads or similar. Source: Fearnley et al. (2015).

Table 8.1 indicate the budget cost effectiveness of the incentives defined as the number of EVs per fiscal budget cost[6]. The effect of "All incentives combined" is not quite the same as the sum of each incentive.

Table 8.1 Government cost, market impact and cost per BEV of incentives in 2020. NOK and number of BEVs. 2014 currency rate: 1€=8.35 NOK, Source: Fearnley et al. (2015).

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 (toll roads or similar)	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

Synergies between the national and local BEV incentives are not large in the Norwegian BEV market simulation (Fearnley et al., 2015), as seen by the "All incentives combined" simulation giving about 35% more vehicles on the road than the sum of each individual incentive would indicate. The Norwegian BEV incentives would not have worked without BEVs being available on the market, which is again a result of EU's transnational regulation on CO_2-emissions from new vehicles.

Access to bus lanes is the most cost effective BEV incentive. It involves no direct outlays for the government, but reduces revenues from petrol taxes. The net burden on public budgets is small. Free BEV parking is the least cost effective policy and, as figure 8.8 shows, is among the least effective policies. It adds little to the BEV fleet, but has a high budget cost relative to its impact. The combination of VAT and purchase tax exemptions is a costly way of introducing electromobility, but generates a large demand for BEVs. It seems impossible to generate large BEV sales without purchase incentives given the current prices of vehicles and technologies (Fearnley et al. 2015). Production costs go down when production volumes increase, leading to a reduced need for incentives as the diffusion of BEVs propagates.

Ineffective incentives should not be introduced and should be the first to be removed when scaling back incentives in countries that already have them.

8.3.3 Government budgets

All BEV incentives will influence government budgets either directly (purchase incentives from allocated government budgets), or indirectly through the reduced income from fuel taxes or tax exemptions for BEVs. If great BEV diffusion is a target, the effects on the government budget may become substantial when the

[6] Here the focus is 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.

policies start having an impact on the sales. The change in government revenue is shown in figure 8.9 for Norway and Austria for the increase in the BEV fleet shown in figure 8.7.

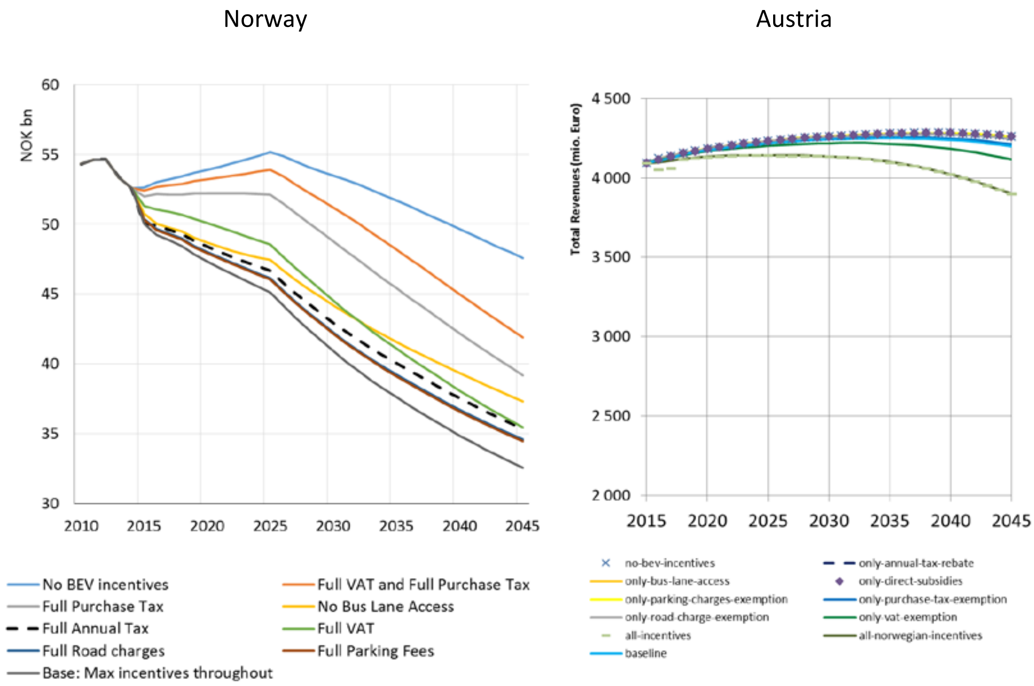


Figure 8.9 Government net revenue per year in NOK billion and million Euro (Austria). 2014 currency rate: 1€=8.35 NOK, Effect of different incentives relative to a base run where no BEV incentives exist after 2015. Source: Reformatted from Fearnley et al. (2015).

The budget costs are considerable in Norway with high BEV sales and the assumed constant vehicle fleet. The loss of revenue is much smaller in Austria, with much lower BEV market shares, and in the beginning losses are overshadowed by increased income resulting from a growing vehicle fleet. There is only a net loss of income in 2045 if all incentives are introduced into the model.

These costs and income losses can be compensated for by higher taxes for other taxable goods. Highly progressive car taxation will increase tax revenues from ICEs and thereby help offset the revenue losses due to the introduction of BEVs. The French bonus/malus system, for example, finances 100% of the BEV bonuses by taxing polluting vehicles.

The Norwegian tax system can maintain government revenues even with large shares of BEV sales, by adjusting taxes on ICE vehicles and fossil fuels as demonstrated by Fearnley et al. (2015). The annual taxes, whose effect within SERAPIS is primarily to raise government revenues, is in the model assumed not to affect the total car fleet. As a BEV incentive, the Norwegian annual tax exemption will be completely phased out from the year 2020 onwards. From then on, all passenger cars will pay the same annual tax. The base scenario assumes no change in real prices and keeps the level at 3 060 NOK (= €365) per year throughout the period. The base scenario of COMPETT was used to generate expected government tax revenues, see figure 8.10, under the condition that the annual tax was increased over time to keep the income stable. Note that the base scenario makes some assumptions concerning scaling back some of the incentives over time, see table 9.1 and Fearnley et al. (2015) for more details. The annual real adjustment (i.e. above inflation) of the annual tax, which is necessary in order to maintain total revenues from passenger cars, was estimated to be an increase of 3.5% per year. The annual tax would then be about 4 500 NOK (= €540) in 2030 for all vehicles and 7 500 NOK (= €900) in 2045, compared with the 2015 ICE vehicle tax of 3 060 NOK (= €365) (Fearnley et al. 2015). Figure 8.11 illustrates this assumed, relatively modest - but necessary, annual increase and the impact on total government auto-tax revenues.

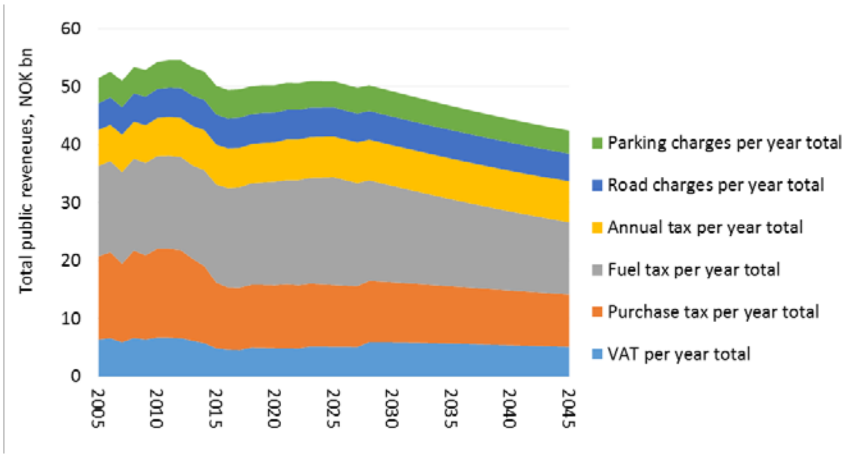


Figure 8.10 Annual public revenue in base scenario, decomposed by source - Norway. NOK billion. 2014 currency rate: 1€=8.35 NOK. Source: Fearnley et al. (2015).

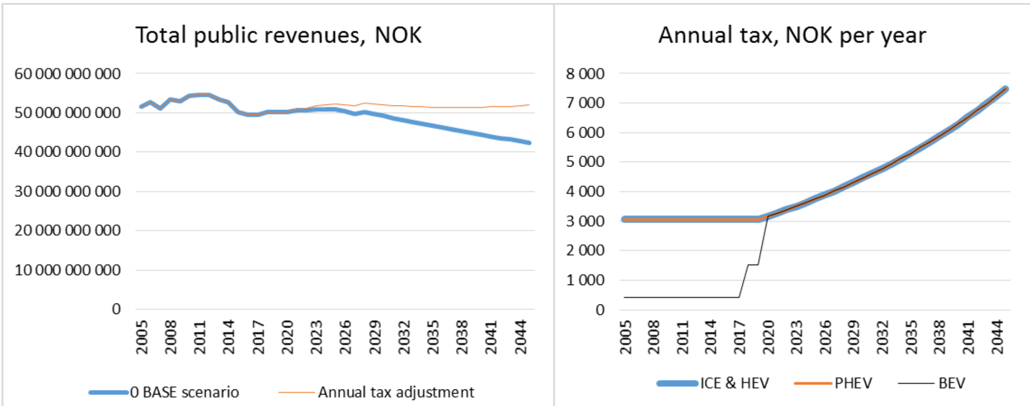


Figure 8.11 Effect on total government revenue (NOK; left) of a 3.5% annual increase in annual tax per vehicle (NOK, right). 2014 currency rate: 1€=8.35 NOK Source: Fearnley et al. (2015).

Incentives should be considered as an introductory offer and be scaled down when sales mature and the cost of technology is reduced.

8.4 Findings on societal impacts

Life cycle analysis

- BEVs are better than ICE vehicles from a life cycle perspective when using the European power mix
- The use of renewable electricity in BEVs leads to much lower emissions than the use of vehicles using other alternative energy sources
- When doing life cycle analysis without taking the EU ETS into account, the general picture is that BEVs lead to a substantial reduction of emissions when using the EU power mix. Emission from the production of vehicles increases,

but is more than compensated for by the reduced emissions during the usage phase.

Emission when taking the EU ETS into account

- When BEVs replace ICE vehicles, the EU ETS functions such that the emission reduction in the usage phase will be 100%. Emissions do not increase even if the BEV is an additional vehicle
- The emissions from the production of vehicles depend on where the vehicle is produced, i.e. inside or outside the EU ETS, and where the parts come from. If the vehicle is produced inside EU, parts of this increase will be cancelled out by the emission reduction elsewhere in industry and power production within the EU ETS.

Rebound effects

- Of the BEVs 28% were purchased as additional vehicles according to the Norwegian user survey. Up to 10% can be estimated to be additional vehicles that would not have been bought without the BEV incentives, i.e. a rebound effect, the owners of the other 18% would probably have bought a new vehicle regardless.

Effectiveness of incentives

- Purchase incentives are the most effective in generating BEV sales and are needed to generate substantial sales of BEVs
- Bus-lane access is also an effective incentive but is limited by the spare capacity of these lanes.

Cost effectiveness of incentives

- Bus-lane access generates relatively large BEV sales at low budget cost
- Free parking is an inefficient incentive having a low cost effectiveness.

Government budget effects

- Purchase incentives may result in large loss of budget tax income
- Budgets losses can be eliminated by increasing taxes on ICE vehicles and fossil fuels, and by reducing incentives when EV technology improves and the production costs go down.

Distributional effects

- Incentives cause distributional effects in the economy. Some people gain from an economic incentive, and some loose from the increased taxes used to generate the revenues used for financing the incentive.

9 The road towards electromobility

The main research question of COMPETT: *"How can e-vehicles come into use to a greater degree?"* was decomposed into the following questions constituting some essential elements of a transition towards Electromobility:

- What are the most likely niches for e-vehicle use from a social-economic and regional point of view for households and businesses?
- What kind of e-vehicles can easily become competitive alternatives to ICE vehicles?
- How to bring about the social acceptability and travel-behaviour changes needed?
- What barriers and potentials exist for use of e-vehicles on the individual, regional and national level?
- How can barriers be overcome and benefits be used in promoting e-vehicles and strategic planning?
- Who will be the main actors involved, and what facilities will be needed?
- What is the economy of existing regulations and incentives for e-vehicles, and how should innovative new measures be designed?
- How can research-based knowledge stimulate marketing and policy making related to e-vehicle use?

The insights into these sub-questions are presented below.

9.1 Elements in the transition towards electromobility

9.1.1 EV niches from a social-economic and regional point of view

Target customer groups for BEVs should be viewed in relation to societal targets for electromobility and to the different groups' ability to use BEVs. Incentives can be used to make BEVs more attractive to these target groups. In the COMPETT project, target groups are defined as the most likely buyers of BEVs.

Multi-vehicle households buy 62% of BEVs in Norway. Single-vehicle households buy 18% and fleets 20%. In the Netherlands, most BEVs are company cars (leased vehicles used by consumers). In most other countries, fleets buy most BEVs, see figure 4.3. Of the BEV owners in Norway, 97% have access to parking with electricity enabling them to charge their vehicles at home, see figure 5.1.

The primary target groups for BEVs will thus be multivehicle households with home parking facilities equipped with electricity, fleets will be the other primary target group.

Multi-vehicle households manage well regarding the BEV range and charge-time limitations. These households are the most affluent and have the greatest transportation needs. A large of them share have children in the household, and the vast majority are full time workers. They have the best home parking facilities as well as many other characteristics of early adopters (Figenbaum, Kolbenstvedt and Elvebakk 2014, Figenbaum and Kolbenstvedt 2015).

There are no differences in terms of target groups in cities compared to rural areas, as BEVs are equally capable of fulfilling the daily transport needs of rural and urban citizens. BEVs are spreading out from urban areas to rural districts in Norway (Figenbaum, Kolbenstvedt and Elvebakk 2014, Figenbaum and Kolbenstvedt 2015). Buyers need a dedicated parking area that can be fitted with electricity, a facility which is less available in dense city zones than outer city zones, surrounding suburbs and rural areas.

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

Secondary target groups will be technology or environmentally oriented single-vehicle households with parking facilities. This target group will gain importance as the range of BEVs improves, the cost goes down and a nationwide network of fast-chargers becomes operational, thus enabling longer distance travel.

Countries beginning to introduce BEVs should direct their efforts to demonstration programs aimed at raising awareness of BEVs, as was done in Austria's model regions (Jellinek, Emmerling and Pfaffenbichler 2015). Policies making BEVs cheaper than ICE vehicles may lead to households without vehicles adopting BEVs, or single-vehicle households becoming multi-vehicle households when adopting BEVs. Such policies should be avoided in the longer time perspective, but may need to be tolerated in a transitional phase to get diffusion started.

BEVs will primarily be used for local transportation purposes and occasional regional trips, as seen in the travel pattern of EV owners in Norway (Figenbaum, Kolbenstvedt and Elvebakk 2014). As the range of BEVs improves, the BEVs will increasingly be used regionally and eventually also for longer distances between regions. The Tesla Model S has this ability already, and is being used for longer distance trips in Norway. Other manufacturers will also launch longer-range vehicles in the period 2017-2020, such as Audi, GM, Nissan and Peugeot (Audi 2015, GM 2014, Nissan 2015c, Peugeot 2015).

The PHEV primary target group will be single-vehicle households having parking spaces at home that can be fitted with electricity. The PHEVs are generally available in the larger vehicle types (Krutak et al. 2015) and will be used for general-purpose travels in a way similar to the ICE vehicles they can replace directly. Multi-vehicle households will be better off economically with BEVs, as discussed in chapter 8, but company car traditions may nevertheless lead to some opting for a larger PHEV.

9.1.2 EV types that can become competitive

A somewhat surprising finding in COMPETT is how easy Norwegian consumers are taking the existing generation of BEVs into use. These vehicles have a theoretical range of 150-200 km and a practical range of 80-150 km. Nevertheless, the users report few problems, driving their BEVs as much per year as owners of ICE vehicles do. Many options for handling range challenges seem to be available (chapter 4, Figenbaum, Kolbenstvedt and Elvebakk 2014). There are several likely explanations for these few problems reported. One is the finding in WP2 that most of the local daily driving is doable with BEVs (Hjorthol et al. 2014). Another is the WP4 finding that most owners have more than one vehicle (Figenbaum, Kolbenstvedt and Elvebakk 2014).). A third is the long BEV history in Norway leading to more knowledge and awareness of BEVs in the general population. A fourth is the Norwegian incentives compensating for the risk of adoption as well as providing the user with advantages that are not available to owners of other types of vehicle (Figenbaum, Kolbenstvedt and Elvebakk 2014)., Figenbaum and Kolbenstvedt 2015, Hjorthol et al. 2014).

The COMPETT simulations using the SERAPIS model show that reducing the BEV purchase price is more important than improving the range when it comes to increasing sales in countries with few or no incentives (Fearnley et al. 2015). In mature markets such as Norway, longer range seems to be the right strategy to increase sales beyond the current levels, as incentives compensate for the higher costs, with range being the main remaining barrier. Further SERAPIS simulations demonstrate that a large selection of models and makes of BEVs is essential to achieve large sales due to customer loyalties to brands and dealers and to the customers' needs for different types and sizes of vehicles (Fearnley et al. 2015). For instance, in Norway BEV sales have been seen to increase more or less additionally when new models come into the market (chapter 7, Figenbaum and Kolbenstvedt 2015).

BEVs will compete with PHEVs for consumer attention. In 2015, BEVs are typically cheaper than PHEVs of a similar type and size, even without taxes and incentives. The complexity of the PHEVs partly explains the high cost in addition to these vehicles being positioned as sporty vehicles in order to command a higher price for them. The range of PHEVs in pure electric drive mode is much shorter than that of the BEVs (Krutak et al. 2015). Consequently, BEV owners will normally be able to cover more of the daily driving with electric power than what PHEV owners will. This situation will be even more evident in multi-vehicle households, because they can redistribute travel between vehicles so that the BEV can cover more of the daily travel needs. In addition, driving in the electric mode is much cheaper than in the ICE mode of PHEVs, as electricity is cheaper to run vehicles on than fuels, in part because electric propulsion requires much less energy per km of driving (see section 6.6.4). Hence, BEVs will be the best option for multi-vehicle households and in single-vehicle households who do not embark on long-distance trips.

BEVs will be more competitive for more households as the range increases. PHEVs will be the best option for those having only one vehicle and a variable driving pattern with short daily trips and frequent long distance weekend and holiday trips. PHEVs may thus be an alternative that will exist for a while, and will then potentially be phased out as the range of BEVs improves and the battery costs go down.

9.1.3 Social acceptability and travel-behaviour adaptations

Experience from Norway shows that social acceptability can be achieved when consumers become aware of and get to know the technology's potential (Figenbaum and Kolbenstvedt 2015). The fact that this process will take some time, must, however be taken into account. The acceptability will be increased by incentives that meet user needs and a consistent positive communication from authorities and politicians.

Travel behaviour needs not change substantially (Hjorthol et al. 2014). Multi-vehicle households can go about their daily travel, but with an added need to coordinate better and plan a redistributed usage of the household vehicles. They must also remember to plug in their BEVs to charge them.

Single-vehicle households face bigger challenges needing to find other transport options when the range is too short. A large adoption in this group will lead to a need to borrowing vehicles, renting vehicles or engaging in carpools when the range is too short. Other strategies used are to change the mode of transport or to reduce longer distance vehicle-based transport (Figenbaum et al. 2015). While feasible for many people, these adaptions deviate from the established practise and the attitudes towards vehicle ownership. ICE vehicles take the owners wherever and whenever they want to travel, and most people may consider at a car as a thing you must own in order to use it. The need for travel-behaviour changes for the single-vehicle group will be reduced as the range improves. In the meantime, some Nissan dealers in Norway have offered a deal where 20 days of ICE vehicle rental is bundled with the BEV purchase.

PHEVs require no specific adaptations to the driving pattern. These vehicles however have to be plugged in frequently to enable more of the driving to be in the pure electric mode.

9.1.4 Barriers and potentials on individual, regional, national level

Individual level - consumers

The real barriers to BEV diffusion are found at the individual level. Price, second hand-value and uncertainty, limited range, poor access to charging infrastructure and long charge times, established ICE vehicle practises, travel behaviour, extent of travels, knowledge of how BEVs work and even awareness of them being an option, are all potential barriers to BEV proliferation among consumers. The importance of these barriers will vary from country to country due to national characteristics, policies and the stage in the progress of the BEV diffusion.

The attractive BEV characteristics such as responsive pedal feeling, a quiet ride with no tailpipe emissions, home refuelling, preheating and precooling of the cabin, are potentials that the BEV owners appreciate. In addition, a large share of consumers do not need longer range (Hjorthol et al. 2014). Still, range tends to be a large barrier to buying a vehicle. Once the EVs are bought and the owners start using them, the owners rapidly come to terms with the EV range limitations, at least those owners living in multi-vehicle households (Figenbaum, Kolbenstvedt and Elvebakk 2014).).

Individuals make the decision of whether to take BEVs into use or not. In this decision process, they weigh in the pros and cons of BEVs, considering their travel patterns. Research done in COMPETT shows that today, BEVs can, and do meet the everyday transport needs of large parts of the population, especially households with more than one vehicle (Hjorthol et al., 2014, Figenbaum, Kolbenstvedt and Elvebakk 2014).).

In Europe, about 45 million of these multi-vehicle households have parking facilities at home, see section 9.3. Most of these households have or will find ways to fit the parking space with electricity. Consumers enjoy covering local transport needs with their BEVs, and most owners would buy a BEV again (Figenbaum, Kolbenstvedt and Elvebakk 2014), Jellinek, Emmerling and Pfaffenbichler 2015). Charging at home will be sufficient for most local driving needs, potentially leading consumers to spend *less time* refilling energy than they would do with an ICE vehicle.

Price and uncertain second-hand value are the main remaining barriers to consumer adoption of BEVs. The purchase prices of BEVs are much higher than the price of ICE vehicles when incentives and taxes are not taken into account. If this issue is tackled by incentives or taxes on ICE vehicles, the BEVs will become a real alternative for consumers. Second-hand values will be established once the diffusion of BEVs has been going for some years, see section 6.4.6. More knowledge of how the battery capacity evolves over time, will lead to better estimates of the second-hand values and life of batteries. The capacity for a longer range will lead to fewer recharge cycles over the life of the vehicle, further contributing to a longer battery life.

Adoption may still be prevented by the lack of awareness of BEVs and knowledge of how they work, and established practises of ICE based motoring. These issues are, however, workable and of a temporary nature, once the cost issue has been taken care of, as seen in Norway (Figenbaum and Kolbenstvedt 2015).

Dealers – vehicle industry

The dealers earn more money the fewer person-hours spent selling a vehicle. Dealers in Norway say the effort is about the same when selling BEVs as ICEs, but the handover of the vehicle may take longer time with the new functions and characteristics of BEVs (Assum, Kolbenstvedt and Figenbaum 2014). In most other countries, consumers will have little knowledge of BEVs and the dealers and sales persons will be likely to spend more time and resources trying to sell BEVs. Dealers in the US, for instance, report spending three times as many person-hours on a BEV sale (NRC 2013). Such effects constitute an "invisible" barrier to EV adoption. The technology is available, but the dealers or sales persons may not be active in promoting it. New technologies also lead to needs to train the employees, possibly involving investments in tools or other equipment. Nissan, as an example, require all dealers to invest in a fast charger.

National level

National barriers are mostly related to challenges in policy formulation and the loss of tax revenues (Fearnley et al. 2015) or costs associated with grants towards BEV purchases. Supporting the introduction of BEVs economically could lead to conflict with other societal targets such as reducing individual car based transport and congestion in cities.

The cost of vehicles is a national barrier to the extent that it leads to more costly vehicles being produced or imported, than what would have happened otherwise. Taxes and incentives are *transfers within the economy* that are not true costs, but they could lead to distribution effects between the buyers of EVs and ICE vehicles. It is, however, questionable to call this a transfer of money between users (Fearnley et al. 2015). The purpose of the transaction is, however, not to increase the personal benefit for BEV buyers, but to even out the purchase price to make users buy these vehicles, thereby supporting the societal goal of reducing greenhouse gas emissions from transport. This is theoretically not different from collecting more taxes from wealthy citizens and using that revenue to provide equal schooling, social and health services for the entire population regardless of the income level of the beneficiary.

Revenue losses due to the policies can be recovered by (higher) taxes on polluting vehicles (Fearnley et al. 2015). A bonus/malus system can be designed in such a way that a malus (tax) on polluting vehicles finances bonuses (grants) for BEV buyers without burdening the public budgets.

Regional level

At the regional level, the main challenge could be that many BEV policy options and incentives are national, and need to be implemented by the government rather than a region. Countries in Europe are, however, not uniform in this sense. In Germany and Switzerland, federal states have control of parts of the BEV relevant policy areas, whereas in other countries regions have little influence.

Regional governments have a larger influence on transport planning issues than on tax policies and laws, and may support charging infrastructure regionally. Regional targets may not be compatible with national policies, and may thus lead to the two levels of governance working against each other. Such issues have been seen in the public debate in Germany, where the government plans to change national laws to make free parking and the use of bus lanes possible for BEVs, whereas some cities say that they are not interested in implementing such incentives[7].

9.1.5 Overcoming barriers and using benefits in promotion of BEVs

Electromobility as a complete socio-technical system needs to be established if BEVs are to succeed in the market (chapter 7, Figenbaum and Kolbenstvedt 2015). Standards, type approval regulations, fiscal policies, environment and energy policies, established practices, products and services, user awareness, user needs and experiences, as well as parking and charging infrastructure need to be in place to make BEVs attractive so that they can compete with ICE vehicles.

A form of *coordinated action plan* will be needed when different levels of governance are involved in establishing BEV policies and incentives or charging infrastructure. The Norwegian case however is different, with policies evolving more or less uncoordinated over a very long period (chapter 7, Figenbaum and Kolbenstvedt, 2015). The need for coordinated action was however evident also in Norway when municipalities wanting to introduce free parking as an EV incentive, but could not do so until the national parking regulation was revised by the government.

*A large selection of models and makes of BEV*s is essential to achieving large sales, due to customer loyalties to brands and dealers and the need for different types and sizes of vehicles (section 9.2). As the diffusion progresses this issue will become more important. More ambitious, transnational policies will be important, such as strengthening the EU regulation of the average CO_2-emission from new vehicles after 2020.

Incentives for infrastructure will be of the utmost importance for FCEVs. Hydrogen is filled at central filling stations, as opposed to BEVs and PHEVs that can be recharged wherever electricity is available. Infrastructure is therefore the main barrier to the adoption of FCEVs in addition to the high cost, and very limited availability of makes and models until sometime after 2020 at least. The availability and success of

[7] See for example: http://www.spiegel.de/auto/aktuell/elektroautos-auf-busspuren-grossstaedte-lehnen-dobrindts-plan-ab-a-986467.html

BEVs and PHEVs will also be a barrier to future FCEV adoption as the technology is much less mature, and may potentially be outpaced by the rapid technical and economic development of the other two technologies.

Incentives for different types of EVs, i.e. BEVs and PHEVs, may hamper the adoption of the other type or other technologies as the customers' attention is drawn towards the technology with incentives. Incentives should therefore be proportionate to the societal gains of the various technologies, i.e. technologies leading to the largest emission reductions should have the largest incentives.

A communication strategy is of the utmost importance for a successful diffusion of new technology. The COMPETT user surveys clearly show that ICE vehicle owners know very little about the functions of EVs and their advantages and challenges (section 6.3.3 and Figenbaum, Kolbenstvedt and Elvebakk 2014).

9.1.6 Main actors and facilities needed

The actors involved in planning and implementation, identified in WP4, are manifold and include different levels of government, the BEV and charge infrastructure industry, communities, Non-Governmental Organisations (NGOs), individuals and firms as well as the press and media (Figenbaum and Kolbenstvedt 2015, Assum, Kolbenstvedt and Elvebakk 2014).

Globally, two main approaches have been taken to promote electromobility:

1. *Bottom up,* where the initiative comes from users and businesses, pressuring governments to introduce incentives, Norway being the prime example.
2. *Top down,* in which governments aim to impose electromobility on society, as seen in most countries in Europe where the governments have set up national targets and incentives.

The same type of actors will be involved in both approaches but they will assume different roles. The commitment 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 type of democratic process where politicians react to the pressure by introducing policies and incentives (Figenbaum and Kolbenstvedt 2015).

In the second approach, the commitment of politicians and governments has the intent of building up commitment among businesses and users, as seen in the Austrian Model Regions (Jellinek, Emmerling and Pfaffenbichler 2015). In many ways, this could be an uphill struggle. Being difficult to create with outside pressure, real enthusiasm and commitment will most certainly take time to be effective.

In Norway, the bottom up pressure model has proven to be effective and enduring. Large increases in sales were, however, not achieved until the large ICE vehicle producers started selling BEVs (chapter 7, Figenbaum and Kolbenstvedt 2015). They have huge resources, a large network of dealers and workshops, storage of spare parts as well as goodwill and trust from consumers. It is therefore difficult to foresee a large transition to electromobility without these actors being involved

Concerted actions and partnerships will be needed when consumers are in the target group. 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. Barriers to adoption must be identified and solutions found. 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, as in the Austrian model regions (Jellinek, Emmerling and Pfaffenbichler 2015).

Partnerships may reduce the actors' risks in later phases of EV deployment by sharing information and providing common funds for infrastructure. Concerted action is still needed among various governance levels, e.g. to coordinate incentives and actions and to disseminate knowledge. In a final stage, when BEVs have reached the mass market, there is no longer a need for partnerships and concerted actions. Each stakeholder and actor will then respond to the general market conditions. Consumers will find people knowledgeable about BEVs, and the inspiration to buy one, in their own social circles.

9.1.7 Economy and design of regulations and incentives

Any new measures should reduce the identified barriers and the perspective should be on how one can turn the purchase decision of consumers in favour of BEVs, i.e. provide consumers buying BEVs with a relative advantage over ICE vehicle buyers (chapter 7, Figenbaum and Kolbenstvedt 2015).

These new measures should be devised in such a manner that they are operable for a long time and are able to cope with large shares of BEVs being sold and entering the vehicle fleets. Budget allocations supporting BEV incentives do not meet these requirements, and bonus/malus types of schemes should replace them. These schemes can operate indefinitely by adjusting the bonus and the malus to achieve any EV sales share. If BEVs become so popular that the malus becomes too large to unload on ICE vehicle buyers, then the bonus can be reduced to achieve a sustainable balance. Any new measures should be designed with flexibility in mind to allow easy phasing in or out, and the adjustment of the level of the measure. The mechanisms for making these adjustments should be made clear at the outset in order to increase stability. All measures will need a long time horizon to reach their full potential.

A particular need is to get the initial diffusion going. Based on Norwegian experience, this can be done by offering attractive user incentives that are not available to ICE owners to compensate for the higher purchase price (chapter 7, Figenbaum and Kolbenstvedt 2015). Once the diffusion starts, the user incentives gradually lose their importance as sales spread to regions without such incentives as seen in Norway (chapter 7, Figenbaum and Kolbenstvedt 2015).

9.1.8 Research based knowledge supporting marketing and policy

As shown in chapter 2, the EV markets in Europe are in very different stages of development. A few countries stand out with large market shares, whereas most others have low shares. Some countries have no incentives for EVs, whereas others have massive incentives. These differences provide many opportunities for later adopting countries to learn from research based knowledge generated in the early adopting countries. These insights can be combined with each country's national characteristics to make policies better and marketing more efficient.

The target groups can be more accurately identified. For example, many politicians seem to think that BEVs are only suited for fleets, whereas the COMPETT research suggests that multivehicle households should be the primary target group. The appropriate dosing of incentives is easier to accomplish when the effects of various incentives and the way they influence each other, are known. For instance, there is no point in setting ambitious BEV targets or investing large sums in infrastructure for BEVs without addressing the high purchase price simultaneously.

Different alternative technologies and transport modes will have their proponents arguing for the advantage of their preferred solution, which could potentially run down other options. Biased information may thus be disseminated to the public, and myths about the various options that may not be based on scientific evidence, can arise. The role of independent researchers will be to produce objective knowledge about what the various options can and cannot do, and that more than one solution may be required to reach the societal goals.

9.2 Electromobility scenarios explored

The COMPETT scenario assessment identifies two main dimensions affecting the BEV market: 1) technology and supply-side factors, and 2) policy factors. In Norway as well as in Austria, the role of the supply side developments is prominent. The main effect of a 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.

Figure 9.1 outlines the scenarios studied in COMPETT, see Fearnley et al. (2015). On the x-axis is the level of technology and supply side factors ranging from low to high. The y-axis shows the level of policy support. New automotive technologies have in general followed the Technology push scenario. Automakers develop and market new technologies starting with luxury vehicles (ABS and airbags were first introduced in Europe in the luxury vehicle, Mercedes S-class in 1978 and 1981 respectively). Gradually, the technology diffuses down to smaller and cheaper vehicles as the cost goes down because of larger production volumes. Eventually, some technologies are also installed in all vehicles as politicians mandate the technology. A typical example would be ABS brakes. In the Electromobility delight scenario, the introduction of incentives speeds up the process. In the Wishful thinking scenario, politicians may want a technology to support societal targets, but it may not be ready for the mass market yet in spite of the incentives. In the Oblivion scenario, the technology is more or less abandoned by politicians and thus not pursued by the automakers.

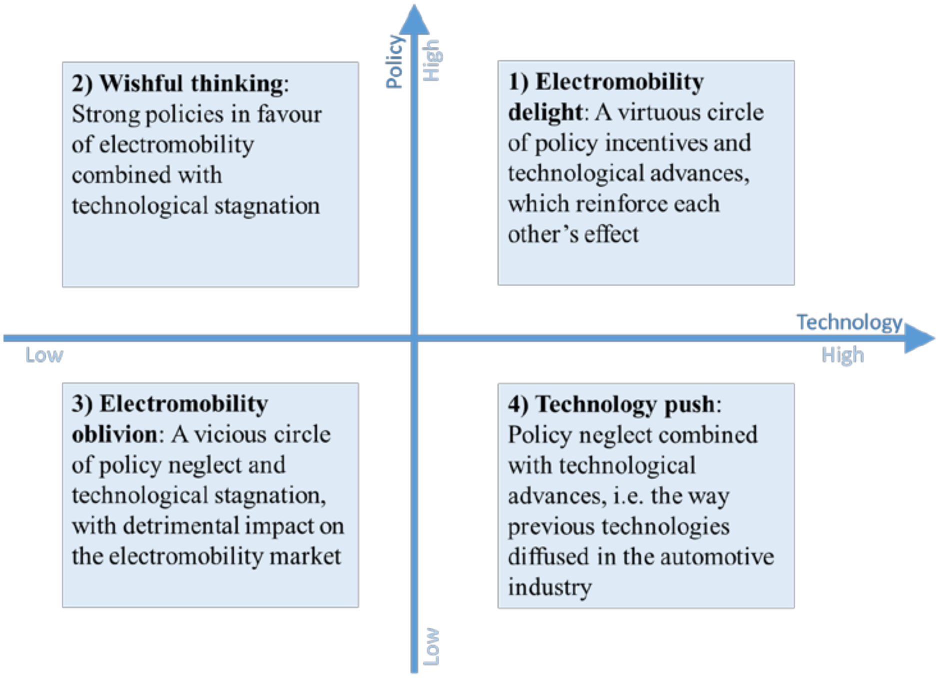
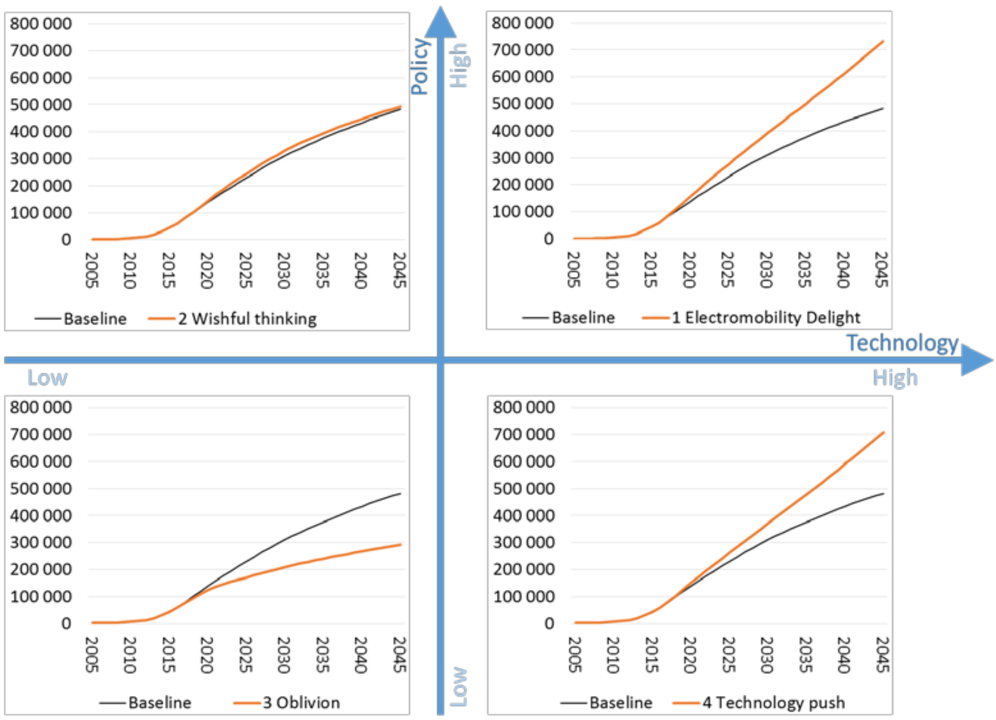


Figure 9.1 Overview of COMPETT Scenarios. Source: Fearnley et al. (2015).

Technology (range, price etc.) and market characteristics (makes and models) as well as policies (taxes, incentives) are varied in these scenarios. The main assumptions for the scenarios are found in tables AIV.1-A.IV.3 in Appendix IV.

The results in terms of sales volumes are shown in figure 9.2, in terms of ICE liquid fuel consumption in figure 9.3, and in terms of electricity consumption in figure 9.4. Given the EU ETS, the reduction in CO_2 emissions will be proportional to the reduction in fuel consumption.

Norway



Austria

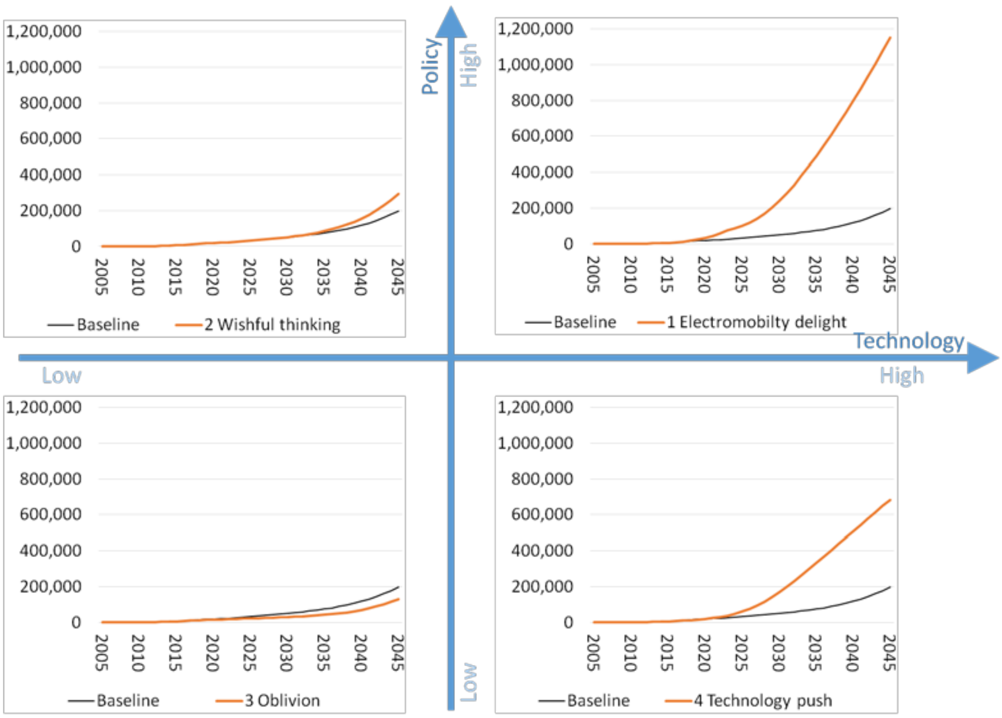


Figure 9.2 BEV sales volumes per scenario in Norway and Austria. Number of BEVs. Source: Fearnley et al. (2015).

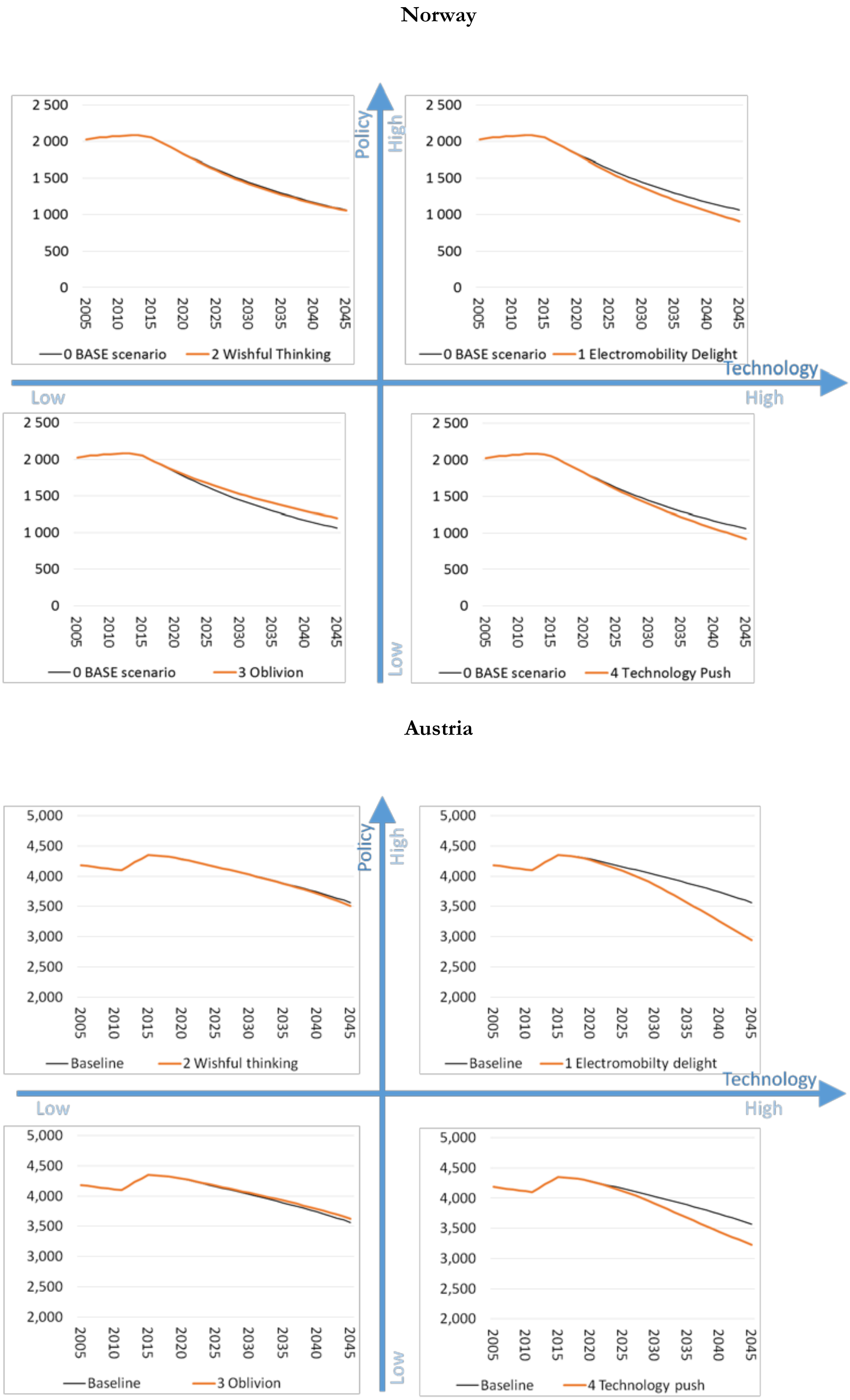
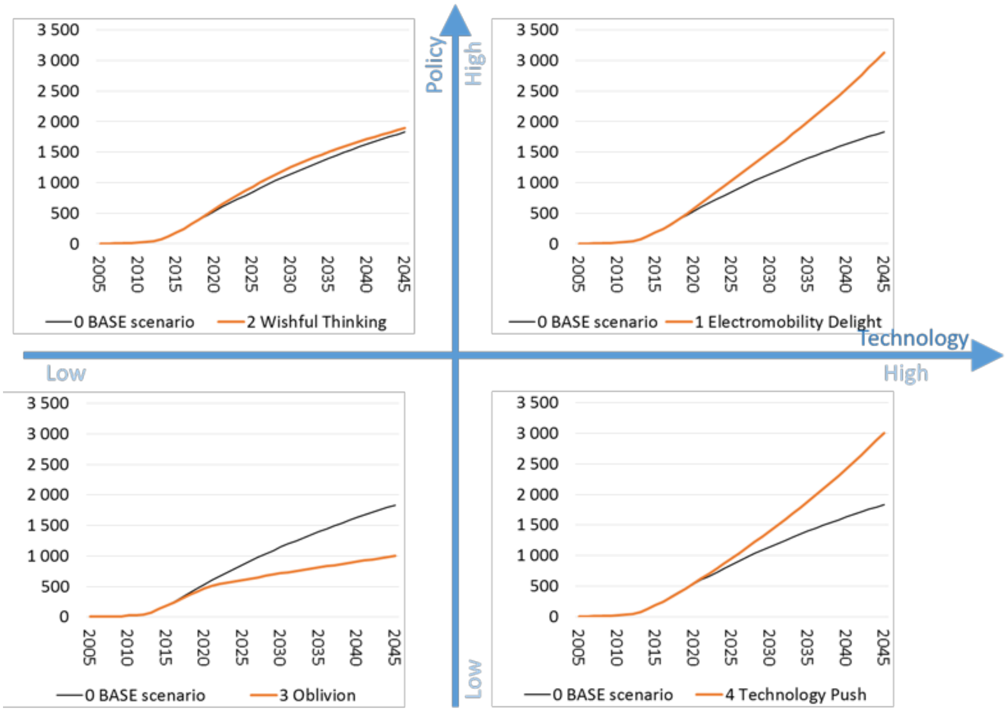


Figure 9.3 ICE vehicle liquid fuel consumption in Norway and Austria, million litres of fuel. Source: Fearnley et al. (2015).

Norway



Austria

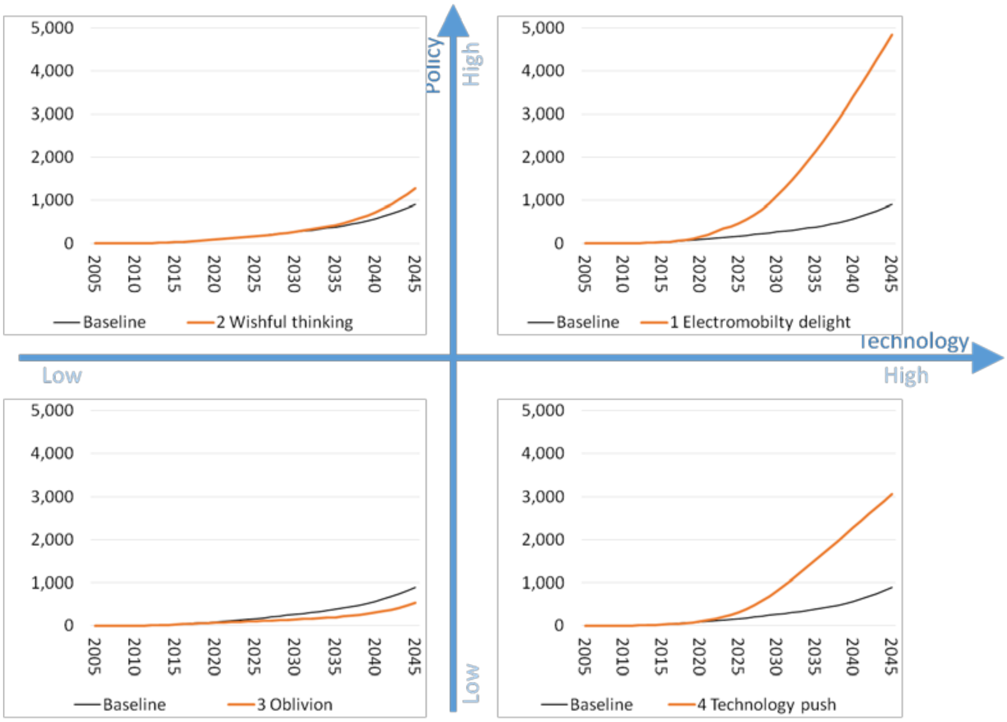


Figure 9.4 BEV (and PHEV) electricity consumption in Norway and Austria, million kWh per year. Source: Fearnley et al. (2015).

Given that the EU ETS is effective, the reduction of greenhouse gas emission will be proportional to the reduction in the fuel consumption shown in figure 9.3.

The effect on greenhouse gas emissions in Norway of the scenarios compared with the base scenario is shown in figure 9.5. The greenhouse gas emission reduction is some 0.4 million tons in 2045 in the Electromobility delight and Technology push scenarios compared with the base scenario, an increase of 0.35 million tons in the Oblivion scenario, whereas the Wishful thinking scenario is more or less neutral.

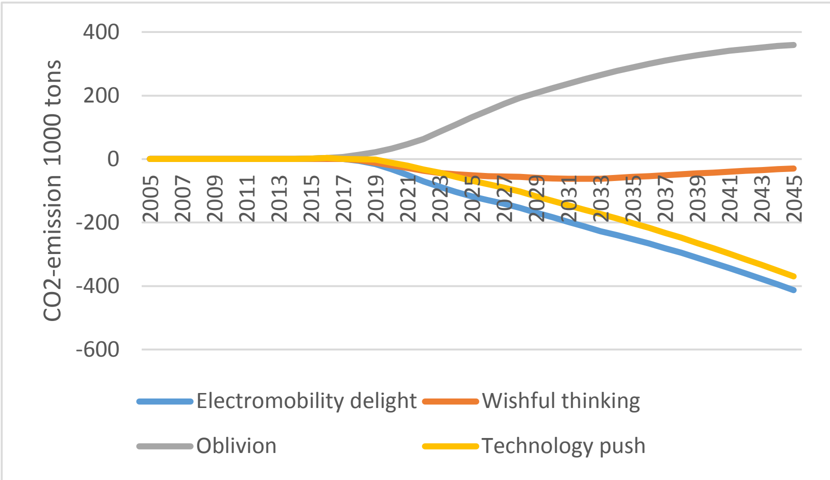


Figure 9.5 Greenhouse gas emissions per scenario relative to base scenario. Norway. Source: Fearnley et al. (2015).

An example of how the result would be without the EU ETS in operation is shown in figure 9.6 for different CO_2-intensities (g CO_2/kWh) of electricity, and different assumptions of BEV energy consumption and mileage, in the Electromobility Delight scenario.

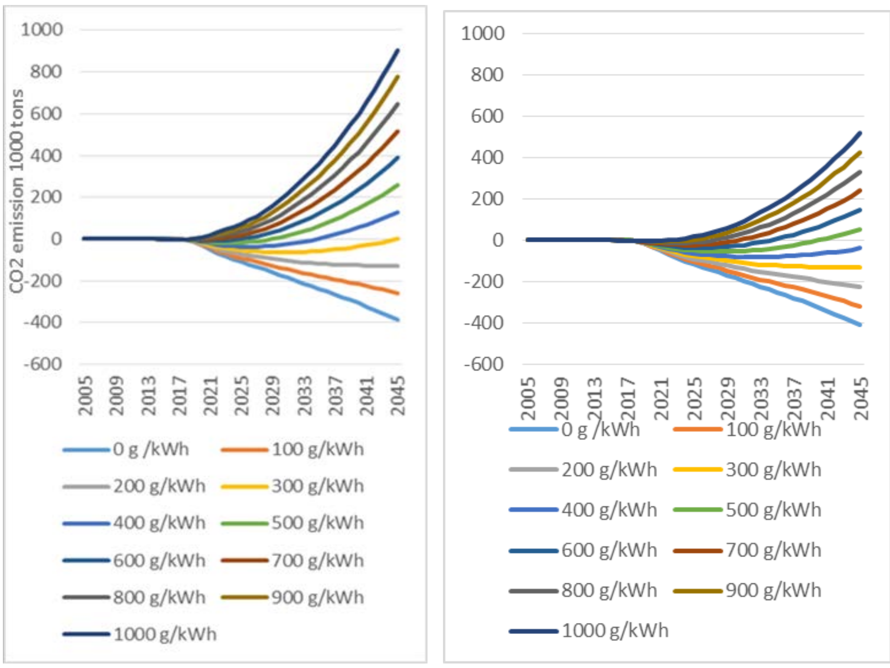


Figure 9.6 The effect of different CO_2-intensity on CO_2-emissions in the Electromobility delight scenario in Norway relative to the base scenario. Left: original assumptions, Right: Sensitivity analysis, 20% lower electricity consumption and 10% shorter annual mileage. Y-axis: 1000 tons CO_2. Given that the EU ETS functions, the 0 g per kWh curve will be followed. Source: Fearnley et al. (2015).

In figure 9.7 the results of a sensitivity analysis of the importance of the number of makes and models are shown for BEVs. In this analysis the baseline scenario was compared with a scenario where the number of makes and models of BEVs and PHEVs increased and the number of ICE models decreased linearly so that in 2045 each of these technologies have 1/3 of the total number of models available for sale. As can be seen, this parameter has a huge impact on sales indicating that a large market share of BEVs requires a large selection of vehicles. The impact on PHEVs was small in Norway but large in Austria, probably due to the Norwegian EV incentives guiding Norwegians buyers towards BEVs.

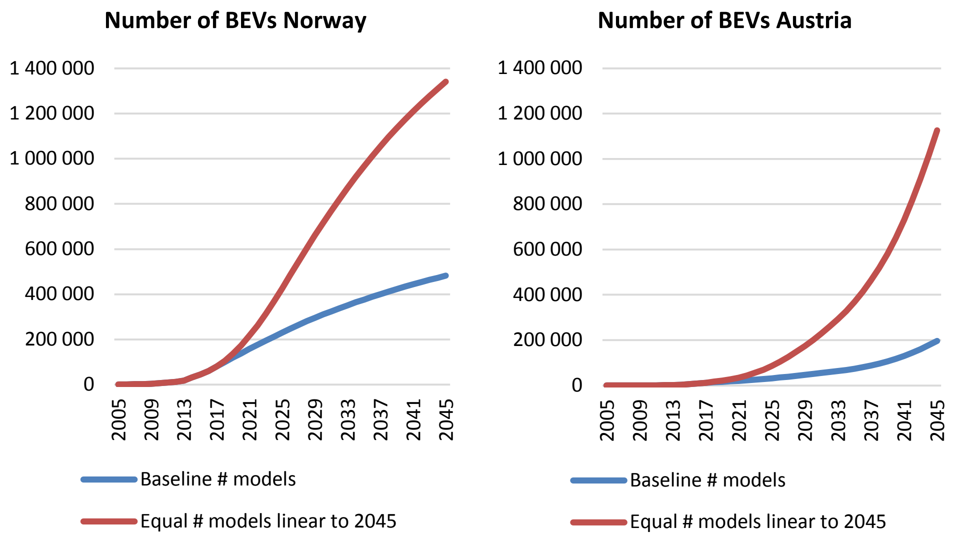


Figure 9.7 Effect on BEV sales in Norway and Austria of making the number of BEV makes and models equal to that of ICE vehicles in 2045 with linear increase 2015 to 2045. Source: Fearnley et al. (2015).

9.3 Potential European consumer market

Of Europe's[8] 220 million households, some 103 million have access to one vehicle, and about 60 million have access to more than one vehicle. The rest have no access to vehicles, see figure 9.9.

Based on the limited information available about parking facilities in each country, about 82% of the multicar households can be estimated to have access to parking at home. These households can potentially charge an EV[9] at home. The share of single-vehicle households having parking facilities is estimated to be 63%. There is a lack of data pertaining to Eastern Europe, where parking availability could be lower than in Western Europe[10].

The number of households and parking availability in Europe is combined in figure 9.8. The total number of multi-vehicle households having available parking exceeds

[8] European Union + EEA countries (Norway, Switzerland, Iceland)

[9] For some countries, the number of cars and parking availability was only partially available (for example only number of garages) see table A.II.1 in appendix II. For these countries, estimates were produced by extrapolating available data using data from similar countries on the relation between share having garages, parking at home, single and multi-vehicle households parking availability.

[10] Countries without parking data have 3.5 million single-vehicle households, 14.3 million multi-vehicle households and 18.6 million households without vehicles.

45 million vehicles in countries with known parking facilities. 55 million single-vehicle households have access to parking

If we apply the same percentages to all of Europe, the total number of multicar households with parking becomes 49 million, and single-vehicle households with parking available becomes 64 million. The number of multivehicle households will thus be in the interval 45-49 million and single-vehicle households 55-64 million. In some countries, such as the Netherlands and Greece, the parking availability is substantially lower. A lower share of households can adopt BEVs on their own initiative in these countries. Multivehicle households can be said to have a great potential for buying BEVs, whereas single-vehicle household will have a smaller potential for BEVs.

Potentially, PHEVs can be sold to both household types. The access to a dedicated parking space that has or can be fitted with electricity is equally important for these vehicles. The total potential market for PHEVs is thus over 100 million in Europe. The BEVs and PHEVs will compete against each other, as it is unlikely that many households will buy two electric vehicles (BEVs or PHEVs) at the current cost level of the technologies. As stated earlier, BEVs will be more attractive for multivehicle households than PHEVs.

A large expansion of curb-side and parking-house charging could potentially increase the markets beyond these numbers. Most owners will probably want to be certain that these vehicles can be charged every day. This situation leads to the question of how much the number of EV buyers would increase if public infrastructure for overnight charging will be established.

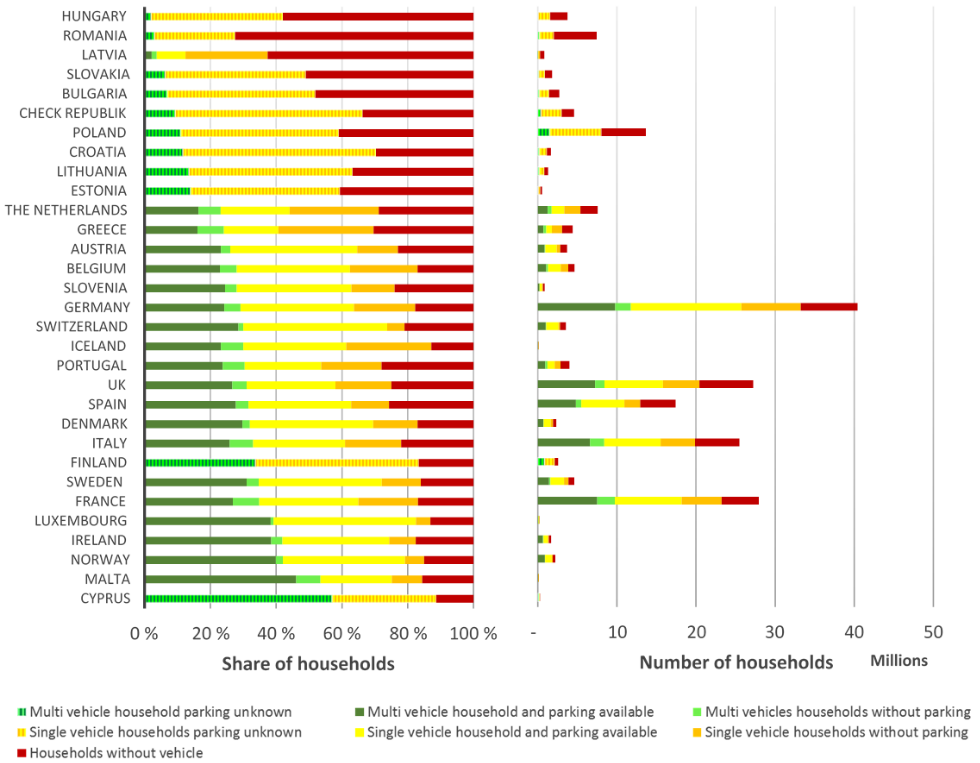


Figure 9.8 Share of households by estimated access to vehicles and parking facilities at home. Percent and number Source: See appendix III.

Data on the availability of electricity at private parking places was only found for Denmark and France, see figure 9.9.

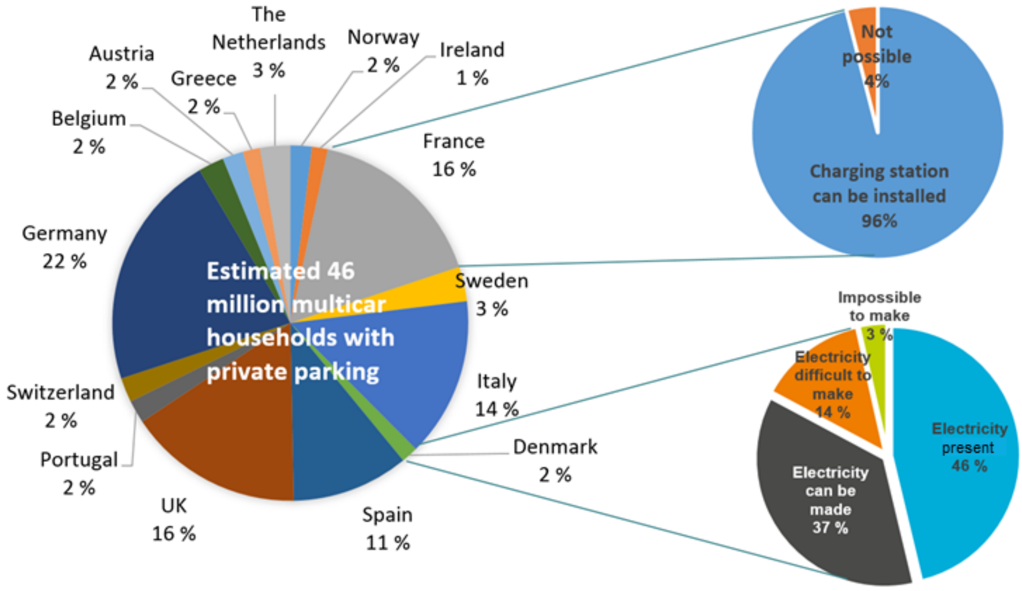


Figure 9.9 Parking and electricity availability in multi-vehicle households in Denmark and France. Source: See Appendix III.

In France, 96% of private parking in multi vehicle households and 86% of parking in single-vehicle households can potentially be equipped with electricity (Windisch 2012). In Denmark 46% of multicar households have electricity available at the private parking already, 37% can make it available and a further 14% can make it available with some difficulty. Only 3% cannot. For single-vehicle households the numbers are somewhat lower (Hjorthol et al. 2014).

Those who have parking may not be able to park more than one vehicle. Even if electricity is available or can be made available, charging more than one vehicle may not be possible.

10 Proliferation of electric vehicles

The main research question of COMPETT was:

"How can e-vehicles come into use to a greater degree?"

An increasing BEV market share requires that dealers and leasing companies actively promote BEVs, and that consumers and fleets chooses EVs. They will only do so if they find it beneficial. The main factors to make the consumers (or fleets) interested in EVs are (figure 10.1):

1. *Their attitudes and values,* which make them more (environment, technology) or less (traditionalist) interested in EVs. How these values limit or support a decision to buy an EV, will be influenced by the other four factors.
2. *Consumers need to know about EVs*, i.e. be aware of the BEVs characteristics, through reliable information sources such as authorities, organisations, vehicle manufacturers and importers, and through testing the vehicles.
3. *The vehicles need to be practical, reliable, and economically viable* and meet the users' needs. Users must have parking with electricity available. The practicality depends on household type (single-/multi-vehicle), availability of types, makes and models, and country specific factors such as driving distances and climate.
4. *The policy framework should be stable over time* to reduce risk for market actors, i.e. consistent in scope and communication, but also flexible to allow for unexpected developments, and wide in scope to allow for business creativity.
5. *Incentives will improve the purchase process* by reducing the price disadvantage, and provide users with relative advantages. Low tax on electricity, high tax on fossil fuels and the low energy consumption of EVs are parts of the picture. Consumers may think primarily in a short-term perspective, and need to see that EVs are favourable 3-5 years ahead. Local incentives can provide enough relative advantage to get diffusion started. Public charging stations make life with an EV easier. This infrastructure may not materialize without incentives in the initial phases.

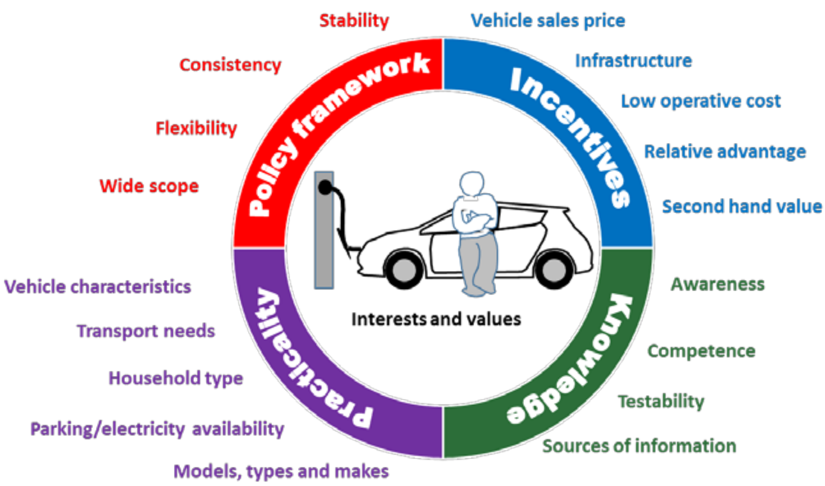


Figure 10.1 Main factors influencing the EV diffusion process.

Most of the learnings in the COMPETT project are about BEVs. PHEVs have not been on the market as long as the BEVs, and relatively few consumers in Norway have bought them when compared to the sales of BEVs. The basic model sketched above and in figure 10.1, will apply also to PHEVs. FCEVs are not yet on the market, and the future price and characteristics of mass produced versions of such vehicles are unknown.

The diffusion of environmental technology of value for society can entail some disadvantages for the users. Thus, it is often necessary and justified for society to stimulate concerted actions between society, industry and users and to put in compensatory measures (incentives) to help the diffusion process (van den Bergh, Truffer and Kallis 2011, Jacobsson and Bergek 2011).

Whereas the slow introduction of BEVs in Austria and Denmark points to the challenges of getting BEVs into the mainstream market, the big success in Norway, although driven by incentives, points to BEVs fulfilling the transport needs of many consumers. The BEVs have been taken into use easily in Norway, are used as much as ICE vehicles, and consumers enjoy driving them once they own one. Of the BEV owners 87% will buy a BEV again and inspire their friends to buy BEVs. Only 1% say they will not buy a BEV again.

One of the main advantages of the Norwegian BEV policy is that it has led to the establishment of stable framework conditions making BEVs competitive in the market. As consumers started buying BEVs, business creativity and the large resources of importers and dealers were unleashed. Selling BEVs has become economically viable in Norway. In many ways, Norway pursues the COMPETT scenario Electromobility delight (see chapter 9.2). In Austria, a different approach has been taken. "Model regions" have been established with projects aimed at promoting BEVs, so far with limited success, as few incentives are available for consumers (Jellinek, Emmerling and Pfaffenbichler 2015).

In mature BEV markets, more range and an improved selection of vehicles will be important factors for further diffusion. In immature markets, cost reductions will be more important to get diffusion started.

More knowledge about low operative costs, real range in relation to travel habits, the life of batteries, and the second-hand value of vehicles are also important factors for consumers. Vehicle manufacturers should release more information on these issues to improve consumer confidence in the EV technology. Once diffusion gets going, the information spreads between neighbours, friends and family.

For countries still in an early phase of promoting BEVs, such as Austria, the COMPETT project has shown that the potential for BEV uptake is promising. BEVs are already a real option for the majority of peoples' everyday trips and trip chains. However, the market will not take off unless BEVs' relative disadvantages to the ICE vehicles, i.e. the extra cost, limited range and long charge times, are reduced by incentives in the initial market launch phase. The lack of knowledge in the population at large must be addressed through awareness raising activities.

The 2015 level of BEV market penetration in Austria is more similar to that seen around Europe than the market penetration Norway is. However, the degree of transferability of the Austrian findings to other European settings depends on local factors such as culture, legislative framework, public finances, taxation regimes, and many more. The COMPETT simulations for Austria suggest that purchase incentives (modelled as VAT exemption) will play a much stronger role in building an initial BEV market than is the case for the continued expansion of BEVs in

Norway, which also has the registration tax system to reduce the BEV price disadvantage. Local incentives such as bus-lane access, which had a huge positive impact on the Norwegian BEV stock, may not be as effective in Austria according to simulations done using the SERAPIS model (Fearnley et al. 2015).

The high market penetration in Norway has been achieved through a broad package of clear, stable and predictable incentives, equalizing the cost of BEVs with conventional vehicles, providing preferential treatment with respect to parking, toll road exemptions, and access to bus lanes, as well as support for the public charging stations, see table 10.1. Technological advances and increased availability of makes and models have also had an impact.

Table 10.1 EV characteristics and policies and incentives influencing diffusion of EVs in Norway. Source: COMPETT Team (2015)

Factors influencing diffusion	BEV characteristics	Fiscal incentives	Local incentives	Other incentives
Relative advantage	Energy efficiency Low operative costs High purchase price	Exemption from VAT and registration tax	Free toll roads and ferry fees	Renewable electricity abun-dantly available at low cost in Norway
		Lower annual tax	Free parking/charging	
		Low company car tax	Access bus lanes	
Compatibility with existing values	Environment friendly Energy efficient No GHG emissions	BEVs in Climate pro-position and Transport Policy		Renewable electricity abun-dantly available at low cost in Norway
Simplicity and ease of use	Easy to drive Complex to charge (due to different plugs, standards) Limited range	Support of charging infrastructure	Build charging stations	Dealers supporting charging Roaming between operators Standardisation
Trialability (ability to test)	Need test to evaluated range limitation vs travel need	Support organisations	Events where one can try a BEV	Social networking, friends Dealer availability
Observability	Special design of many BEVs	BEV number plate	Free parking Charging stations Bus lanes	Info webpages made by organisations, government

There is limited evidence of synergies between the Norwegian incentives. Instead, they address different local needs and opportunities to grow the BEV market. Due to these incentives, the Norwegian BEV market is not limited to major cities, but is expanding across the whole country. Anchored in national policies, the Norwegian BEV incentives apply to all parts of the country. This situation has reduced the perceived risk for market players like car importers. Market actors could use their creativity when marketing BEVs to consumers. The government has signalled a gradual reduction of incentives when technology improves and the cost of vehicles goes down, but it shall remain beneficial to buy BEVs.

Austria has followed a path that relies less on market mechanisms than Norway. It is more top-down with great responsibility and initiative lying with the e-mobility regions rather than general consumer incentives in the market. Fleet vehicles are entitled to limited national purchase incentives. The Austrian BEV market has increased during the latest years, but the Norwegian market is roughly 10 times larger.

The diffusion of technologies normally follows an S-shaped curve (when they are successful). The Norwegian and Austrian positions on the curve, figure 10.2, indicate that the Austrian BEV market can experience increased growth rates for a long time. The Norwegian market, will be reaching an inflection point with declining growth sooner. Increasing the number of makes and models would have the effect of lifting the market saturation level leading to an increase in the BEV's share of the total fleet.

Incentives essentially move sales forward in time so that the steep part of the curve will be reached earlier.

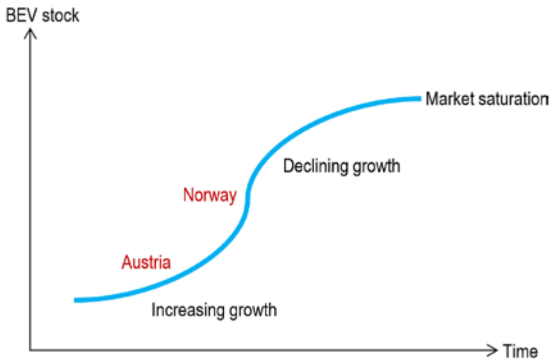


Figure 10.2 Schematic illustration of market saturation curve and Norway's and Austria's position. Source: Fearnley et al. (2015).

Policies addressing the purchase price of BEVs are found to be the most effective. They contribute significantly to BEV market shares, but they are costly. Without any adjustments to purchase taxing regimes, BEV purchase subsidies or tax exemptions may place heavy burdens on public budgets. On the other hand, BEV access to bus lanes is associated with close to zero cost and noticeable effects on BEV sales in urban and suburban areas, as long as bus lanes have spare capacity. The market growth, however, also relies on factors such as advances in technology and diffusion mechanisms that can only in part be managed by policy intervention.

Crucial implementation issues include the formulation of cost-effective policies, strategies to recover fiscal tax revenue, a broad perspective to gain support and manage barriers, and a plan for phasing in and eventually phasing out costly incentives. Cost-effective policies should be the first to be introduced, and the last to be withdrawn. Inefficient policies and those that could be harmful to other parts of society should be avoided, e.g. bus-lane access only makes sense when there is spare capacity in these lanes.

In general, nations are better off introducing incentives late than early. But if every nation does so, the costs may not come down and the BEV market may not develop, as seen in table 10.2.

Table 10.2 Effects of combinations of incentives in different nations. Source: Lindberg and Fridstrøm (2015).

	Nation A introduces incentives early	Nation A introduces incentives late
Nation B introduces incentives early	Cost will be shared, and the BEV market will develop fast	Nation A saves money, but will be lagging behind in the development of BEV based transport Nation B will pay most of the cost, but will get closer to a BEV based transport sector.
Nation B introduces incentives late	Nation B saves money, but will be lagging behind in the development of BEV based transport Nation A will pay most of the cost but get closer to a BEV based transport sector.	BEV technology and market do not develop. Costs do not decline, and manufacturers may abandon the technology

A joint international effort will be called for to unleash the full potential of BEVs at minimum cost and with maximum benefits to the nations and the environment.

COMPETT learnings on taking BEVs into use to a greater degree

- Important real barriers to BEV diffusion are range, price, awareness, and the availability of charging infrastructure. Society can support BEV diffusion by introducing flexible policies and incentives that reduce these barriers.
- BEVs can cover a large share of people's transportation needs. The current selection of BEVs and their characteristics match people's needs better than before. A larger selection of vehicles will stimulate future diffusion.
- Multi-vehicle households and fleets have the best ability to adopt BEVs.
- BEV owners mainly charge at home in private parking places. Some owners do soat work. Charging in other public locations is rare, and on average, the owners fast-charge 14 times per year. Public infrastructure can extend the range of BEVs and increase their usefulness.
- Government costs will be significant when economic incentives lead to a rapid take-up. Smart policy formulation can reduce the burden on public budgets. Purchase incentives can be offset by progressive taxes on polluting vehicles.
- Awareness raising and schemes to allow testing are important in the early phase of BEV diffusion but will not lead to significant sales unless coupled with incentives. Later in the diffusion process, there are new potential customer groups who have scarce knowledge of BEVs. A national communication strategy will therefore be a valuable tool in speeding up EV diffusion. An important part of such a communication plan will be to spread information about BEV assets such as a comfortable ride, the high energy efficiency leading to low energy costs and the advantages of being able to charge at home.
- User incentives providing BEV owners with a relative advantage, can be very effective in the absence of purchase incentives; an example is access to bus lanes, free parking and free toll roads (or congestion charges).
- Incentives only work effectively when vehicles are available from several manufacturers, and consumers have become aware of the BEV's assets. The neighbourhood effect speeds up diffusion in the early majority group
- Policies should be carefully planned and implemented as a stable national framework involving organisations and industry as well.

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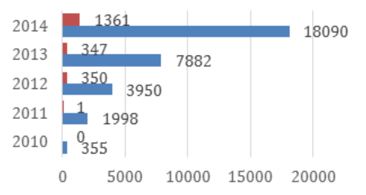
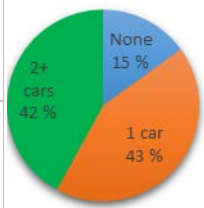
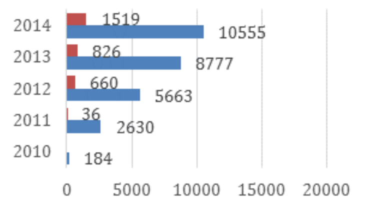
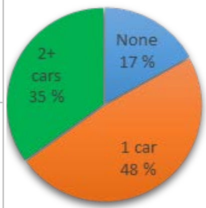
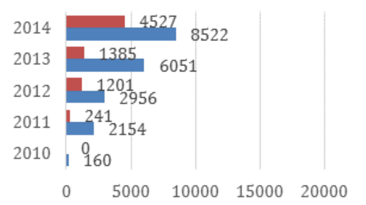
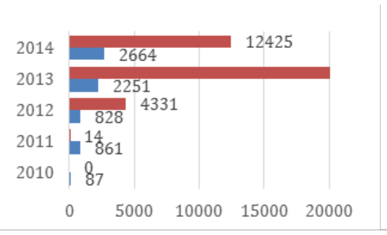
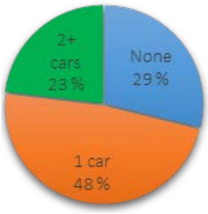
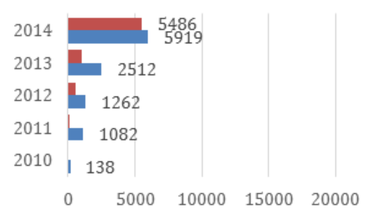
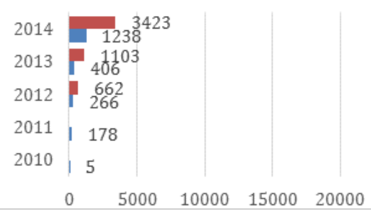
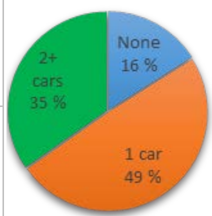
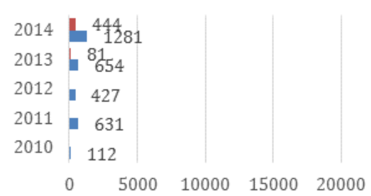
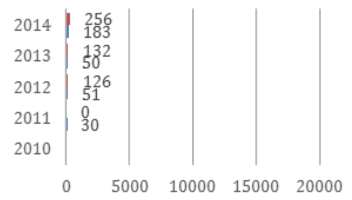
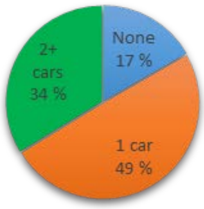
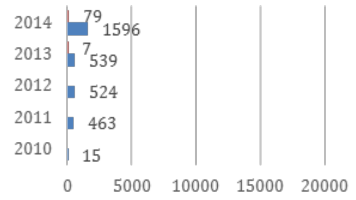
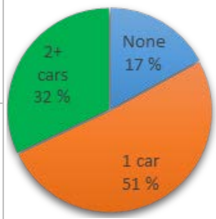
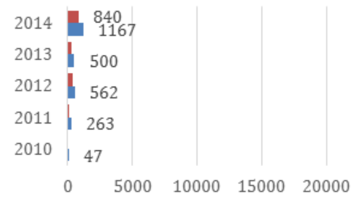
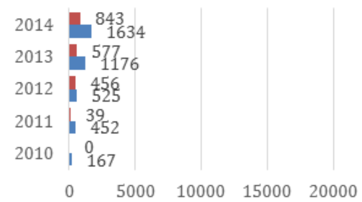
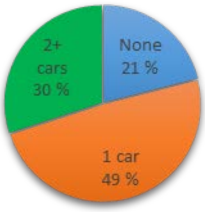
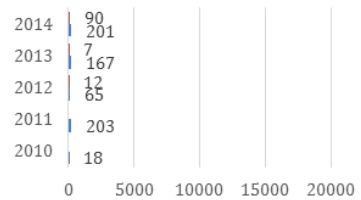
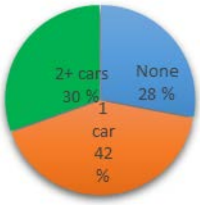
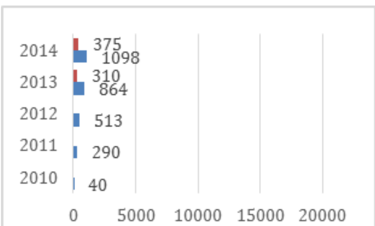
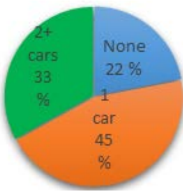
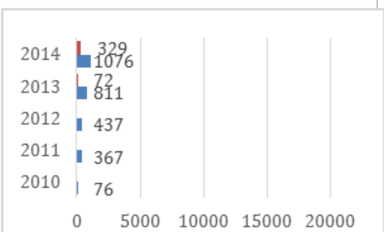
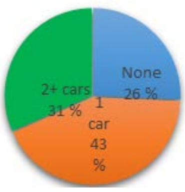
Appendix I: Market characteristics of European countries

	BEV and PHEV sales EV PHEV	BEV fleet 31.12.2014 PHEV fleet 31.12.2014	BEV 2014 Market share Change	PHEV 2014 Market share Change	Vehicles in households Estimate	Parking availability in house-holds Estimate	Charging stations 2014 Normal Fast	Share of consumers buying new BEVs 2014
Norway		38653 BEV + 1624 L7e 2059 (Estimate)	12.5% +130%	0.9% +290%		83%	5000 Schuco 400 Type 2 138 Chademo 76 Combo 132 (Tesla)	80% Also in fleet
France			0.6% +20%	0.1% +80%		68%	7200 200 Fast 1200 Semifast	36% private 37% dealers and car manufacturers 24% businesses
Germany		18948 776	0.3% +40%	0.2% +230%		63%	4800 100	8%, 2012 14%, 2013 25% (2014)
The Netherlands		6825 36937	0.7% +20%	3.2% -40%		42%	5421 Public 6439 Semip. 28000 Private 254	
UK			0.2% +140%	0.2% +460%		67%	2308 887 fast 4776 Semi	39% BEV+PHEV
Sweden		2106 4850	0.4% +200%	1.1% +70%		74%	219 Schuko 389 Type 2 112 Type 1 Chademo 61 58 CCS/COMB 96 Tesla	10% BEV+PHEV (17% of fleet)
Austria		3386 776	0.4% +200%	0.2% +100%		69%	1283 Schuko 816 other 18 Chademo 3 Tesla	

	Purchase incentives	Ownership incentives	User incentives	Infrastructure incentives	Other incentives
Norway	BEV exemption from 25% VAT: 20% price reduction BEV: Exemption from registration tax. Typically: Compact ICE tax 6000€, Small ICE tax 2000€ PHEV: reduced registration tax: Compact PHEV tax down to 500€	BEV Reduced annual tax: Saving about 300€ per year BEV: Reduced company car tax	BEV Bus lane access: Value of time 30€ per hour. Average savings 900€ per EV per year BEV Free toll roads and Reduced rates ferries BEV: Free park and charge PHEV: Access to charging stations	Support for public normal chargers Support for public fast chargers	Specific BEV number plates: Increased visibility, reduce control cost of incentives
France	Ecological bonus: 6300€ per BEV/PHEV with maximum 20 g CO2 per km. 4000€ per PHEV 21-60 g per km, 2000€ per PHEV/HEV/ICE 61- 110 g per km. Malus on vehicles emitting >130 g CO2 per km Planned:10000€ per BEV when scrapping old diesel		Travel restrictions on old diesel ICEs planned to be introduced in Paris 01.01.2016.	Regional support programs for charging stations. Proposal: Tax credit covering 30% of private persons installation and equipment cost when installing charge station in garage/parking area	Local purchase incentives available in Paris (taxis, 2-wheelers) Poitou-Charentes, Haute-Normandie, additional places for utility vehicle,
Germany	None up to 2015. A measure to reduce taxes on company cars is being prepared, "Sonder-AfA" 50% of purchase cost shall be possible to write off 1st year for BEVs and PHEVs.	Electric vehicles are exempted from annual registration tax for 10 years (vehicles registered up to 31.12.2015) and 5 years after until 31.12.2020. Value: Typical 100-200€ per year per vehicle	National law is being changed to make free parking and access to bus lanes possible. Cities and regions will take decision to use these incentives or not.	Regional projects	Special EV number plates to be introduced
Netherlands	Registration tax exemption worth for example 2599€ compared with gasoline with 110 g per km CO2-emission and 8599 for vehicles emitting 160 g per km. PHEVs pay 6€ per g CO2 emission + 175 €.	Income tax on benefit on company/lease car: BEV (0 g per km CO2) 4% of value, PHEV 7% of value (up to 50 g per km) then progressively increasing to 25% when over 110 g per km. BEVs and PHEVs less than 50 g per km pay no annual tax	Preferential parking available in Amsterdam and Rotterdam Free parking available some places	Fast charging network of 200 stations installed along main roads with government support. Support in Rotterdam for home charger installations	Regional or local incentives can be available for purchase of vehicles.
UK	Up to 25% of extra cost limited to 5000£ Plug in vehicle grant to BEVs and PHEVs Up to 20% of extra cost limited to 8000£ Plug in Van grant to electric Vans	No vehicle excise duty (an annual tax graduated after emissions for other cars) Enhanced capital allowance for fleets Exemption from company car tax for 5 years	Exemption from London congestion charge (savings up to 2000£ per year) Some London Boroughs offer free parking for BEVs. Bus lane evaluated, not on the agenda for London. New program cities: Local measures in a bid for 35 mill£ government support	Consumers owning BEVs can get 900£ incentive for private charge points. Support for public charge stations in general, Support for charge stations in car parks at railway stations and at public buildings (up to 7500£)	Support scheme available to cover additional costs for Electric Vans in public procurements
Sweden	4600€ grant (Supermiljöbilspremie) for private consumers (and companies with some max restrictions) when buying BEVs and PHEVs with CO2-emission below 50 g per km	Exemption from annual tax 5 years (Vägtrafikskatt). 40% reduced company car tax compared with the tax on similar ICE vehicles but tax cannot be less than about 1850€ per year	Free parking in many municipalities (30ish) and electricity for free in public charge stations.	10.000 public charge stations to be supported with up to 2150€ per charge pole max 50% of cost under the period 2015-2018 with a total budget of 21 million €.	Common procurement of EVs (Elbilsupphandling)
Austria	(CO2-Emission (in g/km)- 90)/5 = tax rate (max, 32%). All vehicles 400 Euro deducted, 600 for hybrids and other, BEVs exempted. Calculated from net price minus all taxes, always positive. For private persons: Exemption from purchase tax: Gasoline/130 g CO2/1.5 liter: 52Euros. Local incentive available several states	Exempted from annual insurance tax. ICE vehicles are taxed: 100 kW engine: 540 Euros per year.			For fleets: 2000/4000 Euro for BEVs. PHEV 500/1000 Euro over 70 g per km, 1000/2000 Euro for 35-70 g per km, below 35 g per km 1500/3000 Euros. The highest with eco electricity

	BEV and PHEV sales BEV PHEV	BEV fleet 31.12.2014	BEV 2014 Market share Change	PHEV 2014 Market share Change	Vehicles in households Estimate	Parking availability in households Estimate	Charging stations 2014 Normal Fast	Share of consumers buying 2014
Finland		360	0.2% +270%	0.2% +90%			603 normal +1.5 million engine block heater points 65 Fast 130 Semi	15% (BEV 2011)
Denmark		2979	0.8% +200%	0.04% +1029%		73%	1400 Type 2 59 Chademo 32 Combo 16 Type 2	33% BEV (2014, 1-10) 22% of all BEVs sold up to oct 2014
Belgium		1792	0.2% +130%	0.2% +160%		61%	416 28	29% priv. 53% leasing 18% company leasing of BEV fleet march 2014
Switzerland		4439	0.5% +40%	0.3% +50%		85%	930 70	
Portugal			0.14% -11%	0.06% +950%		54%		
Italy			0.08% +22%	0.03% +16%		60%		
Spain			0.13% +13%	0.04% +386%		49% (garage)		

	Purchase incentives	Ownership incentives	User incentives	Infrastructure incentives	Other incentives
Finland	5% purchase tax for BEVs. Other vehicles: 110 g per km=18.3%. Tax is on retail value of vehicle including VAT. Example: VW E-Up 1344 Euro, Gasoline Groove Up w. ASG: 2661 Euro.	Reduced annual tax, BEV: 1,5 Eurocent per day per 100 kg = 82 Euro per year when EV of 1500 kg. Diesel 1500 kg: 300 Euro per Year Gasoline 110 g per km: 93 (http://www.finlex.fi/fi/laki/ajantasa/2003/20031281)	50% discount on parking fees in Helsinki (also available for various other types of low emission vehicles)	None, built out by private companies	None
Denmark	BEV Exemption from the value based registration tax. Small vehicles have very low registration tax so little effect on small BEVs competitiveness. Opposite situation for large luxury BEVs where the competing vehicles are heavily taxed.		Law is being changed to allow local governments to introduce free parking and charging	Vejdirektorat issues tenders for fast chargers along motorways, otherwise private initiatives and there is user payment for all charging.	
Belgium	BEVs are exempt from registration tax in Flanders. “Ecology premiums” are available in Flanders for companies investing in the purchase of BEVs, PHEVs	BEVs pay the lowest rate of tax under the annual circulation tax in all three regions of Belgium.			The deductibility from corporate income of expenses of use of company cars is 120% for BEVs and 100% for PHEVs (1 to 60 g per km of CO_2). Above 60 g per km, it decreases from 90% to 50%.
Switzerland	Exemption from 4% purchase tax. Low VAT (8%) reduce EV on-costs.	Lower annual tax offered locally, level is decided by Kantons. Some places 50% reduction.	None	No public incentives. Some utilities offers free parking and charging.	None
Portugal	BEVs are exempt from the registration tax ISV Hybrid vehicles benefit from a 50% reduction of the registration tax.	BEVs are exempt from the annual circulation tax.			
Italy	15% of vehicle priced, maximum 3500€, subject to funding by the government	Exempted from annual tax (Bollo and Superbollo) over 5 years, thereafter 75% reduction. Value could be around 250€ per year. Some regions (Piemonte and Lombardia) offer permanent exemption.	Exemption from Milan congestion charge (5€ per day) Free parking in certain zones in Milan. BEVs can be used on days when traffic is blocked due to air pollution	Plan to develop a national infrastructure for EVs starting with urban areas, expanding with charging stations at petrol stations. Local authority must establish plans for charging infrastructure in support of new business activities and manufacturing locations.	Planning laws require new buildings with over 500 m2 floor space to have infrastructure in place that is suitable for connection of a car from each parking and garage (not public buildings or residential buildings)
Spain	Movele 2014: Aid of 6500 Euro for BEVs/PHEVs with 90 km or more range, PHEVs/EVs with 40-90 km range: 5300 Euro, 15-40 km range: 3500 Euros. Approved in June 2014, budget 10 million Euros. 2015 to be announced in March, retroactive from January.	Up to 75% reduction in the annual tax which is determined locally within min and max limits set by the national government.	Some places there are cheaper parking rates. In Madrid parking is free, saving up to 1300 Euros per year		New public car parks: 1 in 40 places to be Charging station, for private parkings: prewiring

Appendix II Vehicles and parking availability in households

The data is collected for different years, and has for some countries significant uncertainty due to a large variety of sources. The year of data for parking facilities is considered not to be so critical as the share having parking in the large number of households changes little over time. Vehicle ownership on the other hand can change significantly over a 10-15 year time frame and the year of collection has been presented. Data sources for these tables are presented in Appendix III.

Table A.II.1

	Data from travel surveys, housing, energy, living conditions or economic statistics								Resulting estimate	
	Parking at home possibility for those that have 2+ vehicles	Parking at home for those that have 1 vehicle	Parking garage/ driveway for households that have 1+ vehicles	Parking at home possibility own property total all households	Garage at home household s with 1+ vehicles	Garage at home Total all house-holds	Parking at home possibility 1 vehicle for those that own 2+ vehicles	Parking at home possibility 2+ vehicles for those that own 2+ vehicles	Parking estimate singe car house-hold	Parking estimate share of multi car household
Cyprus										
Malta						46 %			70 %	86 %
Norway	95 %	86.30 %	90.60 %	83 %		58 %			86 %	95 %
Ireland			85 %						80 %	92 %
Luxembourg						66 %			91 %	98 %
France	77.0 %	62.50 %	67.50 %						63 %	77 %
Sweden				73.50 %					76 %	89 %
Finland										
Italy	79 %	62,03 %	69 %	60 %			49 %	29 %	62 %	79 %
Denmark	93 %	73.5 %	81 %	73 %	60 %	53 %			73 %	93 %
Spain						48.90 %			73 %	88 %
UK	86 %		68.6 %	67 %		41 %			62 %	86 %
Portugal				54 %					56 %	78 %
Iceland				53 %					55 %	77 %
Switzerland	95.0 %	89.30 %	91.60 %				13,8 %	81,1 %	89 %	95 %
Germany				63 %					65 %	83 %
Slovenia						48 %			73 %	87 %
Belgium				60.50 %					63 %	82 %
Austria			81 %	69 %	59 %	51 %			76 %	89 %
Greece			47 %	34 %		13.40 %			36 %	67 %
The Netherlands				42 %					44 %	71 %
Estonia										
Lithuania										
Croatia										
Poland										
Check Republik										
Bulgaria										
Slovakia										
Latvia				24.50 %					26 %	59 %
Romania										
Hungary										

Table A.II.2, Vehicle ownership data

	Number of households 2013	Number of households with 1 vehicle	Number of households with 2+ vehicles	Number of household with no vehicles	Year of vehicle owner-ship data	1 car	2+ cars	None	Parking estimate singe car household	Parking estimate share of multi car household
Cyprus	298400	94593	170088	33719	1999	32 %	57 %	11 %		
Malta	150800	46597	80678	23525	2010	31 %	54 %	16 %	70 %	86 %
Norway	2224151	956385	934143	333623	2009	43 %	42 %	15 %	86 %	95 %
Ireland	1707400	691497	715401	300502	2011	41 %	42 %	18 %	80 %	92 %
Luxembourg	220100	104988	86279	28833	2007	48 %	39 %	13 %	91 %	98 %
France	27923000	13486809	9745127	4718987	2013	48 %	35 %	17 %	63 %	77 %
Sweden	4623300	2279287	1604285	739728	2012/13	49 %	35 %	16 %	76 %	89 %
Finland	2571000	1275216	866427	429357	2010/11	50 %	34 %	17 %		
Italy	25475700	11464065	8406981	5604654	2014	45 %	33 %	22 %	62 %	79 %
Denmark	2339100	1192941	748512	397647	2010/13	51 %	32 %	17 %	73 %	93 %
Spain	17418500	7437700	5504246	4476555	2007	43 %	32 %	26 %	73 %	88 %
UK	27232000	11982080	8441920	6808000	2012	44 %	31 %	25 %	62 %	86 %
Portugal	4005200	1663920	1219824	1121456	2010	42 %	30 %	28 %	56 %	78 %
Iceland	124000	70928	37200	15872	2009/11	57 %	30 %	13 %	55 %	77 %
Switzerland	3553711	1741318	1066113	746279	2010	49 %	30 %	21 %	89 %	95 %
Germany	40342800	21462370	11780098	7181018	2008	53 %	29 %	18 %	65 %	83 %
Slovenia	854700	410256	239316	205128	2002	48 %	28 %	24 %	73 %	87 %
Belgium	4644600	2554530	1300488	789582	2012/13	55 %	28 %	17 %	63 %	82 %
Austria	3704400	1889244	963144	852012	2009/10	51 %	26 %	23 %	76 %	89 %
Greece	4414500	2008598	1063895	1342008	2011	46 %	24 %	30 %	36 %	67 %
The Netherlands	7549500	3646409	1751484	2189355	2011	48 %	23 %	29 %	44 %	71 %
Estonia	555500	247198	76659	221645	2012	45 %	14 %	40 %		
Lithuania	1309800	650971	176823	482006	2009	50 %	14 %	37 %		
Croatia	1665300	975866	194840	494594	2011	59 %	12 %	30 %		
Poland	13660100	6556848	1502611	5600641	2012	48 %	11 %	41 %		
Check Republik	4582800	2612196	426200	1544404	2009	57 %	9 %	34 %		
Bulgaria	2729500	1228275	188336	1312890	2007	45 %	7 %	48 %		
Slovakia	1810500	773152	113993	923355	2012	43 %	6 %	51 %		
Latvia	833100	280755	30825	521521	2008	34 %	4 %	63 %	26 %	59 %
Romania	7451700	1825667	223551	5402483	2005	25 %	3 %	73 %		
Hungary	3757100	1502840	75142	2179118	2014	40 %	2 %	58 %		
Total	219732262	103113496	59734628	57020496		26 %	47 %	27 %	64%	82%

Appendix III References used for Annex II data and figures in the report

Numerous data-sources have been used to compile the data in this report. For the various countries relevant sources of information have been listed below.

Overview

Total vehicle fleet:

- ACEA publishes monthly vehicle sales numbers for all countries in Europe, which has been used in the calculation of BEV market shares. http://www.acea.be/statistics
- http://www.theicct.org/european-vehicle-market-statistics
-

BEVs and PHEVs sales

- National statistical offices, vehicle importers associations, transport authorities is the main and preferred source.
- ACEA occasionally publish BEV and PHEV sales statistics, for some countries the statistics is unreliable. Have been used where information from above mentioned sources are not available. http://www.acea.be/statistics/tag/category/electric-and-alternative-vehicle-registrations.
- Other sources:
  - The industry news blog: www.insideevs.com
  - Blog about new plug in vehicle sales: http://ev-sales.blogspot.no/
  - Manufacturers press releases on vehicle sales.
  - http://www.theicct.org/european-vehicle-market-statistics
  - http://ev-observatory.eu/
-

BEV and PHEV incentives:

- COMPETT documents: Figenbaum et al. (2014), Figenbaum and Kolbenstvedt (2013), Figenbaum, Assum and Kolbenstvedt (2015), Krutak et al. (2015), Fearnley et al (2015)
- ACEA publishes yearly information about BEV incentives in European countries,
- D2.1-Market Review MOBI.EUROPE 2012.
- Electric vehicles, Europe in Brief, U.S. Commercial Service Global Automotive Team, 2010-2011 edition,
- Mock, P. Yang, Z, Driving Electrification – A global comparison of Fiscal incentive policy for Electric vehicles. ICCT 2014.
- Press articles, conference papers
- https://en.wikipedia.org/wiki/Government_incentives_for_plug-in_electric_vehicles

Households vehicle ownership:

- Travel surveys have been used in countries where such surveys are available and are not mentioned specifically below..
- Population censuses from national statistical offices
- Housing and energy statistics from national statistical services

Households and parking:

- Eurostat have statistics on households.
- EU-SILC data

Charging stations

- IEA, http://www.iea.org/topics/transport/subtopics/electricvehiclesinitiative/
- http://ev-observatory.eu/, http://www.chargepoint.com/, http://www.plugshare.com/
- Other national sources

Country sources:

Austria	Vehicle ownership, households from Statistisk Austria. www.statistik.at. STATISTIK AUSTRIA, Konsumerhebung 2009/10. Fleet: http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/verkehr/strasse/kraftfahrzeuge_-_bestand/index.html, Sales statistics: http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/verkehr/strasse/kraftfahrzeuge_-_neuzulassungen/index.html Charging stations: COMPETT: WP1 report, Krutak et al. (2015). https://www.bmf.gv.at/steuern/fahrzeuge/motorbezogene-versicherungssteuer.html
Belgium	Febiac.be http://statbel.fgov.be/fr/modules/publications/statistiques/circulation_et_transport/evolution_du_parc_de_vehicules_2014.jsp http://statbel.fgov.be/fr/modules/publications/statistiques/circulation_et_transport/immatriculation_de_vehicules_neufs_et_d_occasion_2008_-_2014.jsp http://www.mobilit.belgium.be/fr/circulationroutiere/stats/imma/2014/
Bulgaria	Vehicle ownership: UN Generations and Gender program
California	Total vehicle and BEV/PHEV sales statistics: http://www.cncda.org/
Croatia	Croatian Bureau of Statistics
Cyprus	Statistical service (of Cyprus)
Czech Republic	Ščasný, M., Urban,J. PASSENGER CAR OWNERSHIP IN THE CZECH REPUBLIC, International days of Statistics and Economics, Prague September 22-23, 2011.
Denmark	Share consumers buying EVs: www.danskelbilalliance.dk: GRØN OMSTILLING I DANMARK – OGSÅ PÅ VEJENE, http://www.danskelbilalliance.dk/Publikationer_DEA/AArspublikation%202014%20Groen%20omstilling%20i%20Danmark%20-%20Ogsaa%20paa%20vejen.aspx http://www.danskelbilalliance.dk/Statistik/Bestand_modeller.aspx De danske bilimportører: http://www.bilimp.dk/press/content.asp?id=406 http://politiken.dk/forbrugogliv/biler/ECE2380303/nedsat-p-afgift-for-elbiler-paa-vej/ http://www.statistikbanken.dk/statbank5a/selectvarval/saveselections.asp
Estonia	http://mnt.ee/index.php?id=10797; http://elmo.ee/about/
Finland	Fleet: Trafi.fi: http://www.trafi.fi/filebank/a/1424769047/939691865f74e703ffd55d7e89bdfb21/16934-Sahkohenkiloautot_31_12_2014.pdf, http://www.trafi.fi/tietopalvelut/tilastot/tieliikenne/ensirekisteroinnit/ensirekisterointien_paastotilastot/vuosi_2014 Chargemap.com 03.02.2015; IEAHEV, http://www.lapinkansa.fi/Kotimaa/1194741487014/artikkeli/yksityisilla+vain+viisi+sahkoautoa.html?utm_source=twitterfeed&utm_medium=twitter National Travel Survey 2011. http://www.sahkoinenliikenne.fi/ http://www.clrsearch.com/Finland-Demographics/MN/55603/Number-of-Vehicles-per-Household
France	Automobil-Propre, Share of consumers: http://www.carfutur.com/le-marche-des-vehicules-electriques-pret-a-rebondir/ Incentives : Aide à l'acquisition d'un véhicule électrique pour les particuliers, Région Haute Normandie 2014, http://www.connexionfrance.com/france-haute-normandie-normandy-renault-electric-car-zoe-subsidy-regional-council-nationwide-scheme-15650-view-article.html Incentives: Electric mobility in Paris 2014. November 2014, Mairie de Paris. Incentives: http://www.avere-france.org/, http://www.avem.fr/index.php?page=news_list

	Vehicle ownership : CCFA http://www.ccfa.fr/IMG/pdf/ccfa_ra_2014_gb_md-complet.pdf BEV registrations: http://www.automobile-propre.com/dossiers/voitures-electriques/chiffres-vente-immatriculations-france/, http://www.avere-france.org/ http://www.statistiques.developpement-durable.gouv.fr/transports/trv/deplacement-mobilite/mobilite-longue-distance.html http://evfleetworld.co.uk/news/2014/Aug/France-to-offer-10000-euros-scrappage-for-EV-purchases/0438015820 http://www.diplomatie.gouv.fr/en/french-foreign-policy/economic-diplomacy-foreign-trade/facts-about-france/one-figure-one-fact/article/france-is-the-largest-electric#
Germany	Fleet: kba.de: http://www.kba.de/DE/Presse/Pressemitteilungen/2015/Fahrzeugbestand/pm5_fz_bestand_pm_komplett.html?nn=646300 New vehicle, BEV and PHEV sales: kba.de: http://www.kba.de/DE/Statistik/Fahrzeuge/Neuzulassungen/neuzulassungen_node.html, www.goingelectric.de Share consumers buying BEVs: KBA.de Housing and mobility: ADAC, Deutsches Mobilitätspanel (MOP), Statistiches Bundesamt, http://daten.clearingstelle-verkehr.de/223/ Gesetzesentwurf der Bundesregierung: Entwurf eines Gesetzes zur Bevorrechtigung der Verwendung elektrisch betriebener Fahrzeuge (Elektromobilitätsgesetz – EmoG) http://nationale-plattform-elektromobilitaet.de/ http://www.electrive.net/studien/
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Ireland	National Transport Authority National Household Travel Survey 2012, Ireland 2011 (this is Ireland)-Statistical tables, National travel survey 2009 Eakins, J. The Determinants of Household car ownership: Empirical evidence from the Irish Household Budget Survey, No. 2013, SEEDS 144. School of Economics University of Surrey EV sales by model: http://www.beepbeep.ie/stats
Italy	BEV and PHEV sales: http://www.unrae.it/ Parking: Population and housing census, http://dati-censimentopopolazione.istat.it/?lang=en#. Gli automobilisti pagano allo Stato 44 mld l'anno, 2005, Automobile Club d'Italia, 62a Conferenza del Traffico e della Circolazione http://www.aci.it/ http://carloiacovini.net/english/electric-mobility-in-italy-overview-and-potential-growth/ http://www.tax-news.com/news/italian_parliament_to_propose_electric_car_incentive____55650.html http://www.osborneclarke.com/connected-insights/publications/incentivazione-della-mobilita-bassa-emissioni/
Japan	http://www.jama-english.jp/, www.insideevs.com, http://evn.blog.eonet.jp/; http://www.jada.or.jp
Latvia	Vehicle ownership: Latvijas Statistikia, Households: http://catalog.ihsn.org/index.php/catalog/3225/related_materials
Lithuania	Vehicle ownerhip: UN Generations and Gender program; http://www.ggp-i.org/online-data-analysis.html Raslavičius, L. et al., 2014, Electric vehicles challenges and opportunities: Lithuanian review, Renewable and Sustainable Energy Reviews
Luxembourg	Sebastien Petit. Le processus de d_ependance automobile au Grand-Duch_e de Luxembourg. Population et territoire. 2007. <halshs-00259397>

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Norway:	Charging stations: Gronnbil.no: http://www.gronnbil.no/ladepunkter/ EVs sold and registered: Spread sheets from elbil.no, OFVAS.no with data from the central vehicle register containing EVs in fleet and EVs sold, PHEVs sold/registered from gronnbil.no: http://www.gronnbil.no/statistikk/?lang=en_US; Statistics also provided by: OFVAS.no and the Norwegian public roads administration. Parking availability, ssb.no housing census 2001: https://www.ssb.no/statistikkbanken/selectvarval/Define.asp?subjectcode=&ProductId=&MainTable=FoBBolig12Avrund&nvl=&PLanguage=1&nyTmpVar=true&CMSSubjectArea=befolkning&KortNavnWeb=fobhushold&StatVariant=&checked=true Vehicles in households: National travel survey 2009. https://www.toi.no/getfile.php/Publikasjoner/T%C3%98I%20rapporter/2011/1130-2011/1130-2011-el.pdf Incentives: Figenbaum et al 2014 and Figenbaum and Kolbenstvedt 2013.
Poland	Central Statistical office: Energy consumption in households 2012. 2014.
Portugal	Vehicles in households: Inquérito ao Consumo de Energia no Sector Doméstico 2010, Estatísticas oficiais, Parking: Statistics Portugal, www.INE.pt Estaticas dos Transportes e comunicacoes 2012, Estatísticas oficiais,
Romania	Vehicle ownerhip: UN Generations and Gender program; http://www.ggp-i.org/online-data-analysis.html
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Slovenia	Parking and vehicle ownership: www.Stat.si
Spain	Movilia 2006/2007, http://www.fomento.es/MFOM/LANG_CASTELLANO/ATENCION_CIUDADANO/INFORMACION_ESTADISTICA/Movilidad/Movilia2006_2007/ 2001 population census. http://aniacam.com/datos/2012/06jun2012.php http://www.diariomotor.com/tecmovia/2014/01/02/ventas-de-coches-electricos-en-espana-2013-mucho-por-hacer/ http://forococheselectricos.com/2015/01/ventas-de-coches-electricos-en-espana-diciembre-2014.html http://www.avele.org/ http://www.elmundo.es/motor/2014/11/07/545d2719ca4741c26a8b457c.html http://costadelsol.angloinfo.com/information/transport/driving/road-tax/

	http://www.cev-pc.or.jp/event/pdf_n/japanese/8-3.pdf http://www.measures-odyssee-mure.eu/public/mure_pdf/transport/SPA51.PDF http://www.theicct.org/sites/default/files/Spain.pdf
Sweden	Vehicles sold: Bilsweden.se Fleet: http://powercircle.org/nyhet/146-procents-okning-av-laddbara-fordon-2014/ Vehicle ownership: The swedish national travel survey 2012–2013, RVU Sverige - den nationella resvaneundersökningen 2012–2013, Sveriges officiella statistikk Charging stations:Powercircle: http://laddinfra.se/start/statistik/ Downloaded 06.03.2015 Incentives: Transportstyrelsen Share consumers buying: Statistics from Grants of Supermiljøbilspremie (vehicles emitting less than 50 g/km), share of physical persons receiving grant, http://transportstyrelsen.se/sv/kontakta-oss/Vanliga-fragor-till-Transportstyrelsen/Supermiljobilspremie/. Consumers share in fleet: powersircle.se, http://powercircle.org/nyhet/146-procents-okning-av-laddbara-fordon-2014/ http://www.energimyndigheten.se/Press/Nyheter/Forutsattningar-for-att-elfordon-ska-fa-genomslag/ http://www.transportstyrelsen.se/sv/kontakta-oss/Vanliga-fragor-till-Transportstyrelsen/Supermiljobilspremie/
Switzerland	Vehicle registrations: Auto-Suisse.ch, BEVs: http://www.e-mobile.ch/pdf/2014/PW-Neuzulasssungen-CH_2012-13.pdf Bundesamt für Statistik BFS. Statistical data on Switzerland Mobilität in der Schweiz 2013 Vehicle ownership: Quelle: Bundesamt für Statistik, Bundesamt für Raumentwicklung; Mikrozensus Mobilität und Verkehr 2010 Number of households: Structural Survey / Information Service of the Structural Survey, info.pop@bfs.admin.ch http://www.bfs.admin.ch/bfs/portal/de/index/themen/11/04/blank/03/03.html Kantonale Motorfahrzeugsteuern: Rabatte für energieeffiziente Fahrzeuge 21.01.2015 / e-mobile.ch http://www.energieschweiz.ch/de-ch/home.aspx
UK	Vehilce fleet and sales: SMMT: http://www.smmt.co.uk/category/news-registration-evs-afvs/ Charging stations: www.zap-map.com Meeting Carbon Budgets – the need for a step change Progress report to Parliament Committee on Climate Change 12 October 2009 English Housing Survey HOMES 2010, The United Kingdom Statistics Authority National Statistics, including datatables on vehicle ownership and parking provisions https://www.gov.uk/government/statistical-data-sets/veh01-vehicles-registered-for-the-first-time
USA	Total vehicle and BEV/PHEV sales statistics: http://www.cncda.org/, http://insideevs.com/monthly-plug-in-sales-scorecard/ https://www.gov.uk/government/statistical-data-sets/veh02-licensed-cars

Appendix IV. Scenario assumptions

Table A.IV.1 presents the main assumptions of technology and market, used in each scenario for Norway and Austria. Table 9.2 and 9.3 present the policy assumptions for Norway and Austria respectively.

Table A.IV.1 Key characteristics of the four scenarios and the base scenario for Norway and Austria. Technology and supply factors. Source: Fearnley et al., 2015.

	Base scenario	1) Electromobility delight:	2) Wishful thinking	3) Electromobility oblivion:	4) Technology push
BEV 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 year up to 2020 followed by slower reduction	Same as base scenario	Same as base scenario	Same as base scenario	Same as base scenario

The technology push scenario generates almost as many BEV sales as the technology delight scenario indicating that there are limits to what can be achieved with individual countries' national policies. The Wishful-thinking scenario illustrates this further, as sales cannot be influenced by stronger policies without technological improvements and a larger selection of makes and models and models becoming available on the market. In a scenario of low policies and limited technological, the development of the BEV market stagnates. Government revenues and the consumption of fossil fuels and electricity develop proportionally to the BEV fleet shares.

Table A.IV.2 Key characteristics of the four scenarios and base scenario for Norway. Policy factors. Source: Fearnley et al., 2015.

	Base scenario	1) Electromobility delight:	2) Wishful thinking	3) Electromobility oblivion:	4) Technology push
VAT	0% 2005-17 8% 2018-22 13% 2023-27 25% 2028→	Base scenario developments postponed 5 years	Same as 1) Electromobility delight scenario	0% 2005-17 8% 2018-19 13% 2020-21 25% 2022→	0% 2005-17 8% 2018-19 13% 2020-21 25% 2022→
Purchase tax	Luxury BEV: from 0 to 20% 2017-21. Other BEVs: 0% Compact and family PHEVs fall to zero 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[11]	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. 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 BEV bus lane access and dedicated parking	Gradually reduction to zero in 2030	Reduction twice as fast as the base scenario, due to congested bus lanes and parking lots	Same as base scenario	Reduction twice as faster as the base scenario, due to unfavourable policy	Reduction twice as faster as the base scenario, due to unfavourable policy

[11] Cf. The Norwegian Climate Policy settlement, which states that EVs and low-emission vehicles shall be treated favourable in the tax system compared to ICE vehicles. .

Table A.IV.3 Key characteristics of the four scenarios and base scenario for Austria, Policy factors. Source: Fearnley et al., 2015.

	Base scenario	1) Electromobility delight:	2) Wishful thinking	3) Electromobility oblivion	4) Technology push
VAT	No exemption	no exemption	no exemption	no exemption	no exemption
Purchase tax	0% for all types of BEVs 2.8% instead of 6.1% Compact PHEV 5.0% instead of 7.3% Family PHEV 9.5% instead of 14.0% Luxury 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. 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 (end of) is postponed by 5 years	Same as base	Subsidies stop in 2016	Same as 3) Electromobility oblivion

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