TØI report 1420/2015

Erik Figenbaum
Marika Kolbenstvedt

COMPETT

Electromobility+

Institute of Transport Economics
Norwegian Centre for Transport Research

Vejdirektoratet
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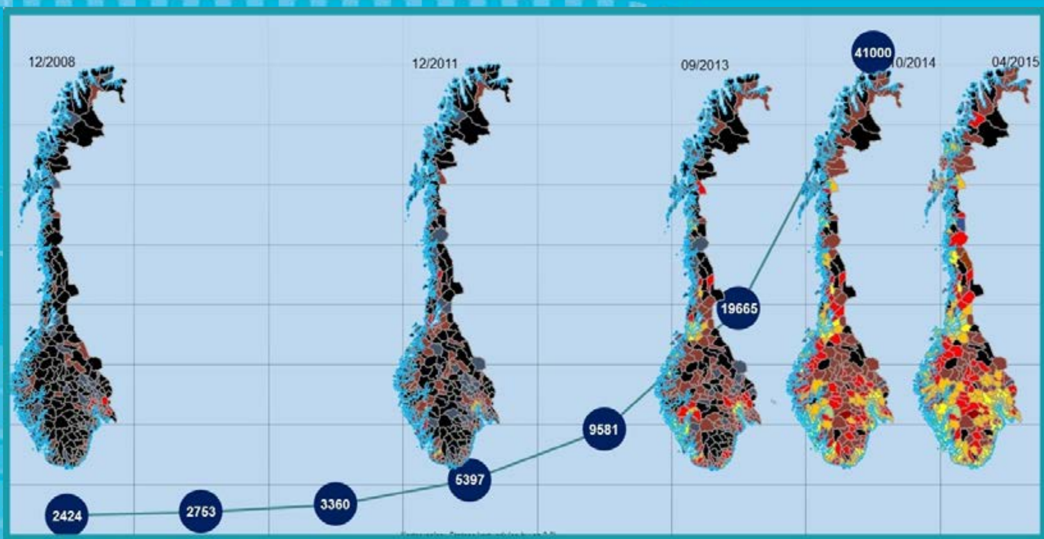
AUSTRIAN ENERGY AGENCY

Pathways to electromobility - perspectives based on Norwegian experiences



TØI Report
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Pathways to electromobility - perspectives based on Norwegian experiences

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Summary:

The report presents two analyses of the Norwegian Electric Vehicle (EV) story. The first one is using the multi-level perspective (MLP) framework to investigate how the interaction of events in and between the niche, regime and landscape levels, shaped the Norwegian EV policies that led to the world's fastest diffusion of EVs. The second one looks at user adoption from a socio-technical perspective. A long-term evolving political framework built up piece by piece by many actors and with an ability to maintain stability and focus over long time periods, seem to be ways to success. EVs qualities, incentives giving relative advantages and increased availability of vehicles were effective diffusion mechanisms. The process started in urban regions but is now covering other locations as well. Technology development leading to longer range and lower prices should make it easier for other countries to choose between the many incentives tested in Norway and develop their own packages.

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Forfattere: Erik Figenbaum
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Sammendrag:

Rapporten presenterer to analyser av den norske elbilhistorien. Den første bruker et fler-nivå perspektiv (MLP) for å se på hvordan samspillet mellom hendelser i og mellom nisje-, regime- og landskapsnivåene formet den norske elbilpolitikken og ledet til verdens raskeste diffusjon av elbiler. Den andre ser på brukernes kjøp og tilnærming fra et sosio-teknisk perspektiv. Et langsiktig, tydelig og stabilt politisk rammeverk etablert bit for bit og med evne til opprettholde stabilitet og fokus over lengre tidsperioder, synes å være gode veier til suksess. Elbilenes kvaliteter, insentiver som gir brukerne relative fordeler framfor andre biler og økt tilgang på elbiler har vært effektiv diffusjonsmekanismer. Prosessen startet i byregionene, men elbiler selges nå over hele landet. Bedre teknologi som gir lengre rekkevidde og lavere priser vil trolig gjøre det lettere for andre land å velge blant de mange insentiver som er testet ut i Norge og å utvikle egne tiltakspakker.

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Preface

This report is a part of the COMPETT project (Competitive Electric Town Transport) which is part of the ERA-NET Electromobility+ programme. Electromobility+ has initiated eighteen projects about electric vehicles concerning topics from the development of battery and charging technology to sociological investigations of the use of electric vehicles.

COMPETT is a co-operation between the Institute of Transport Economics (TØI) in Norway, The Austrian Energy Agency (AEA), the University College Buskerud and Vestfold in Norway, Kongsberg Innovation in Norway and the Danish Road Directorate (DRD). The COMPETT project is jointly financed by the EU's 7^{th} FP (Electromobility+ programme), Transnova (up to 31.12.2014), the Norwegian Public Roads Administration (from 01.01.2015), the Research Council of Norway (RCN), the Austrian Research Promotion Agency (FFG) of Austria and the Ministry of Science, Innovation and Higher Education in Denmark.

The objective of COMPETT is to facilitate the uptake of electric vehicles, particularly focussing on private passenger cars. The main question to be answered is: "How can electric vehicles come in to use to a greater degree?".

This report contains two analyses of the Norwegian electric vehicles (EV's) history. The first one, using the multi-level perspective framework to investigate the development of the framework for EVs in Norway, is presented in Part I. The second analysis, looking at user adoption from a socio-technical perspective with the theory of diffusion of innovations, is presented in Part II. The two parts can be read separately, and also have some duplicating parts or figures. However, since they supplement each other, TØI decided to publish them together.

Part I is mainly written by Erik Figenbaum with contributions from Marika Kolbenstvedt. Part II is jointly written by these two authors. Tove Ekstrøm has been responsible for the finishing. Following COMPETT's quality assurance guidelines, COMPETT partners Reinhard Jellinek, AEA and Lykke Møller Iversen, DRD have reviewed the report. Terje Assum has been TØI's quality assurer.

Oslo, May 2015

Institute of Transport Economics

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Contents

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Acronyms used in the report

EV	Electric vehicle, is used for Battery Electric vehicles
BEV	Battery Electric Vehicle, only powered by electricity
ICE	Internal Combustion Engine
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
PEV	Plug-in Electric Vehicle, includes both BEVs and PHEVs
PHEV	Plug-in Hybrid Electric Vehicle, powered by electricity recharged from the grid and ICEs fuelled by diesel or gasoline. Alternatively an ICE running as generator producing electricity used in the motor.

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Summary:

Pathways to electromobility - perspectives based on Norwegian experiences

TØI Report 1420/2015
Authors: Erik Figenbaum and Marika Kolbenstvedt
Oslo 2015, 65 pages English language

Electric propulsion is much more energy-efficient than internal combustion engines (ICEs), and electric vehicles (EVs) emit no local pollutants and greenhouse gases. Norwegian authorities have introduced a number of incentives for EV diffusion, in order to support a transition to more environmentally friendly transport. Norway is at the moment a leading EV country where 20% of the new vehicle market were EVs in the 1st quarter of 2015 and EVs constituted 2% of the total fleet of passenger vehicles. The report is a part of the Electromobility+ project COMPETT, which should answer the main question: "How can EVs come to use to a greater degree?" The report provides some insights by presenting two analyses of the Norwegian EV story. The first one uses a multi-level perspective (MLP) to look at the interaction of events and actors at the niche, regime and landscape levels. The second one looks at user adoption from a socio-technical perspective using the theory of diffusion of innovations.

Introduction

Norway has had incentives for EVs since 1990. In the beginning these incentives were put in place to allow testing and experimenting with EVs. From about the year 2000 focus shifted to support a potential growing Norwegian EV industry, whereas from 2010 and onwards the policies have been linked to the policies for reducing climate gas emissions in Norway. Purchase incentives reduce the purchase cost of EVs. EVs are exempted from the Value added tax (25%) as well as the registration tax imposed on other vehicles being registered for the first time in Norway. The result is that small EVs cost about the same as comparable gasoline and diesel vehicles in Norway whereas compact and larger EVs are cheaper. In addition EVs have access to bus lanes and free parking, they do not pay on toll roads and have reduced rates on main road ferries crossing the Norwegian fjords. Annual tax is also reduced.

Part I: A multi-level perspective on EVs in Norway

The multilevel perspective framework developed by Geels (2003) and others, centres around the concept of interaction between niche activities in the market, regimes that consist of automotive actors, stakeholders, established practises of vehicle usage and the landscape being external factors originating internationally or nationally such as oil prices and the climate policies. Niche activities may according to this framework breakthrough as a result of windows of opportunity opening up the established regime often as a result of pressure from the landscape.

The success of EVs in Norway seems to be a result of the long-term stable political framework built up piece by piece by many actors and stakeholders. Heavy vehicle taxes have given room for tax relief incentives rather than direct subsidies. There has not been much criticism of these policies. The introduction of long-term EV policies and incentives, addressing the various weaknesses of EVs, have allowed businesses to recognize and seize opportunities. The policies and incentives have been so successful that in April of 2015, Norway had 50 000 EVs, this being 2% of the total fleet of passenger vehicles in the country. Thus, Norway has become the forerunning country within electro mobility.

The framing of the policies has evolved from first allowed testing of EVs, then support to industrial development, and finally the EV policy framed as a climate mitigation measure, leading to greater acceptance of the policies. These policies gave the traditional vehicle manufacturers a head start in the Norwegian market as they established a new EV regime within the ICE regime. This new regime could utilize the effects of all the achievements and incentives built up by the independent EV regime over a period of two decades. Other countries can take inspiration from the Norwegian policies, but may need to follow other paths as different windows of opportunity may open up for them.

The EV diffusion seems to be on a *transformational path* of transformation internationally where moderate pressure on the ICE regime is leading to a gradual establishment of an EV regime. The EV regime grew out of the old regime through a reorientation of the powering of automobiles while keeping other basic vehicle features unchanged. In Norway, the policies and pressure from the landscape have been much larger, leading towards an incentive driven "*technology substitution path*".

Being a country at the forefront of electro mobility could cost more money and strain public budgets more than Norwegian politicians originally anticipated. Globally electro mobility develops more slowly compared to the rapid changes seen in Norway. This will lead to the cost of vehicles remaining higher for longer, as the total volume of EVs produced will increase at a slower rate, than if all countries had progressed at Norway's rate. It could also lead to a narrower selection of models as the automakers may delay the introduction of new models. The risk of international setbacks in EV development is, thus, the main uncertainty for electro mobility in Norway. The other major uncertainty, the revision of the incentives, will also have an inevitable impact on sales.

Part II: Diffusion of EVs in Norway

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, is the key element of diffusion. The rate of diffusion (Rogers 1995) is influenced by the perception of technology with respect to:

- *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, improved comfort, saving time or effort, immediacy of reward.
- *Compatibility* with the users' needs, basic values and norms in the social system. The more radical and disruptive technology, the less it is compatible with existing practises, norms and values, the slower its rate of adoption.
- *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.

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- *Trialability* applies to the opportunity for trial. Innovations that can be tried out on a small scale are perceived as less uncertain and easier to implement than those that require full implementation immediately. Trialability is more important for early than for later adopters. The latter will be helped by information from adopting peers.
- *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 EV adoption should address these factors, especially the first one, Relative advantage, which is the most influential in the diffusion process. The improved technology and reduced costs combined with the incentives have resulted in Norwegian EV buyers noticing that EVs have many relative advantages over ICE vehicles. The limited range is not a hindrance to adoption. Drivers learn to manage range limits. The reward is immediate as the EVs cost the same or less than ICEs, and their operative costs are much lower due to their energy efficiency and low cost energy carrier. Hence, one may claim that EVs are both climate friendly and low variable cost vehicles suitable for daily travel needs.

The diffusion process started in larger urban regions of Norway but now covers smaller cities and rural areas as well. To get the diffusion of EVs started, cities should be targeted. However, they should not be targeted when there is concern regarding an increase in traffic. Although this is a dilemma, the diffusion pattern shows that EVs spread to rural areas from the cities, suggesting that the issue is temporal.

There is potential for future growth supported by diffusion through interpersonal networks, i.e. friends, families and colleagues and the anticipated availability of new longer-range models attracting new customer groups. Technology that gives longer range at lower prices, should make it easier for other countries to support the introduction of EVs by choosing between the many incentives tested in Norway and developing their own packages.

The diffusion of EVs in Norway resembles what is expected from diffusion theory. An achievement of the EV policy is that national, regional and local governments, businesses and NGOs have been motivated to move in the same direction. The actual rate of diffusion will be heavily influenced by possible modifications to the societal and economic framework and cooperation. The Norwegian EV market is, however, dependent on the other automotive markets. If diffusion does not catch on globally or in Europe, the diffusion of EVs in Norway may slow down.

Part III: Learnings from Norway based on part I and II

The two perspectives in this report complement each other and provide a good understanding of how the EV policies in Norway came to being and how they have influenced the market actors and the vehicle buyers.

The EV policy has consistently been pro EV 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 EV communication in Norway might have inspired a greater share of the general vehicle owners to consider buying an EV compared to the general vehicle owners in other countries were the communication is more ambivalent.

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From the experience of EVs in Norway it is evident that incentives are needed to speed up diffusion whilst EVs are more expensive than ICEs. 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 EVs as other windows of opportunity may appear and they will have their own framework of vehicle policies to start from.

Incentives that address and improve on the perceived relative advantage of EVs as seen by the potential buyers will be the most effective in speeding up the adoption of EVs. In Norway it has been seen that purchase incentives have been particularly effective in speeding up adoption in combination with user incentives that give EVs a relative advantage that is not available to others.

When the price is right and vehicle buyers are aware of and see the advantages of EVs, the diffusion pattern will be similar to that of other innovations.

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Sammendrag:

Veier til elektromobilitet - perspektiver basert på norske erfaringer

TØI Rapport 1420/2015
Forfattere: Erik Figenbaum og Marika Kolbenstvedt
Oslo 2015, 65 sider, engelsk språk

Elmotorer er langt mer energieffektive enn motorer som drives av bensin eller diesel og elbiler slipper ikke ut noe lokal forurensning eller klimagasser. For å støtte en overgang til en mer miljøvennlig og bærekraftig transport har norske politikere og myndigheter derfor innført en rekke insentiver for å øke bruken av elbiler. Norge er i øyeblikket et ledende land for diffusjon av elbiler. I første kvartal 2015 utgjorde elbiler 20% av nybilsalget og elbiler utgjorde 2% av den samlede personbilflåten. Rapporten presenterer to analyser fra COMPETT prosjektet under EU's Electromobility+ program. COMPETT skulle belyse spørsmålet: «Hvordan kan man gjøre elbiler mer konkurransedyktige og øke bruken av dem?» Rapporten søker å gi noen svar ved å presentere to analyser av den norske elbilhistorien. Den første bruker et fler-nivå perspektiv (MLP) for å se på hvordan samspillet mellom hendelser og aktører på nisje-, regime- og landskapsnivåene har formet den norske elbilpolitikken. Den andre ser på brukernes kjøp og tilpasninger fra et sosio-teknisk perspektiv basert på teori om spredning av innovasjoner.

Bakgrunn

Norge har helt fra 1990 hatt en rekke insentiver for å støtte elbiler. Begrunnelsen på dette tidspunkt var å legge til rette for å teste ut og eksperimentere med elbiler, og ble fra 2000 klart uttrykt som å støtte en mulig voksende norsk elbilindustri. Fra 2010 og framover har elbilpolitikkens fokus vært koplet til klimapolitikken og målet om å redusere klimagassutslippene i Norge. Unntak fra registreringsavgift og merverdiavgift ved kjøp av elbiler redusere kjøpskostnadene for mindre elbiler til et nivå på linje med prisen til tilsvarende bensin- eller dieselbiler, mens større elbiler blir billigere enn de tradisjonelle bilene i dette segmentet. I tillegg har elbiler enkelte steder tilgang til å kjøre i kollektivfelt og til gratis parkering og ladning. Andre økonomiske insentiver er fritak for bompenger, redusert avgift for bilen på ferger og redusert årsavgift.

Del I: Et fler-nivå perspektiv på elbiler i Norge

Rammeverket for fler-nivå analyser utviklet av Geels m.fl. (2003) er ment å fange samspillet mellom aktiviteter på tre nivåer; 1) nisjenivået som viser aktiviteter og ikke minst innovasjoner i markedet, 2) regimenivået som omfatter de etablerte interessenter i bilbransjen, poltikken og den vante praksis for bilbruk samt 3) landskapsnivået som fanger de mange ytre påvirkningsfaktorer, internasjonalt og nasjonalt, fra oljepriser til klimapolitikk. Nisje aktiviteter kan i henhold til denne tankemåten få et gjennombrudd / vinne fram når et mulighetsvindu åpnes som følge av press fra landskapsnivået.

Suksessen i Norge synes å være et resultat av et langsiktig, tydelig og stabilt politisk rammeverk etablert bit for bit og som har involvert mange interessenter. Høye norske bilavgiftene ga rom for avgiftslettelser, noe som nok er lettere å få til enn nye direkte subsidieordninger. Denne langsiktigheten, insentivene og etablering av egne "elbilregimer" gjorde det lettere for den tradisjonelle bilbransjen både å se og utnytte mulighetene og å møte elbilenes ulike svakheter. Politikken har gitt resultater. I første kvartal 2015 sto elbiler for 20% av nybilsalget og elbiler utgjorde 2% av den samlede personbilflåten, noe som har gjort at Norge i øyeblikket er et ledende land når det gjelder diffusjon av elbiler.

Rammeverket utviklet seg fra tilrettelegging for testing av elbiler, så støtte til norsk industriutvikling, og til slutt en elbilpolitikk innenfor rammen av klimapolitikken. Dette synes å ha medført en høy akseptanse for politikken. De tradisjonelle bilprodusentene som etablerte et elbilregime innenfor forbrenningsmotor-regimet fikk et forsprang på det norske markedet. Dette nye regimet kunne bruke alle de fordelene det uavhengige elbilregimet hadde fått bygget opp gjennom tjue år.

Elbilregimet vokste fram fra det gamle bilregimet via en nyvinning mht. motordrivkraften, mens andre kjennetegn ved en bil forble uendret. I Norge ga mulighetene for teknologisk og miljømessig endring et sterkt press fra det politiske system, fra landskapsnivået. Også internasjonalt synes det nå å være et press på forbrenningsmotor-regimet i retning av en økt tilrettelegging for bruk av elbiler. Andre land kan bli inspirert og lære av den norske politikken, men trenger å lage sin egen vei utfra de mulighetsvinduer som kan åpne seg i deres land.

Å være et foregangsland for elektromobilitet kan komme til å koste mer enn det norske myndigheter hadde forutsett. Elektromobiliteten utvikles mye saktere globalt enn i Norge. Det fører til at produksjonsvolumet ikke blir så stort og at en får en lengre periode med høye kostnader på bilene. Det kan også gi et smalere utvalg av modeller. Risikoen for et internasjonalt tilbakeslag når det gjelder salget av elbiler er den største usikkerheten for utviklingen framover i Norge.

Del II: Diffusjon av elbiler i Norge

Elbilteknologiens egenskaper, evne til å møte brukernes behov samt å videreutvikle teknologien for å unngå eventuelle svakheter er nøkkelelementer i en diffusjons-prosess. Diffusjonstakten (Rogers 1995) påvirkes av hvordan teknologien oppfattes når det gjelder:

- *Relative fordeler* i forhold til andre teknologiers, f. eks. lavere innkjøpspris, lavere driftskostnader, bedre komfort, miljøvennlighet, tidsbesparelser, sosial status eller tilfredshet.
- *Overenstemmelse* med brukerens behov, grunnleggende verdier og normer i samfunnet.
- *Kompleksitet,* dvs hvor enkelt det er å forstå og bruke teknologien, og dens evne og fleksibilitet mht å utvikle flere muligheter.
- *Testbarhet* eller muligheter for å få prøve ut teknologien. Innovasjoner som kan prøves ut i liten skala oppleves som mindre usikre enn de som krever full implementering med en gang. Mulighetene for utprøvning er viktigere for tidlig-brukerne enn for de som kommer seinere som lettere kan få informasjon.

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- *Synlighet* øker diffusjonstakten og understreker viktigheten av nettverkskommunikasjon og en strategi for å lansere det nye produktet.

Insentiver som skal bidra til økt adopsjon av elbiler må ta hensyn til de nevnte faktorer, særlig relative fordeler. Stadig bedre teknologi og lavere kostnader kombinert med insentiver har medført at norske brukere oppfatter at elbiler har flere fordeler som ikke de tradisjonelle bilene har. Begrenset rekkevidde er ikke noe hinder for de fleste daglige reiser og førerne lærer å håndtere dette. Belønningen er umiddelbar siden elbilen, gitt insentivene, har samme eller lavere pris enn tilsvarende bensin/diesel-biler og dessuten mye lavere operative kostnader pga. sin energieffektive motor. Det er dermed mulig å markedsfører elbiler både som et klimavennlig og billig kjøretøy egnet for hverdagens reiser. Diffusjonsprosessen startet i byregionene, men elbiler selges nå over hele landet, i tettsteder og på landsbygda. Å satse på økt elbilbruk i byene samtidig som det er nettopp der man vil unngå økt trafikk er et dilemma, men som ut fra erfaringene synes å være av temporær karakter.

Potensialet for framtidig vekst ligger både i teknologiutviklingen som kan gi lengre rekkevidde til lavere pris og dermed tiltrekke nye brukergrupper og i at de sosiale nettverk (venner, familie, naboer og kollegaer) fungerer som ambassadører for elbiler. Med billigere pris blir det lettere for andre land å støtte elbildiffusjon og å utvikle sine egne pakker ut fra de mange insentiver Norge har testet.

Elbilspredningen i Norge er som forventet ut fra diffusjonsteori. Elbilpolitikken har fått nasjonale, regionale og lokale myndigheter, bransjen og ulike organisasjoner å jobbe i same retning. Det norske elbilmarkedet er imidlertid avhengig av det internasjonale markedet. Om prosessen ikke tar fart internasjonalt, vil den kunne sakte opp i Norge.

Del III: Lærdommer fra Norge

De to perspektivene brukt i rapporten kompletterer hverandre og gir en forståelse for elbilpolitikken i Norge og hvordan den har påvirket markedsaktørene og elbilkjøperne.

En langsiktig elbilpolitikk har vist brukerne at teknologien er i overensstemmelse med samfunnets behov og verdier, selv om målet har vært endret. Andre alternative drivstoffer har i større grad vært temaer for diskusjon. Den positive elbilkommunikasjonen kan ha gjort flere vanlig bileiere mer positive til å vurdere et elbilkjøp.

Erfaringene fra Norge viser helt tydelig at det trengs insentiver for å få fart på diffusjonsprosessen så lenge elbilene er dyrere enn de tradisjonelle bilene. Insentiver som øker potensielle brukeres oppfatning av relative fordeler er de mest effektive for å øke takten på diffusjonen. Når prisen er riktig, bilkjøperne har fått informasjon om og ser fordelene med elbiler vil diffusjonsmønstret bli det samme som for andre innovasjoner.

De norske insentivene kom til gjennom en serie unike hendelser der ulike aktører klarte å utnytte de mulighetesvinduer som oppsto. Andre land må finne egne veier til å støtte elbilutviklingen siden andre mulighetsvinduer kan dukke opp og de har andre rammebetingelser for sitt arbeid.

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Background

To reach the 2°C target for global warming put forward by the UNFCC in 2014, a decrease of 40-70% of greenhouse gas emissions is estimated to be required in 2050 compared to emissions in 2010 (IPCC 2014). Road transportation emissions were 18.5 % of total EU emissions in 2012 according to the European Environment Agency. In Norway road transport accounted for 19% of emissions according to the Norwegian Environment agency (2014).

Electromobility at the EU level is anchored in the 2011 EU White Paper on Transport, setting ambitious goals for phasing out conventionally fuelled cars in cities (EU 2011). Other important documents are the European Green Cars Initiative (EU 2009a), the EU Action Plan on Urban Mobility (EU 2009b) and the European alternative fuels strategy (EU 2014). These policies form the background for ERA-net's Electromobility+ programme, funding 18 European projects on this topic. One of these projects, "Competitive Electric Town Transport" (COMPETT), which this report is part of, focuses how to make electric vehicles competitive in the motorized individual transport market. COMPETT have partners in Austria, Denmark and Norway.

Policies reducing transport volumes, shifting transport into more efficient modes and improving the energy efficiency of each mode, will be required to contribute to the targets for reduction of greenhouse gas emissions from transportation. Electrification of passenger vehicles, being the theme of this report, is targeting the improvement of the energy efficiency.

Electrification to reduce greenhouse gases from transport

Electric vehicles (EVs) having a motor and four wheels like all cars, constitute an environmental innovation, being more energy efficient and emitting no local pollutants. The energy is charged into batteries from the electricity grid, mainly overnight at home. Charging at work or public places during the day will extend the driving range. Also fast charging will extend the range. Normal charging takes 6 - 13 hours depending on the vehicle and the electrical connection available. Fast charging can typically give 80% charge in 20 minutes, less in winter as batteries do not handle fast charging well when cold. In daily driving, the drivers usually do something else while the vehicles charge, such as sleeping, eating, being in a meeting, at work or some other activity.

In the early 20th century, EVs were popular because of the ease of operation. Range limitations and the invention of the electric starter for internal combustion engine vehicles (ICE), made EVs disappear. Recent years' progress in Li-Ion battery technology and increased environmental policy pressure have led to the rebirth of EVs.

Greenhouse gas emissions from well to wheel are much lower from EVs than from ICEs when electricity is produced from hydroelectric or wind power and from the more controversial nuclear power. The average European electricity mix will also yield significant benefits. These benefits will increase as the electricity production becomes less CO_2-intensive over time in Europe. Being part of the EU Emission Trading Scheme, electricity production will gradually be decarbonized as the

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maximum cap on CO_2-emissions is reduced. Electrification of vehicles is thus an important measure to reduce environmental impacts and greenhouse gas emissions from transport.

Norway - a test site for electromobility

Norway has been a highly successful EV market with consumers buying 80% of the EVs sold (Gronnbil 2015). The market share of EVs reached 12.5% of new vehicle sales in 2014 and increased to 20% in the first quarter of 2015 (OFVAS 2015). Most other countries have market shares less than 1% and most often fleets is the dominating adopter. In fact no other country have moved past 5% market share for battery electric vehicles in any year according to Statistical sources in each country, see figure 1.

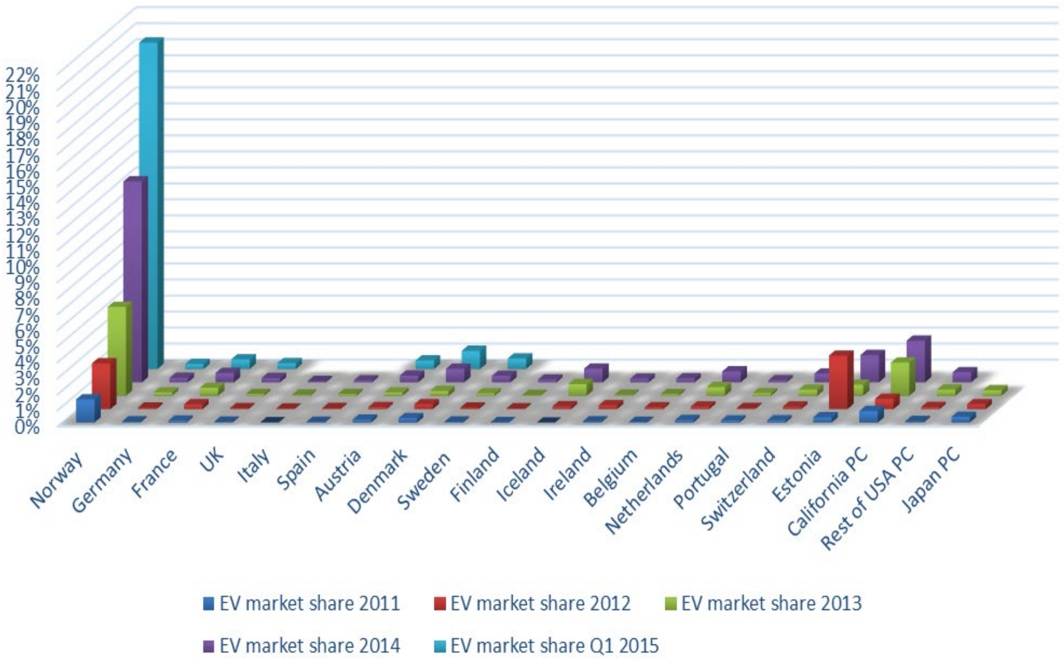

Figure 1 EV market shares in Europe, USA and Japan. Percent. Sources includes: National statistical offices various webpages, historical sales material, for detailed references see Figenbaum et.al. (2015).

Learnings from the Norwegian diffusion of EVs as well as the identification of elements in society, car technology/ industry and related to stakeholders and users, having contributed to the success, are thus of general interest. Understanding the interplay between the society, the technology and the users must be seen from different perspectives. Other studies of potential EV market diffusion are often more theoretical, with no basis on real life experiences and real user attitudes and considerations. In Norway we find:

1. Enough EVs to study the users' experiences of pro's and con's in using EVs and how the users adjust to possible challenges.
2. Many incentives making it possible to study their effect on various aspects of diffusion of EVs.
3. A clear EV policy with incentives anchored in a climate policy settlement (2012) in the Norwegian parliament.

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The purpose of this report is to investigate why and how EVs entered the Norwegian automotive market and how the political framework and stakeholder activities evolved and influenced EV adoption.

Different frameworks to analyse diffusion

Several models or frameworks exist for the diffusion of technologies in a market. Some attempt to present the complex interaction between different actors at different level of society and how that interaction affects the ability of a technology to make a breakthrough into the mass market. One such framework is the multilevel perspective (MLP developed by Geels 2012). The MLP framework aims at explaining diffusion of technologies as interplay between the actors and practises at three levels:

1. Niche activities among the users and buyers.
2. The regime with actors being car producers, charging network providers, NGOs, municipalities, other industries as well as established practises of car usage.
3. The landscape with influencing exogenous factors such as the oil price, international politics, peak oil etc.

The MLP is most commonly used at the global level, but it can be adapted to a local level. This types of models are not so well developed when it comes to explaining diffusion at the micro level, such as:

- the pattern of EV diffusion in a region or between population groups and vehicle segments,
- what actually makes EVs diffuse,
- how the decisions to adopt are made and who influence it,
- why is the diffusion is going so fast in Norway after 2010,
- why some do adopt and others no.

The MLP models are better at explaining the early parts of the diffusion before the more stable mass market phase starts. Once the rules are set, i.e. the policies have been defined and incentives are introduced, the technologies spread as a result of cost reductions resulting from mass production, growing information, competence and confidence among potential buyers, as the number of buyers and users increases. In this phase more traditional models such as the diffusion of innovations by Rogers (1965, 1995) may be more relevant and better at explaining the diffusion pattern, i.e. why, how and when various adopter groups decide to adopt or not and who influence the decision.

The political framework in Norway, i.e. incentives and policies, affecting the introduction, has remained stable since 2011, the entire period with rapid increase in sales of EVs in Norway from a market share of only 0.3% in 2010 to over 20% in 2015. 2010 also marks the year when the initiative in the market switched form niche actors to the traditional car industry with EVs becoming available in unlimited volumes all over Norway from several car manufacturers. The fact that 80% of the vehicles sold after 2010 belong to individual consumers highlights the need to use a consumer oriented diffusion model.

In this report the MLP model will be used as the basic theory to analyse the interplay between actors and markets over the first two decades of EV development in Norway, i.e. from 1990-2010, and the main factors that contributed to the establishment of the EV market in Norway. The analysis of consumer adoption of

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EVs will mainly be analysed using Roger's theory of diffusion of innovations focusing on the period after 2010, a period when the users had options for real choices.

Common materials

Knowledge on consumer attitudes, behaviour and experiences is taken from the COMPETT net surveys of 1721 EV owners belonging to the Norwegian EV association and of 2241 general vehicle owning members of the Norwegian Automobile Federation (NAF) in January and February 2014 (Figenbaum, Kolbenstvedt & Elvebakk (2014). The latter survey could further be divided into potential EV users and determined non-users, expressing respectively an interest or no interest in taking up EVs the next time they would buy vehicles. In addition a series of interviews was conducted with various stakeholders from government, local authorities, NGOs, consumer organizations, car importers and car dealers from April to September 2014 (Assum, Kolbenstvedt & Figenbaum 2014). Results from these surveys are used in both parts of this report.

Links to the survey was sent out in a newsletter from the EV and NAF associations. The response rates were in the interval 22-40% depending on the assumptions made about how many actually saw the link of those who opened the newsletter (Figenbaum, Kolbenstvedt & Elvebakk 2014).

At the time little knowledge existed on how the latest generation EVs were used. The questionnaire to the EV owners was developed taking the following considerations:

- It could not be too long so as to avoid people terminating in the middle of the survey
- It should cover as many as possible of the relevant topics for EV adoption
- The possibility to identify who the EV owners are and what their motivations are
- Compatibility with some questions asked in earlier surveys, to be able to follow changing attitudes to and perceptions of EV
- The possibility to compare with data from the national travel survey.

Prior to the surveys a brief review of the literature on EV adoption was done to identify factors of relevance to EV adoption. Separate reviews of international EV related surveys (Hjorthol 2013) and of 20 earlier Norwegian surveys (Figenbaum & Kolbenstvedt 2013) were also used as inputs to the survey formulation. It is, however, important to note that the rapid technological development of EVs makes such comparisons with earlier surveys complicated. The technical development has been rapid and the vehicles available in 2014 were different from the ones commonly in use in 2010. The result was that this survey contained up to 70 questions. The number varied as some questions were follow-ups depending on earlier answers.

The survey of the ICE vehicle owners of the Norwegian Automobile association contained a subset of the questions asked to the EV owners. Some questions were reformulated to provide answers to the same topics as those asked to EV owners but seen from the perspective of non-owners. The COMPETT interviews of stakeholders during 2014 (Assum, Kolbenstvedt & Figenbaum 2014), provide further insights. In addition facts about incentives, the timeline of introduction of EV models and of the EV history in Norway (Figenbaum & Kolbenstvedt 2013), are used to explain the diffusion.

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Part I: A multi-level perspective on EVs in Norway

I:1 Introduction

The aim of this part or the report is to analyse the beginning of the transition from ICEs to EVs in Norway and identify what elements in society, car technology/ industry and different stakeholders and users that have contributed to the success of EVs. In particular the interplay between society, technology and users at different levels based on Rogers (1962, 1995) and Geels (2012) earlier work. Geels developed the *multi-level* perspective (MLP) framework that forms the basis for this part of the report, further as a tool to study transitions in the transport system.

The analysis is structured in six chapters. Chapter 2 describes the MLP approach as given by Geels (2012), the assumptions or kind of hypotheses we will look at and the reasons for choosing them. Chapter 3 presents the methods and materials used. Chapter 4 presents results related to the three levels in the MLP model operates with, 1) the *landscape*, 2) the *regime* and 3) the *niche* level as well as the interplay between the levels. The results are discussed in relation to the proposed hypotheses/assumptions in chapter 5, paving the way for the conclusions in chapter 6.

I:2 Theoretical framework

Socio-technical frameworks conceptualise socio-technical systems of transportation as a configuration of elements, including technology, policy, markets, consumer preferences and behaviour, infrastructure, cultural meanings and scientific knowledge (Geels 2012). The systems are maintained, reproduced and changed by the actors, such as automakers, fuel providers, consumer organizations, media, engineers, authorities, researchers and others. A major shift in these systems is termed a socio-technical transition, possibly taking decades to unfold given the long development times and life of vehicles, as well as the extent that personal mobility using individual vehicles is entrenched in society.

The multi-level perspective (MLP) framework is "*a heuristic framework to analyse ….co-evolution and interaction between industry, technology, markets, policy, culture and civil society*" (Geels 2012, p. 471). The perspective is defined like this:
"*The basic premise of the multi-level perspective is that transitions are non-linear processes that result from the interplay of multiple developments at three analytical levels: niches (the locus for radical innovations), socio-technical regimes (the locus of established practices and associated rules), and an exogenous socio-technical landscape (Rip and Kemp 1998; Geels, 2002 Geels and Schot 2007). These 'levels' refer to heterogeneous configurations of increasing stability, which can be seen as a nested hierarchy with regimes being embedded within landscapes and niches existing inside or outside regimes (Fig. 1). The MLP helps explain why there may simultaneously be a flurry of change activities (at the niche level) and relative stability of existing regimes.*" (Geels 2012, p. 472).

"*The MLP does not employ linear cause and-effect relationships or simple drivers. Instead, it emphasises mutually reinforcing developments, alignments, co-evolution, innovation cascades, knock-on effects, and hype-disappointment cycles. Because of these characteristics, the MLP is not a 'truth machine' that automatically*

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produces the 'right' answers when the analyst enters the data. Instead it is a heuristic framework that guides the analyst's attention to relevant questions and issues. Application therefore requires both substantive knowledge of the empirical domain and theoretical sensitivity (and interpretive creativity) that help the analyst 'see' interesting patterns and mechanisms. The MLP represents a certain epistemological style (interpretive research), which is well suited to study uncertain and messy processes such as transitions." (Geels 2012, p. 474)

Figur I:1 provides an ideal-typical representation of how 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: (a) niche-innovations build up internal momentum, (b) changes at the landscape level create pressure on the regime, and (c) destabilisation of the regime *creates windows of opportunity* for niche-innovations (Geels 2012).

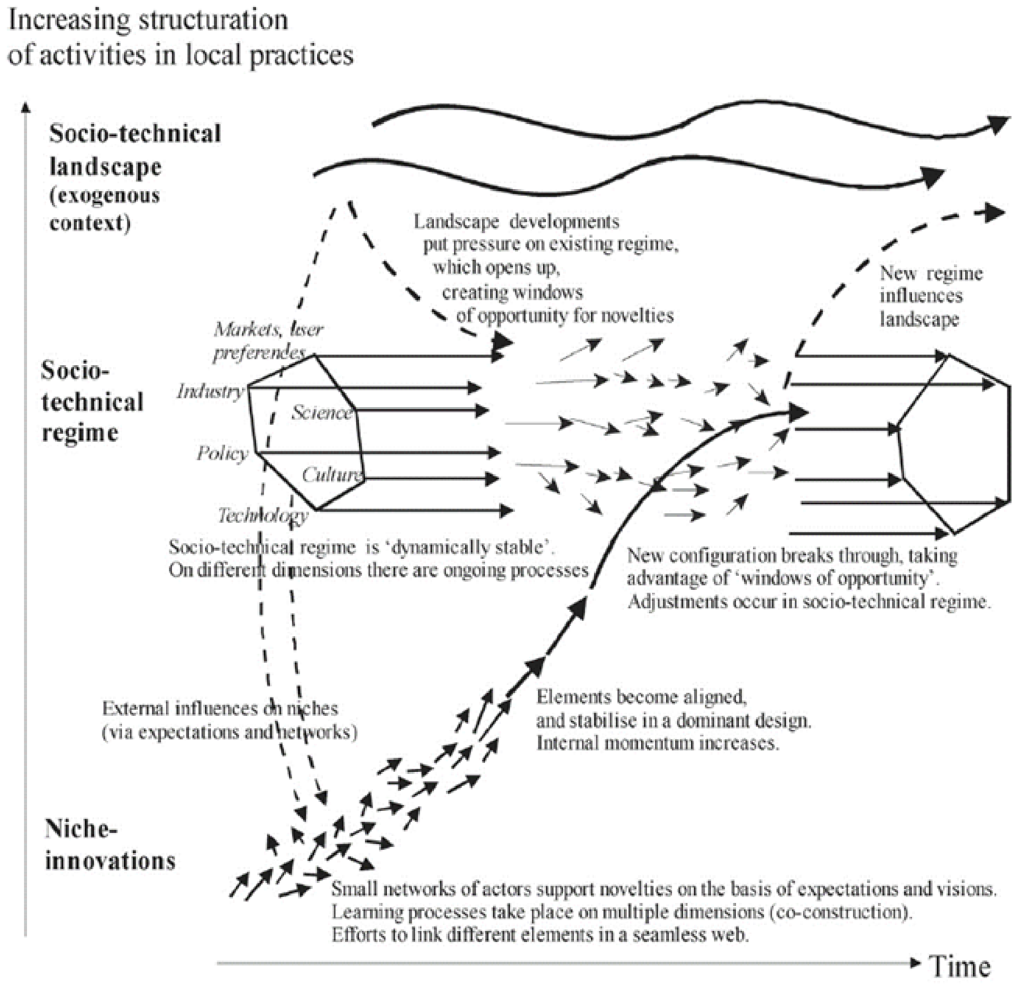

Figure I:1 Multi-level perspective on transitions, Source: Geels 2012.

An example related to electromobility is a study of diffusion of EVs in Stockholm by Nykvist and Nilson (2014). They used the MLP framework developed by Geels (2002), c.f. figure I:1 and adapted it to a local scale with the result shown in figure I:2. They used a spatial scale on the x-axis and structuration of activities in local practises on the y-axis. The framework was then used to investigate three hypotheses, concerning why the EV market in Stockholm has not developed. The three hypotheses were (1) a lack of or poorly functioning niches, (2) a strong ICE regime and 3) the lack of economic incentives, policy direction and visions. They found

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support for the *niche* and *regime* hypotheses and some but not conclusive supporting evidence for the *landscape* hypothesis.

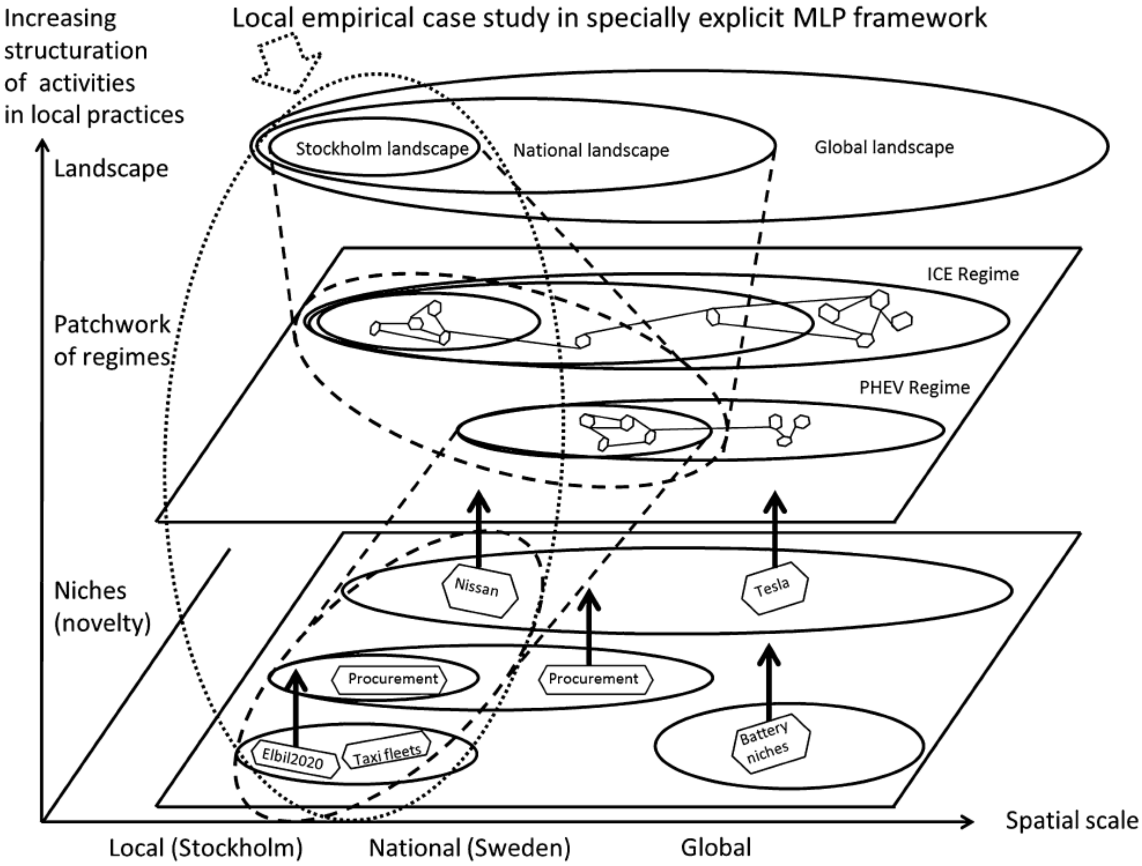

Figure I:2 Adapted MLP framework of Nykvist and Nilson (2014).

Norway being a highly successful EV market and a neighbouring country to Sweden makes it relevant to test the opposite three hypotheses on the case of Norway:

1. *The niche hypothesis*: The rapid development of EVs in Norway is the result of well-functioning niches for EVs to expand in and from.
2. The *regime hypothesis*: The rapid development of EVs in Norway is the result of a weak ICE regime in Norway
3. *The landscape hypothesis*: The rapid development of EVs in Norway is the result of economic incentives, policy direction and visions at different scales.

A central part of the framework of Geels (2012) is that destabilisation of the established regime creates windows of opportunity for niche innovations. There is no guarantee that transitions succeed: niche-innovations may fail to build up sufficient momentum or suffer setbacks; or tensions in existing regimes may remain small so that 'windows of opportunity' for niche-innovations do not materialise (Geels 2012). A fourth hypothesis to be investigated is thus how exploitation of windows of opportunity may explain the rapid introduction of EVs:

4. *The opportunity hypothesis*: The rapid development of EVs in Norway is the result of "windows of opportunity" opening up the established regimes.

The perspective of this part of the report is national with the sociotechnical landscape split in two, one global and one national. The activities of the auto-industry, the European Union and activities in other countries is in the global landscape not controlled by Norwegian actors or Norwegian policies. In the national

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landscape we find national policies of transportation, pollution control and greenhouse gas emission reduction, as well as initiatives to support a Norwegian emerging EV industry in the early 2000s and the incentives for EVs.

The proposed x-axis for the MLP framework is time as in Geels (2002). The y-axis shows the degree of structuration at different levels, while the z-axis is used for the spatial dimension using niches, regional and national as the three spatial levels. The EV activities at all levels will be discussed together with other competing technologies, i.e. biofuels, hydrogen and PHEVs as these may have influenced the EV transition. Niches can be activities or sub markets based on usage patterns that can be geographically spread. The regional and national dimension is used to show the scale of EV development in Norway having now entered the main stream automotive market.

I:3 Methods

Norway is unique in being the first country where EVs have reached market shares above a few percent of new vehicle sales. This situation allows for the investigation of the four hypotheses using both market statistics and various policy documents from the actors in the investigation such as government white papers, settlements and decisions in the parliament, municipality actions and white papers from consumer and trade organisations as well as Non Governmental Organisations (NGOs). Being the most important ones, the vehicle manufacturers and importers can be studied by looking at the actions they have taken to respond to changes in their environment. Results from the surveys and interviews described in the chapter on common material in the beginning of the report have also been used.

I:4 Results

The Norwegian EV market development can be divided into four periods. 1989-1998, 1999-2002, 2003-2009 and 2010-2015. We will go through the niche, regime and landscape events in each of these phases. But first a brief look at some national characteristics of Norway that may influence EV developments.

I:4.1 National characteristics

Norway is an oil producing country with Norwegian companies being developers and operators of national oil fields, supported by a large supplier industry. These companies are operating globally, selling the oil as a commodity on the world market. Statoil, the largest Norwegian oil producer, used to sell fuels in the Norwegian market. That business was separated out in 2010 and bought up by a Canadian company in 2012. No other companies are simultaneously involved in oil extraction business and the retail sales of fuels. The oil producing industry is thus not part of the ICE regime in Norway but the companies that sell fuel to consumers are.

Norway is a large country in areas extending 2000 km north to south with a population of only 5 million people, owning 2.5 million passenger vehicles (SSB 2015a). The population density of 14/km^2 is the second lowest in Europe (Worldbank 2015). Even the cities are small in Norway. Oslo, the largest city, have

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617 000 inhabitants. Bergen the second largest city have 260 000 inhabitants (SSB 2015). Small cities and the low population density is a challenge to establishing public transport alternatives to private car use. The climate is mild in the summer and cold in the winter with large variations. Topography is mostly hilly and a drive between some of the major cities will require the tackling of mountain passes with harsh winter conditions. In the inland winters can be very cold with temperatures of -20 to -30º C. On the coast the winter climate is not so cold, typically in the 0 to -10°C range. Driving range variability is thus large between summer and winter due to the need to heat the cabin and winter tyres with higher rolling resistance as well as higher resistive loads on the vehicle due to the low temperature. The fairly cool summers on the other hand puts less stress on the batteries which should last longer in Norway than in countries with hotter climates (Francfort & Shirk 2014).

The Norwegian transportation sector is heavily taxed. There are taxes on the registration of vehicles the first time as well as a yearly tax on vehicle ownership. A large number of roads are toll roads. Fuel taxes are also among Europe's highest, and so is also the value added tax of 25%.

Norwegian speed limits are EV friendly, i.e. low. Most main roads have a limit of 80 km/h and most motorways 100 km/h (some have 110 km/h). The average annual mileage of vehicles is 13 000 km.

98% of Norwegian electricity is produced by hydroelectric power-plants (Ministry of Petroleum and Energy 2013). Electricity is abundantly available, pollution free, cheap and non-controversial compared with other countries. It is used for many purposes, including heating houses. Households have thus more electric power installed than in other countries in Europe.

Norway does not have any vehicle production apart from several unsuccessful attempts to start EV production. There is an industry selling parts to the auto industry in other countries. Norway has a large oil extraction industry and high national income from oil production. The sales of the petroleum products in the Norwegian market is, however, done by separate companies. There is no direct link between companies involved in oil extraction and the sales of Gasoline and Diesel in the Norwegian market. The small population of Norway may make it easier for stakeholders to identify and approach politicians and thus influence them.

Numerous EV incentives have been introduced over the years. They are listed in table I:1 to provide the background for the sequential analysis of factors influencing the diffusion of EVs in Norway.

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Table I:1 National incentives, policies and initiatives. Source: Figenbaum, Assum and Kolbenstvedt (2015).

Incentives	Introduced	Benefits for users
Fiscal incentives Reduction of purchase price/yearly cost gives competitive price		
Exemption from registration tax	*1990/1996*	The tax is based on emission and weight. Example taxes on ICE vehicles: VW Up 3000 €. VW Golf: 6000-9000 €. The tax makes the vehicles competing with EVs more expensive
VAT exemption	2001	Vehicles competing with EVs are levied a VAT of 25% on sales price minus registration tax.
Reduced annual vehicle license fee	1996/2004	Three rates apply for private cars. EVs and hydrogen vehicles have the lowest rate of 52 € (2013-figures). Conventional vehicle rates: 360-420 €.
Reduced company car tax	2000	The tax on using a company car is lower for EVs. Most EVs are not company cars.
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 avoided costs are 600-1 000 €/year for commuters. Some places have tolls exceeding 2 500 €/year
Reduced rates on ferries	2009	Similar to toll roads avoiding costs for those using car ferries frequently. Not important up to 2013, but the value of the incentive can be high in some areas.
Financial support for charging stations	2009	Reduces the economic risk for investors establishing charging stations. Contributes to reduced range anxiety and expand the EV market and get more EV miles out of every EV.
Financial support for fast charge stations	2011	More fast-charging stations become available increasing the EV miles driven and the total EV market including fleets. Fast charging does not void vehicle battery warranties.
Reduction of time costs and giving relative advantages		
Access to bus lanes	2003/2005	EV users saves time driving to work in the bus lanes during rush hours. Very efficient, high value to user in regions with large rush-hour congestion. But only a limited number of vehicles can use the bus lanes. Can lead to increased vehicle ownership.
Free parking	1999	The benefit for users is to get a parking space where these are scarce or expensive and time saved looking for a space. Impact depends on how many spaces that are available.

I:4.2 Experimental niche activities between 1989-1998

Some small pioneers and enthusiasts started up niche electric vehicle activities around 1990. In 1989 the first EV was imported to Norway (Asphjell et al 2013). A company developed electric drive systems for VW. A few vehicles were built with this drive system of which four was taken into use in Norway (Ibid 2013, Figenbaum 1994). A small dealer/vehicles repair workshop started imports of the Danish mini EV Kewet Eljet from 1992. 43 Kewets was on the roads of Norway (Figenbaum 1994) in November 1993. The National Institute of Technology (TI) started testing EVs (Figenbaum 1993, 1994, 1995, 1997, 1998). The first market niches were fleets, mostly energy companies and municipalities testing the technology (Figenbaum 1994). All of these activities were established separately from the automotive industry regime that at the time showed little or no interest in manufacturing or selling EVs in Europe. An exception was a test production of 250 Citroën C15 in France (Arval 2010). Vehicle manufacturers were, however, evaluating various options, developing and testing some EVs for the Californian market. The ZEV mandate specified that a certain share of EVs had to be sold (California ARB 2015).

A small, separate EV regime parallel to the ICE regime was being established in Norway, independently of the traditional automakers, importers and dealers that were not taking an interest in EVs. The first attempts to establish an EV association

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was initiated by the municipality of Oslo, EV actors, other industrial actors, local utilities and others (Asphjell et al 2013). By 1995 the association was founded in the beginning as a sort of a common interest stakeholder organisation that later evolved into a consumer organisation. The Norwegian government introduced the first EV incentive, the exemption from the vehicle/registration tax from 1990 to stimulate the usage and development of EVs (Ministry of Finance 1989). The exemption became permanent from 1996 (Ministry of finance 1995). From 1997 EVs were exempted from the toll roads of Oslo, a situation leading to exemptions on other toll roads in use or established later (Figenbaum & Kolbenstvedt 2013). From 1998 municipalities could offer free parking following a change to the national parking regulation (Figenbaum & Kolbenstvedt 2013). These changes were induced by actors at the *landscape* level such as municipalities, from actors of the EV *regime* under establishment, NGOs, as well as the *niche* fleet users. They claimed that more incentives were needed to sell EVs. As an example NGO drove their EV multiple times past the toll roads of Oslo without paying. They also parked on public streets without paying the parking fees. These activities led to substantial media coverage, putting pressure on the municipality of Oslo and the Norwegian Public Roads Administration to allow EVs to use the toll roads and park free of charge. The EV association and its members added to the pressure, and the combined efforts resulted in the introduction of the free parking and the free passing of toll roads incentives from 1997 and 1999.

At the Lillehammer winter Olympics in 1994 a small EV prototype made by the Norwegian company PIVCO demonstrated that EVs could operate in Norway's winter climate (SNL 2015). The company developed the vehicle further. From 1995/96 a second-generation prototype was made and tested by Norwegian fleets (SNL 2015) and as a "station car" in California delivering last mile transport (CALSTART 1995). The company succeeded in getting investors on board for an industrialisation of the 2-seater EV. The factory opened in 1998 near Oslo with the company renamed *Think*. A month later the company got bankrupt (SNL 2015). In Denmark Kewet went bankrupt leaving the Norwegian importer without vehicles to sell (Asphjell et al 2013).

In 1990 the Californian ZEV mandate included an obligation to sell 2% EVs from 1998 increasing to 5% in 2001 and 10% in 2003 (California ARB 2015). Expectations faded, and the mandate was postponed in 1996, leaving out requirements for 1998-2001 while keeping the 2003 target.

In the same timeframe the utility company Stavanger Energy, unable to get the Norwegian Peugeot importer to import Peugeot EVs, cut a deal directly with Peugeot in France (Figenbaum 2015). The result was that Peugeot EVs became available in the Stavanger area through the local Peugeot dealer. They also set up a small EV workshop in their premises to support the EV servicing in the region. In the region of Grenland (130 km southwest of Oslo) local investors, supported by a seed fund tasked with transforming the heavy industry based region to a more diversified base, started an EV leasing business, Miljøbil Grenland. In the beginning, Peugeot EVs were leased out as a result of a deal with the French utility company EdF (Asphjell et al 2013). These activities are illustrated in figure I:3, by a small overlap between the ICE regime and the EV regime under establishment, marking a partial assimilation of EVs by the incumbent ICE regime.

The competitive situation between EVs and gasoline vehicles in the late 1990's as illustrated in figure I:3. EVs cost at the time twice as much as the small gasoline

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vehicles they competed with. In addition the vehicles were mostly produced by unknown companies. The quality was not quite up to automotive standards, and a proper dealer network was not established. Although the Peugeot importer did import some vehicles, they were not too eager to sell them. The result was that the vehicles mostly were sold to fleets and enthusiasts that could take advantage of free parking or had much to save on the road-toll exemption.

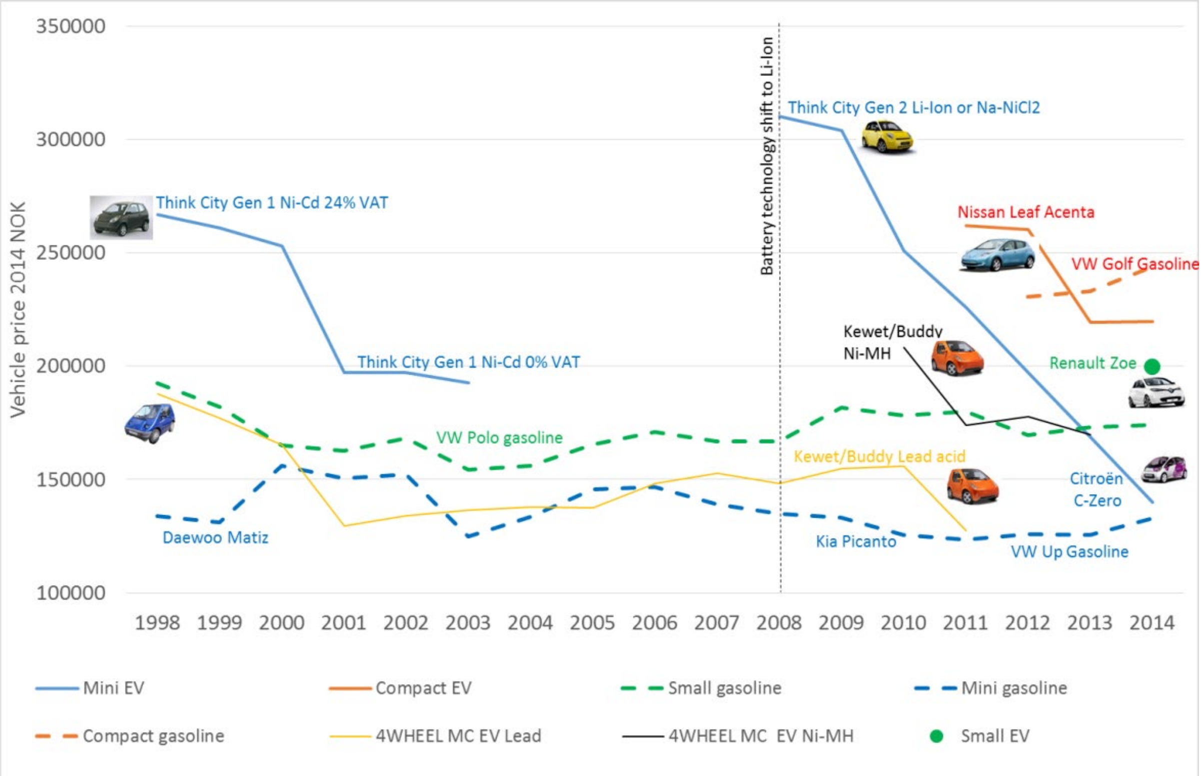

Figure I:3 Sales prices of EVs in Norway compared with gasoline vehicles. EV prices are without all taxes according to the incentives. ICE vehicle prices include all registration taxes and VAT. Source: Taxnorway 2015, various webpages, news articles, historical sales material

The ICE regime seems to have accepted the EV incentives. At least they did not openly fight against them. Then again, they may not have felt threatened by the EV technology at the time.

I:4.3 The rise of the EV regime from 1999 to 2002

A few months after Think went bankrupt in October 1998, Ford Motor Company bought Think and industrialized the vehicle with sales starting in late 1999. Their main target was to deliver low-cost EVs to California to meet Fords ZEV mandates (Ford 2000). Their own internal EV project had experienced massive cost overruns with the resulting vehicle becoming too expensive to produce and sell (Figenbaum 2015). The Norwegian management at Think was tasked with developing the Norwegian and European market (Ford 2000). Ford had expectations of deliveries to fleets owned by the Norwegian government (Asphjell et al 2013). With Ford owning Think, new pressure came for more incentives from the now more influential EV regime partly assimilated by the auto industry.

A second EV producing company was under establishment in Oslo from the early 2000s. The importer of the Danish Kewet bought the bankruptcy estate from

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Denmark, moved the production equipment to Oslo and started a small scale production.

These two initiatives pointed at a possible emerging cluster of EV production and services in Norway, a country with no prior vehicle production. Politicians were now receptive to arguments about the establishment and expansion of EV production in Norway, introducing new incentives such as exemption from VAT, lowering EV prices with 20% from 2001, and reduced company car taxation from 2000 (Figenbaum & Kolbenstvedt 2013). EVs got specific EL number plates from 1999 to facilitate the control of admission to local incentives such as free parking and free passing of toll roads. In the region of Grenland, Miljøbil Grenland expanded its leasing business reaching 150 vehicles in 2000 and from 2002 they started selling EVs (Asphjell et al 2013).

The competitive situation of EVs improved substantially as the result of the exemption from VAT introduced in July 2001, seen as a price drop from 2000 to 2001 in figure I:3. Sales, however, remained modest due to limited supply of vehicles as seen by the slow increase in the EV fleet shown in figure I:4.

In France, the car manufacturers with government support commercialized EVs with Ni-Cd batteries from 1995-2002 when the French automakers launched a few EV models (Arval 2010). Renault also launched an EV in the same period. Total production of these EVs was less than 10 000.

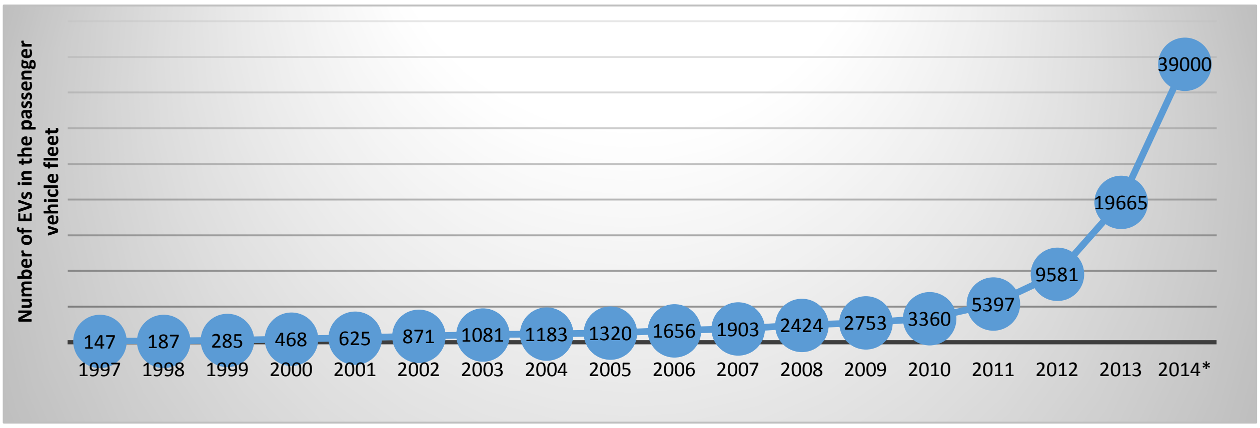

Figure I:4 EV fleet in Norway. 2014 estimate based on sales up to November. Source: Asphjell et al 2013 and OFVAS 2015.

I:4.4 The EV regime muddles through from 2003 to 2009

From 2003 and onwards there were several setbacks in the EV development.

All French car manufacturers stopped producing EVs. Poor sales, changing priorities and Cadmium being gradually banned from use in batteries may have contributed to the decision. The California regulators amended the ZEV regulation in 2001 allowing PHEVs to fulfil 8% of the 10% of the 2003 ZEV requirement. A lawsuit prohibited the enforcement of the 2001 amendment resulting in further relaxation of the mandate in 2003 and automakers could abandon electric vehicles altogether.

Ford re-Think-ed their EV strategy. California relaxed the ZEV mandates and Ford decided they no longer needed Think (Figenbaum 2015, Asphjell et al 2013). The

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company was put out for sale in late 2002 with the takeover by a new owner in 2003. Within a couple of years Think went into receivership as the owner was unable to get production going. Kewet lost its type approval as the end date of the approval expired. The Norwegian company resorted to redesign it to a lower vehicle class, a light weight 4 wheel "motorcycle" with less demanding type approval.

The EV market was kept alive by enthusiasts in the EV regime importing second hand EVs (Aspjell et al 2013) made by Peugeot, Citroën and Renault between 1998 and 2003. These vehicles were abandoned by their original owners as other countries terminated EV activities and incentives. Think vehicles that had been exported earlier could also be reimported to Norway and sold to private consumers. Some of them were saved from crushing in the US as Ford when bailing out of Think terminated leases and recalled the vehicles (Asphjell et al 2013).

In 2003 the Norwegian Public Roads Administration intended to ban minibuses from the bus lane. These minibuses was bought by commuters to avoid the rush hour delays. From 2003 the bus lanes were opened for EV owners in a test area consisting of Oslo and the surrounding municipalities (Figenbaum & Kolbenstvedt 2013) after intense lobbying from the EV regime. Minibuses already in use could continue using the bus lanes until finally being ousted from 2009.

During the same time period there was a steady increase in the establishment of toll roads around cities and on the main roads. These toll roads were free of charge for EV owners. Unfortunately, the Norwegian EV producers were not in a position to take full advantage of this market. Think was then not producing EVs, and the production of Kewet's was only about 100-200 vehicles per year. The Kewet was sold at a price comparable to the smallest 4-seater gasoline vehicles available in the market, c.f. figure I:3.

Think was re-established in 2006 by Norwegian investors, later with support from large international investment funds. A new Think model emerged in 2008 with production aimed at starting up in 2009. The company stumbled once again in the final industrialisation phase in the wake of the financial crisis of 2008-2009. The company managed to secure funds eventually, but the production was then moved to Valmet in Finland on a contract basis. According to Asphjell et al (2013), the Norwegian investment fund Investinor required an automotive actor to get involved in the project as a requirement for investing in the company. Having a long experience as a contract producer of vehicles, Valmet became a shareholder of Think. The production was moved to Valmets premises in Finland. At the same time Kewet re-emerged with the new Buddy-model. A new major incentive was introduced, the introduction of reduced ferry rates from 2009. Things started looking rosy for the EV regime. The price of the Think vehicle, with either Li-Ion or Na-NiCl2 batteries, was, however, very high at launch, roughly three times that of the smallest gasoline vehicles, c.f. figure I:3.

Having problems obtaining EVs for leasing, Miljøbil Grenland decided to attempt to establish an EV production based on gliders (vehicles taken off the assembly line prior to the installation of the motor and drive system). First the idea was to use Smart vehicle gliders, but they did not manage to get the permission to do so. The focus shifted to gliders from the Indian vehicle producer TATA, and a prototype was made. Eventually, the company was bought by Tata which had the intention to start up EV production in Grenland. Tata went so far as to invest in an establishment of a battery production facility in Grenland as a precursor to establishing EV production.

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The ICE regime represented by the Vehicle Importer Association, was in 2009 starting to voice some concerns over the loss of income for the government due to the incentives. They stated that these losses could not be recovered by increasing the taxes on ICE vehicles. They also stated that incentives should be technology neutral (Resource group 2009).

I:4.5 Joining the party in 2010, the ICE regime swiftly took the initiative

After the financial crisis in 2008/2009, the government introduced an economic stimulation package that included some six million Euros for installing charging stations for EVs, thereby keeping up the activity for electricians (Innst. S. nr. 139 (2008–2009).

The traditional car industry entered the scene in 2010. Mitsubishi I-Miev presales started in second half of 2010 and deliveries in early 2011. The Norwegian importer was selling the vehicle through all its dealers across the nation. They profited from all the achievements, incentives and market activities the independent EV regime had accomplished until then. The price was set at roughly twice the smallest gasoline vehicles, lower than the price the re-launched Think was selling at. Think lowered the price to the same level, the first of several "price wars" in the Norwegian EV market, c.f. figure I.4. The target of selling a 1000 I-Mievs the first year was reached with chaotic conditions at the dealer in Asker, a municipality 20 km southwest of Oslo (Asphjell et al 2013). No longer having access to the bus lanes with minibuses, the commuters were buying EVs to regain this privilege. Later the same year, Peugeot, Citroën and Nissan joined the EV market, and sales increased rapidly, c.f. figure I:5.

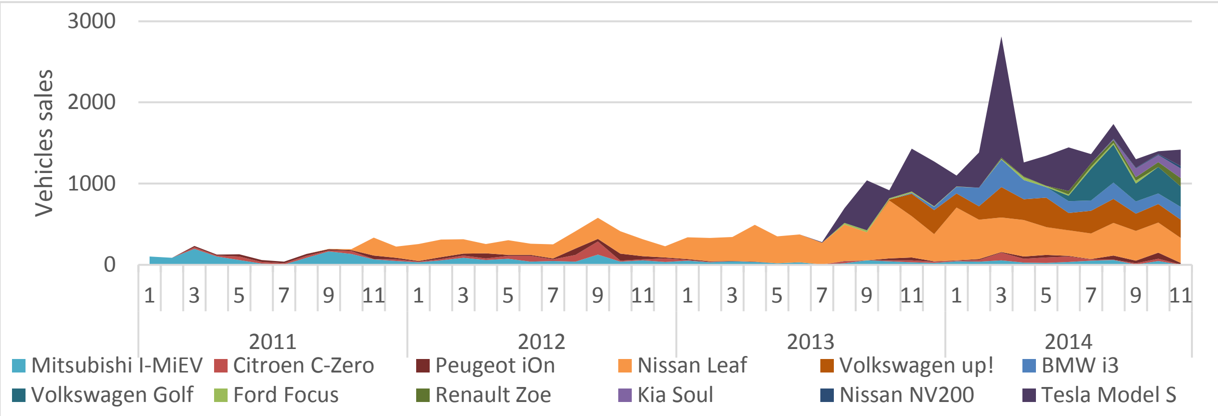

Figure I:5 Monthly EV sales 2011-2014. Source: OFVAS 2015.

The Norwegian EV producers Think and BuddyElectric (formerly Kewet) soon ran out of cash. Tata's EV production in Grenland never materialized, and the battery business stumbled into problems and attempted to diversify to the maritime sector. Thus, the Norwegian EV production ambitions ended. The companies were unable to compete when the ICE regime used its powers to manufacture, distribute and sell EVs through its regular dealer structure. They essentially built up an internal EV regime inside the ICE regime by using systems, facilities, tools and skills established in the ICE regime.

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In this period, the focus of the policy shifted away from supporting industrial development, to focusing EVs as a climate mitigation effort for the transportation sector. To support a coming government white paper on climate policy, several government agencies joined forces (an activity called Climate Cure) and developed grounds for decision-making identifying EVs as one of the measures (Figenbaum 2010). In the following climate policy white paper from 2012 an official EV-specific policy was proposed for the first time (National Climate Policy 2012). This white paper stated the intention to continue using the tax system to contribute to the greening of the vehicle fleet, continue to be at the forefront internationally when it comes to the framework for EVs, and to contribute to the establishment of infrastructure for EVs, allowing EVs to continue using the bus lane for as long as possible. With the follow up climate policy settlement in the Parliament later the same year, the EV policy was for the first time firmly anchored in a broad political agreement between most political parties (Climate policy settlement 2012). No specific volume target for EV introduction was, however, stated in the settlement. The settlement specified the continuation of the EV-incentives until the end of 2017 or until 50 000 EVs were on the road.

Nissan has increased sales in Norway due to the Leaf EV. It became one of the top five bestselling brands in 2015 compared with being nr 10 in 2009 (OFVAS 2015). Being Norway's largest vehicle importer, Toyota was dethroned by VW in 2014. VW has two EVs on the market selling in large volumes whereas Toyota has none.

In 2013, Tesla proved that an independent EV regime could still be viable with massive sales of its large Model S EV in Norway, c.f. figure 1:5. Tesla challenged directly the large and luxury vehicle segments previously controlled by actors in the ICE regime. The success of Tesla Model S in the global market has led to announcements from Audi (2015) and GM (2015) to build and market vehicles aimed at competing with Tesla in a few years. Tesla, however, plans to expand into new vehicle segments to enlarge their independent EV regime, launching a SUV in 2016 and a smaller model in 2017/18. Meanwhile, most other players in the independent EV regime internationally have gone bankrupt or given up the EV business altogether. Some examples are Fisker, Better Place, Coda, Azure Dynamics and Boulder Electric. Tesla is by now the only real contender to the automakers EVs.

At the national *landscape* level, the municipalities have been slow in including EVs into their own fleets. Leasing is the preferred ownership model for most municipalities. EVs are not exempted from VAT when leasing, explaining the slow uptake. Also some fleets need to run vehicles in multiple shifts, leading to the EV range potentially falling short of the driving requirements over the day.

The status in 2015 is that the EV regime is strengthened, still consisting of two parts, one internal to the ICE regime with the main manufacturers being Nissan, Volkswagen, Kia, Renault and Mercedes/Smart, and the external regime with Tesla as the main player together with companies importing second hand EVs. The fuel providers of the ICE regime such as Statoil fuel and retail are diversifying and establishing fast chargers at some of their petrol stations. A host of new players cooperate with both EV regimes in providing various charging services, such as setting up home chargers.

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I:4.6 Windows of opportunity

Windows of opportunity have opened and been explored many times during the EV development in Norway, supporting *the opportunity hypothesis*. The two most obvious one are the bus-lane access and the start of sales of EVs by the traditional auto importers. The Norwegian Public Roads Administration wanted to prohibit minibuses from using the bus lanes from 2003. EV enthusiasts used this opportunity to lobby and succeeded with the help of others in getting access for EVs to the bus lanes. The traditional car importers and dealers came to a set table of EV incentives established over two decades, when they launched their EVs into the market in 2010. The incentives had been built up in order to sell small, rather basic, hand built and expensive EVs with rather basic quality, and unknown levels of safety. Being produced by unfamiliar independent manufacturers, these EVs were sold through a small network of new dealers. The warranty given for EVs was short, and there was a risk to the buyer if the producer or dealer of these vehicles went bankrupt. When Mitsubishi, then Citroën, Peugeot and Nissan launched EVs with the size and quality that buyers were accustomed to, offering a five-year warranty through their regular dealers, the incentives proved much more powerful than before. The result was rapidly increasing sales.

Some of the players in the independent EV regime embraced the new EV regime. The EV association managed to get all vehicle dealers to give a free year of membership in the association with the vehicle. The number of members and the ability to lobby politicians increased. The EV Association was by now a user organisation for EV owners, promoting EVs, providing membership advantages, defending incentives and fighting for new ones. They also established and maintained the Norwegian database of charging stations. By increasing the membership base of the organisation, a positive feedback loop was created, enabling the organisation to work more effectively to improve EV policies to the advantage of current and future owners as well as the dealers selling EVs.

A third window of opportunity was the EVs getting an exemption from the road toll in Oslo. The exemption set precedence for all later toll-road projects, where the government was one of the contracting partners. A rapidly increasing number of toll roads appeared all over Norway during the 2000s (Lauridsen 2011), making this incentive much more potent. In 2000 less than two billion NOK of revenues came from toll roads. In 2014 the expected revenue from toll roads is five times higher at 10.5 billion NOK (Ministry of Transport and Communications 2015).

Windows of opportunity have been exploited also at the *landscape* level. In 2000, negotiations were carried out in the Parliament concerning a change in the VAT system. The intention was to introduce VAT for services. During these negotiations, lobbyists and small parties managed to lobby in the zero-rate VAT for EVs. This result was also influenced by Ford at the time owning Think and planning on expanding their EV production in Norway.

The 2009 financial crisis resulted in several countries introducing countermeasures such as support for new green technologies to foster future growth. In Norway, charging stations were put up. In the US and in the UK, Nissan got support from the governments in setting up the Leaf production and battery production facilities. In Norway, electricians and construction workers were kept busy with a six-million Euro programme to set up charging stations around the country. Other countries wound down their EV policies from 2002 such as France (Arval 2010) and the USA,

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opening up the opportunity to export second hand vehicles to Norway from these countries. This situation helped keeping up the EV activities, coinciding with the opening up of the bus lanes for EVs from 2003.

Figure I:6 summarizes the timeline of windows of opportunities having influenced the EV development and some of the factors leading to the opening of these windows. Interestingly, the first window of opportunity to start sales of EVs in Norway came about right after the first EV was imported. The owner got an exemption from the sales tax, making it possible for another company to start importing and selling EVs. All subsequent EVs sold without registration tax.

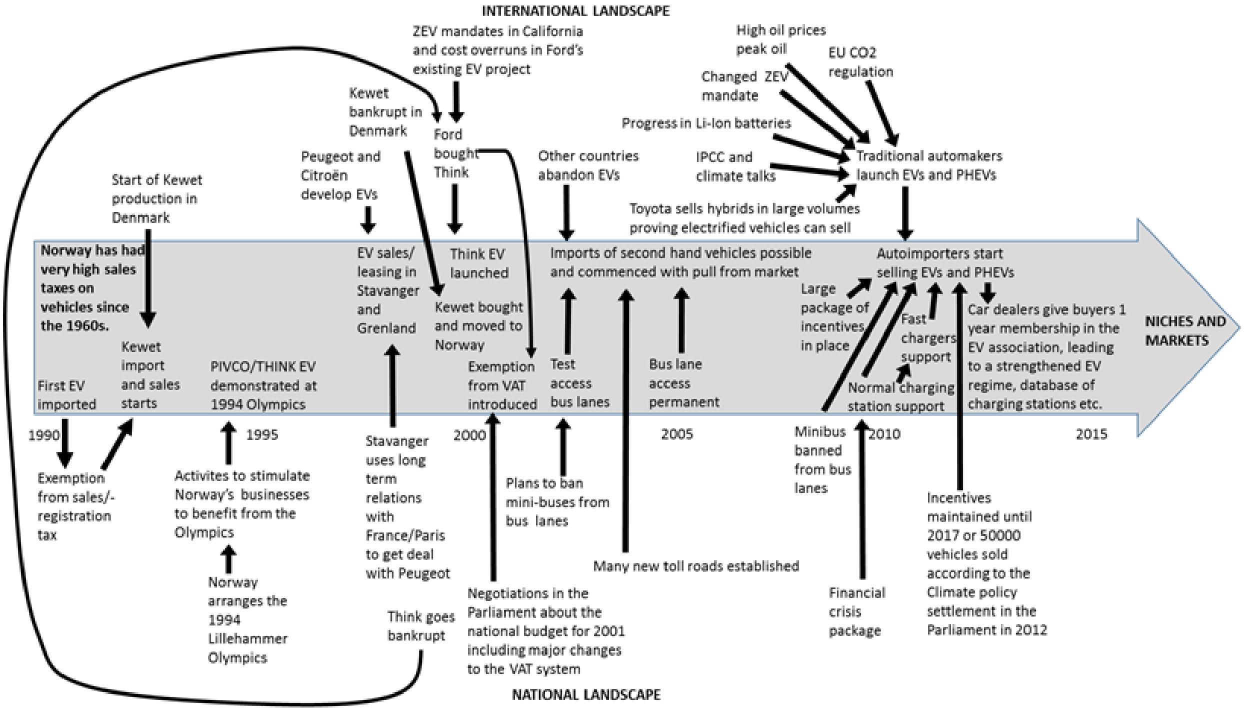

Figure I:6. Exploitation of windows of opportunity for Electromobility in Norway, To be read from left to right as a chain of events. Arrows indicating opportunities arising from previous events.

The open-window concept should also include the options not intended, resulting from changes at the regime and landscape level. To examples given by Geels, Dudley and Kemp (2012) could be mentioned:

- EVs link transport to the energy system that may lead to upgrades being required or to further changes to the functioning of the grid.
- People driving more if cars become cheaper to own or operate as is the case for EVs in Norway.

Little evidence about the first statement can be found in the Norwegian market. The number of EVs passed 50 000 in April 2015, consuming around 0.15 TWh of electricity which is only 0.15% of the total consumption, 109 TWh in 2013 (SSB 2015b). Regarding the second statement, the COMPETT user survey (Figenbaum, Kolbenstvedt & Elvebakk 2014), shows that a fifth of the EVs bought were additional cars, and the total number of km driven by in some households increased. However, we do not know if the households would have bought a car anyway, and if so, what type of car.

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I:4.7 The fate of the competing technologies

Some automakers, such as Toyota, have opted for plug-in hybrids rather than EVs. Others have launched models of both vehicle types, such as Volkswagen, BMW and Mercedes. Nissan and Renault have only launched pure EVs. In 2015 the first "hand built" fuel-cell electric vehicles (FCEV)s are coming into the market in low volumes.

In Norway, the large and sustained support for EVs and the establishment of EV regimes have led to few incentives for PHEVs. The PHEVS are considered by the government and NGOs as less environmental friendly and desirable than EVs, albeit better than ICE vehicles. They can drive on gasoline or diesel only if the user does not plug it in. They have essentially no user disadvantages that could have been used as an argument to establish user incentives, other than the high cost.

Thus, the long and hard work by the independent EV regime to improve on the EV framework made it easy for the ICE regime players to launch EVs but difficult to launch PHEVs. It is now a challenge for PHEVs to compete with EVs whose owners are given very generous and desirable incentives, i.e. bus lane access and free toll roads. In 2014 an increased weight allowance was introduced for PHEVs before calculating the vehicle registration tax. The result was a reduction in the PHEV purchase price. The allowance was increased further in 2015, resulting in zero registration tax for the smaller PHEVs. Sales started to climb to 0.9% in 2014 up from 0.2% the two previous years. The market share in the first quarter of 2015 reached 2.5%, a fact proving that the economic incentives introduced at the landscape level are sufficient to start the diffusion of these vehicle types. The PHEV regime is being strengthened by many new models being launched at more competitive prices in 2015. They are also appearing in segments were ICEs are heavily taxed, PHEVs have low taxes, and EVs are not available. In these segments PHEVs are more competitive than in the compact vehicle segment they originally were launched in.

Biofuels proponents failed to sustain necessary incentives supporting these alternatives. 10 000 NOK support was offered covering the extra cost of making vehicles bioethanol capable, without much sales. The bioethanol capable vehicles were modified large gasoline vehicles that always have had high registration taxes in Norway. These vehicles have high CO_2-emissions in the type approval tests being conducted using gasoline fuel. The result was that these vehicles became more expensive to buy than comparable diesel vehicles even with the 10 000 NOK support. Some 20 bioethanol pumps became available after 2008, but this number is now reduced rapidly as bioethanol fades out as an option. Biodiesel was also about to be established as an optional fuel in Norway, being exempted from the regular diesel fuel tax. A change in the tax on biodiesel from 2010 when half the tax of mineral-oil based diesel was introduced on biodiesel ended the activities to market pure biodiesel. Biofuels are now mixed into regular fuel under a government obligation to all transport fuel providers. They have to sell at least 3.5% biofuels, increasing to 5.5% in the middle of 2015. The result of these activities is a weak biofuel regime that is assimilated by the traditional transport fuel providers. It is now not possible to sell pure biofuels profitable in the Norwegian market. Interestingly the surprise tax introduction on biodiesel from 2010 is now being used as a warning to politicians not to reduce EV incentives too soon or too rapidly and without warning.

Fuel cell hydrogen vehicles have been tested in various test programmes in Norway since 2006 and received high focus as an alternative or a complement to electric

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vehicles. The purchase and user incentives are the same as for EVs, both being zero emission vehicle types (depending on primary energy used). The proponents used arguments about equal treatment with EVs to get these incentives established. Limited marketing of fuel cell vehicles will take place with Toyota and Hyundai as the main players over the next few years. In the beginning from 2006, hydrogen was promoted by three large Norwegian companies, the industrial conglomerate Hydro, the national oil company Statoil and the state owned electricity producer Statkraft. These industrial actors later backed out, and the main actors pursuing hydrogen now is the hydrogen association, some small industrial actors and the counties of Akershus and Oslo.

I:4.8 Resulting MLP-model for Norway

In figure I:7 the relevant activities at the landscape, regime and market levels discussed in earlier sections are summed up. This figure represents the proposed MLP based model for the EV market development in Norway. Table I:2 shows the timescale (nonlinear for 1990-1999) with the sales volumes of EVs, PHEVs and biofuels. Hydrogen vehicles do not appear with sales volumes as only a handful of these vehicles are in use. The total fleet of PHEVs was less than 0.1% of the total fleet at the end of 2014.

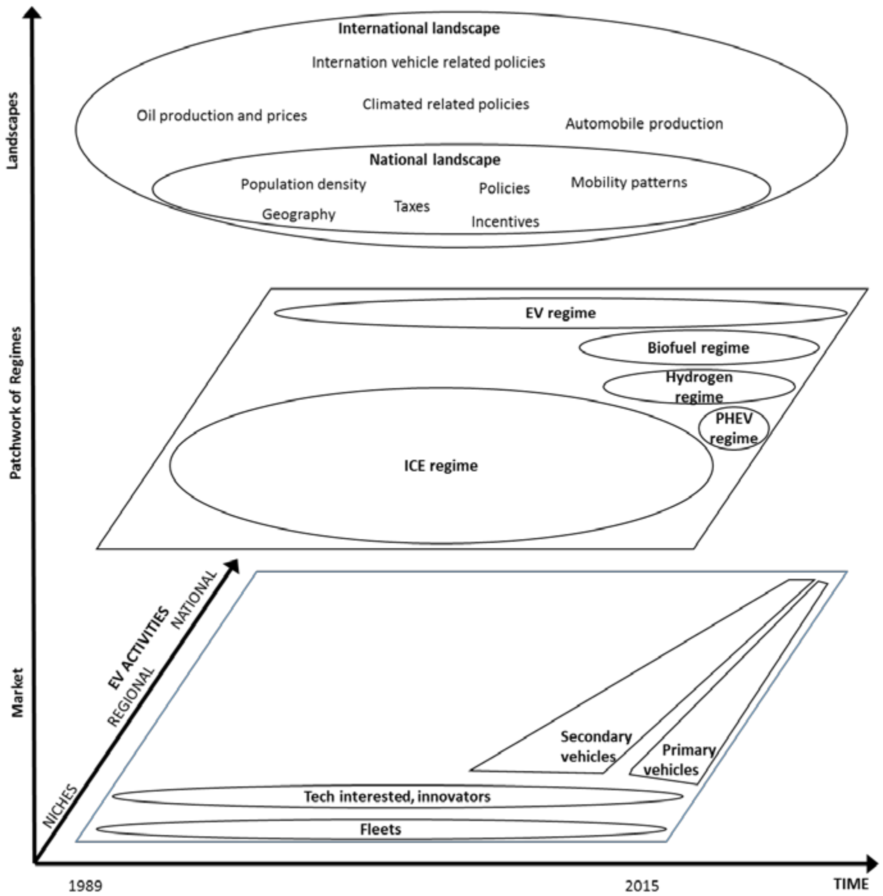

Figure I:7 Multi-level perspective framework for analysing electromobility in Norway (Adapted from Geels 2012).

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Table I.2 Sales volumes of EVs, PHEVs and biofuels. Sources: OFVAS (2004-2015), SSB (2004-2015), Gronnbil (2012-2015) and Norwegian Environmental Agency (2014).

1990 1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015 01-02
EV percent of total fleet	0.03%	0.03%	0.05%	0.06%	0.06%	0.07%	0.08%	0.09%	0.11%	0.12%	0.15%	0.23%	0.4%	0.8%	1.6%	1.8%
EV market share percent of new vehicles											0.3%	1.4%	2.9%	5.6%	12%	18%
PHEV market share percent of new vehicles													0%	0.2%	0.9%	2.5%
Biofuels volume percent total transport fuels					0%	0.1%	0.2%	0.8%	2.2%	2.6%	3.1%	3.1%	3.5%	3.5%	3.5%	3.5%

I:5 Discussion

The following observations can be made about the hypotheses formulated in chapter in chapter I:2.

The niche hypothesis finds much support. The economic incentives reducing user cost combined with incentives making EVs attractive with advantages not available to users of other types of vehicles have created niches. The economic incentives have enabled multicar households to adopt EVs by lowering the price to or below the level of ICE vehicles.

The bus-lane access and toll-road user niches have been particularly effective. These users have experienced substantial benefits in time saving or economic savings compared with users of ICE vehicles. These incentives have been so successful that the first bus lanes will soon need to be closed for EVs during peak rush-hour traffic to avoid delaying buses. On some expensive toll roads, the share of EV have passed 10%, and these toll-road companies can be expected to run into problems paying their debts by the income from the tolls. The traffic volumes have in many cases increased even more so that the yearly budgets of the toll road companies have not yet been stressed. The budgets are linked to the expected traffic growth at the time the toll gates were installed. In the contracts regulating the establishment of toll roads there are general terms allowing the company to increase toll rates by 20% and to extend the tolling period by up to five years (NPRA 2014). There is thus no imminent threat to the ability of the toll roads companies to pay their debts due to EVs not paying tolls.

Geels, Dudley and Kemp (2012) state that in the beginning niche activities are important, but as time goes by the traditional regime actors will be crucial in future transition to more sustainable transport. They have many complementary assets such as specialized manufacturing capabilities, distribution channels and service networks, giving them a competitive edge over niche actors. This point is illustrated in the Norwegian EV market taking off when the automakers launched EVs into a market where niche actors had stirred up the interest for EVs earlier in the transition. To the assets of the automakers one should also add brand loyalty and trust in and knowledge of local dealers. The expected second-hand value of the car will be better,

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and most importantly the exposure to the new products will expand rapidly. This way, also those who go to a dealer just to buy a car, not particularly interested in what energy it uses, will be reached.

The ICE regime hypothesis is strengthened. Norway has no national ICE vehicle production, a fact which in itself is an indication of a weak ICE regime. Norway has oil production and large dominating companies deeply involved with the oil industry. The sale of fuels to the Norwegian drivers is done by separate companies. Therefore, the government and municipalities had no need to consider the impact of changing vehicle incentives and taxes on the competitiveness of incumbent automakers or the oil industry. For the government the potential for national electric vehicle production was attractive as it would lead to more employment than merely importing ICE vehicles built in other countries. This effect would come in addition to the environmental benefits of using EVs. The EV regime was received positively in the political landscape when asking for (more) EV incentives. This effect is likely to have contributed substantially to Norway's EV friendly policy development.

It seems like some of the ICE-regime players have taken an opportunistic approach by exploiting the EV-friendly policies and incentives in Norway. As long as they did not import or sell EVs themselves, they did not support specific EV incentives. They preferred technology-neutral incentives, i.e. based on emissions, which would be more favourable to their product portfolio. Importers who could get EVs in their portfolio did so as soon as the vehicles became available from the automakers. They thus gained an advantage over importers not having EVs available, thereby contributing to a further weakening of the ICE regime. From a governmental perspective it is not important which of the importers that gain a competitive edge as the total number of employees and company taxes per sold vehicle should remain the same.

The landscape hypothesis is strengthened. Clear policy direction resulted in the large incentives introduced earlier, being maintained over the five years since 2010. The rapid EV development in Norway during those years came as a direct result of these incentives remaining in placed. The policies and incentives proved much more efficient as soon as the traditional car producers started delivering EVs from December 2010. For the first time, EVs became available in the entire country and without volume limits.

The policy goals were, however, not so clear earlier when market shares were much lower. In the 1990s, the incentives were introduced mainly to allow testing and experimentation (Ministry of Finance 1989). The pressure for incentives, or in the beginning rather the removal of disincentives, came from enthusiasts. The government could offer the incentives at hardly no cost given the low sales. In the middle period 2000-2009, the target for the policies seems to have been to support industrial development. Incentives that potentially could have a high future cost, such as the zero rate for VAT were introduced. The zero VAT rate came about as an agreement in the Parliament about the national budget for 2001. It was not included in the original national budget proposal for that year.

Ever more incentives were introduced when EV sales still did not grow. The bus lane access from 2003 as a test, and made permanent from mid-2005, had a huge value to the users. The cost to society was zero as long as there was spare capacity available, although the capacity could have been used in other ways with a potential higher value. The full effect of this incentive was achieved in the beginning of 2009 when minibuses driven by private citizens were banned from the bus lane. Starting in 2007

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and more strongly from 2010-2012, policy focus shifted towards EVs as a climate mitigation measure. The government started using vehicle taxes as a tool to reduce emissions of greenhouse gases. In the climate policy white paper from 2012 an official EV specific policy was introduced (National Climate Policy 2012) and anchored firmly with the follow up climate policy settlement in the parliament later the same year. This settlement specified the continuation of the EV-incentives until the end of 2017 or until 50 000 EVs were on the road. When the present government came into office, they proclaimed that the economic incentives should last until 2017 (Political platform 2013).

It should also be noted that the economic incentives are up for revision in each yearly budget in the Norwegian political system. The fact that they have remained unchanged through all years up to 2012 through varying governments, points to a long lasting "silent" political consensus on EVs in Norway

Being opened and explored many times during the EV development in Norway, the windows of opportunity support *the opportunity hypothesis*. These windows take the form of a chain of events leading up to an unexpected result, one that would not have been possible under normal circumstances. In fact one could say that the Norwegian EV breakthrough is in itself the end result of many windows of opportunity opening along the way. Each had a modest effect on EV sales and therefore remained open as new ones appeared. In the end, a giant window of opportunity lay open for the auto industry when they started launching EVs. It is not likely that all these incentives would have been introduced in the period from 2010, had they not already been in place.

Criticism of the EV policies have mostly been absent or rather weak in Norway, a situation leading to more opportunities opening up. Maybe this fact can be explained by most incentives being introduced when sales were miniscule and EVs unknown. Other drivers were not so critical to EVs when the rather basic slow vehicles passed by in the bus lane. When Teslas started using the bus lanes, the debate started heating up. Costs to society were up to 2011 negligible and sales of EVs were so low that no apparent threat to the incumbent ICE regime was apparent. The policies and incentives are now difficult to criticize as they have proven to do exactly what they should do, i.e. make EVs diffuse at a fast rate.

Emissions from electricity production is mostly a non-issue in the Norwegian debate as 98% of the production is based on hydroelectric power plants *(*Ministry of Petroleum and Energy 2013*)*. In other countries this issue can be an important factor.

The incentives have addressed the various weaknesses of EVs. The long-term policies, incentives and the establishment of EV regimes have allowed businesses to see and more easily act upon opportunities as these were introduced. An important factor has been the fact that all incentives are national, although not all have an effect everywhere. The incentives are also without an end date. Stable conditions over a period of five years were achieved from mid-2012 after the climate policy settlement (Climate Policy Settlement 2012) in the Parliament maintained the incentives through 2017 or until the EV fleet reaches 50 000. At that time, no one thought the EV fleet would pass 50 000 before 2017. The policies have been so successful that the number of 50 000 vehicles was achieved in April 2015. Thus, Norway has become the forerunning country within electromobility.

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I:6 Conclusions

The success of EVs in Norway seems to be a result of the long-term stable political framework built up piece by piece by many actors and stakeholders. Heavy vehicle taxes have given room for tax relief incentives rather than direct subsidies. There has not been much criticism of these policies, and leading politicians have been outspoken positive. The framing of the policies have evolved from first allowing testing of EVs, then support to industrial development, and finally the EV policy framed as a climate mitigation measure, leading to higher acceptability for the policies, in line with Geels, Dudley & Kemp (2012). The lack of vehicle production in Norway means that the ICE regime actors are not affected so much by which vehicle type they sell, although the dealers' workshops may have less work as EVs 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 EVs instead of ICEs.

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

The EV privileges in the Norwegian policy framework can lead to suboptimal effects. The future of transport may consist of fragmented markets with multiple dominant designs, i.e. EVs for short-distance travels, for cities, and FCEVs (and PHEVs) for longer distance travels, and biofuels for heavy-duty vehicles.

Using the classification of Geels & Schot (2007) the electric vehicle diffusion seems to be on a *transformation path* internationally where moderate pressure on the ICE regime is leading to a gradual establishment of an EV regime. The EV regime grew out of the old regime through a reorientation of the powering of automobiles while keeping other basic vehicle features unchanged. In Norway, the policies and pressure from the landscape have been much larger, leading towards the following of a "*technological substitution path*".

The competitiveness of other technologies and the ability to provide incentives for these technologies have been hampered by the strong EV regime in Norway. An example is the few incentives available to PHEVs. The difference between the technologies can be considered a result of the strength of the long lasting EV regime and its ability to influence politicians, but also their ambivalence towards technologies that can be used in more or less environmentally friendly manners.

Being a forerunning country of electromobility could last longer and cost more money than anticipated by Norwegian politicians. Electromobility develops rather slowly globally in contrast to the rapid changes in Norway. This difference will lead to higher costs for vehicles and a narrower selection of models than if all countries had progressed as much as Norway. The risk of international setbacks in EV development is thus the main uncertainty for the future of electromobility in

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Norway. Representing the other major uncertainty, revision of the incentives will also inevitably have an impact on sales.

The Norwegian White Papers present Norway as a test site, with a global responsibility to test t incentives and learn from experiences that can be useful in other countries also. Norway may push electromobility even further, potentially succeeding in a transition to passenger vehicles largely running on electricity, by increasing the pressure on the ICE regime now that alternatives to ICEs exist and expand rapidly, as suggested by Geels, Dudley and Kemp (2012). They 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, although one might say they have merely left the incentives in place, i.e. been passive. The coming years when the EV incentives will have to be downsized gradually, may be more challenging.

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Part II Diffusion of EVs in Norway

II.1 Introduction

This part of the report is focussing the concrete transition of the car market regionally and among different car user groups in Norway. Many studies have analysed the potential for an electromobility transition, these studies are mainly theoretical. It is only in Norway that:

1) There are enough EVs to study the users experiences of pro's and con's with using EVs and how they adjust to possible challenges.
2) There are many different incentives making it possible to study their effect on different aspects of diffusion of EV.

The following questions will be investigated:

- How has EVs diffused in Norway – regionally and among different users and markets?
- Which technical, societal, individual and communicative factors have affected the diffusion?
- How do Norwegian EV policy, incentives and characteristics influence the relative advantage of EVs?

II:2 Theoretical framework

II:2.1 Diffusion as a social process

The theory of diffusion of innovations developed by Rogers (1962, 1995) seeing diffusion as a social process, will be used as the main theoretical baseline for explaining the development of the market and the rate of diffusion. In addition, newer theorists like Axzen 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 of how the new technology can meet the user needs are shown in figure II:1. The users must be seen in a wider sense, from individuals to decision makers at different levels and sectors.

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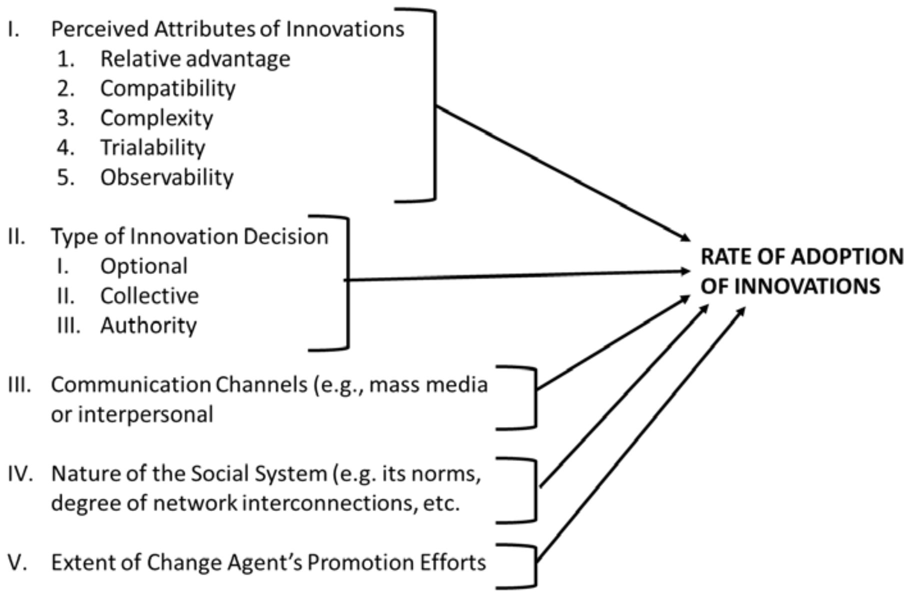

Figure II:1 Crucial factors in the diffusion process that can influence the rate of adoption. Source: Rogers 1995.

II:2.2 Characteristics of innovation

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, is the key element in diffusion. The rate of diffusion (Rogers 1995) is influenced by perception of the technology with respect to:

- *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, improved comfort, saving time or effort, immediacy of reward.
- *Compatibility* with the users' needs, basic values and norms in the social system. The more radical and disruptive technology and the less its compatibility with existing practises, norms and values, the slower its rate of adoption.
- *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.
- *Trialability* applies to the opportunity for trial. Innovations that can be tried out on a small scale are perceived as less uncertain and easier to implement than those that require full implementation immediately. Trialability is more important for early than for later adopters. The latter will be helped by information from adopting peers.
- *Observability/visibility* for new users can increase the speed of implementation. This factor stresses the importance of network communication and the strategy of launching the product.

Incentives to speed up EV adoption should address these factors, especially the first one, Relative advantage, which is the most influential in the diffusion process.

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Characteristics pertaining to vehicle innovations

Vehicles are complex products with 3-5 years development time before being launched into the market (Plotkin, Stevens & McManus 2013). They are sold for a period of five up to eight years before being replaced by the next generation. Diffusion of technologies across all automotive brands and models takes 12-17 years (Ibid). Vehicles are designed for 10 years life but last up to 20 years. During this period, the car manufacturers provide service and spare parts to owners. The life cycle of vehicles can thus reach 30 years. Replacing the total car park takes 20 years (Fridstrøm & Østli 2014). Full diffusion could thus be achieved from around 2040. Innovations improve over time in diffusion processes. When the innovation is launched, costs are high. The target group is buyers with a high willingness to pay. Technology improve during future iterations, and new customer groups can be reached. In the automotive sector, new technology diffuses to new models, to other brands and to new market segments with successively lower purchasing power, i.e. from luxury vehicles to SUVs, larges cars and further to compact cars and small vehicles.

The private household vehicle market can be split in two parts, primary and secondary vehicles. Primary vehicles in Norway are typically compact and larger vehicles. Secondary vehicles are low cost mini, small and compact vehicles used for commuting and daily travel.

Technological challenges with EVs influencing diffusion

The *battery and the drive systems* are the crucial new technical systems in EVs. Battery lifetime, performance and potential replacement costs over vehicle lifetime are the main uncertainties.

Most EVs produced after 2010 have a typical on-road range in Norway of 80-130 km (COMPETT estimate) depending on season and driving styles, plus a range reserve of 20% (Figenbaum, Kolbenstvedt & Elvebakk 2014). A full recharge at home takes 7-10 hours. Thus, owners need to have a dedicated parking space with electricity available. In comparison, an ICE is driven 600-800 km between fill-ups taking a few minutes.

For households with short daily driving needs compatible with EVs range capability, such as those owning more than one vehicle, adapting to EVs will be relatively easy. Those with a more variable driving pattern may need to adapt or plan trips better. Given such challenges, incentives giving EV owners other comparative assets, i.e. a relative advantage, might be necessary to support diffusion. Other factors of great importance are *safety, reliability and durability* (Figenbaum, Kolbenstvedt & Elvebakk 2014).

II:2.3 Diffusion systems and innovation decisions

Diffusion systems can be *centralized and decentralized*. In the automotive sector, an example of the centralized system is the mandated technical requirements for vehicles, such as emission controls. In a decentralized system, each individual user decides whether to adopt which is typical of vehicle buyers choosing between gasoline, diesel or electric vehicles. The advantage of a decentralized adoption system is that the solution more likely will meet individual user needs. The disadavantage, however, is that the collective needs may not be met.

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Preventive innovations are often based on societal needs, having a slow rate of adoption (Rogers 1995). Recent studies of dissemination of preventive innovations (Jacobsen & Bergek 2011, van den Bergh, Truffer & Kallis 2011, Propfe et al 2013, Moch & Yang 2014) stress the importance of societal support for these types of innovations. EVs offer less extensive and less flexible mobility compared with a gasoline vehicle. Reduced local pollution, noise and home fill up of energy may be perceived as advantages. The main point of EVs is, however, to reduce the emission of climate gases to *prevent* global warming in the future, a typical societal motive.

Diffusion of EVs can be *interactive and non-interactive.* An interactive invention brings added benefits to early users as more users take the innovation into use (Rogers 1995), whereas a non-interactive does not influence the earlier adopters. With more EVs sold, spare parts cost goes down, service will be available in more locations; the future replacement EV will have better characteristics. The expansion of the charging station network is an interactive element in EV diffusion. The more users, the more charging stations in more locations. A non-interactive characteristic is that EVs can be taken into use without any need for public charging stations if owners only charge at home.

II:2.4 Communication, channels and change agents

The communication processes underlying diffusion constitute a net between all the elements, and influenced by these, defines the role of the innovation in society. The processes for the decision makers on several levels include five phases: Knowledge, persuasion, decision, implementation and confirmation or rejection.

The knowledge of innovations diffuses through several media and social networks that may be influenced by change agents aiming to speed up diffusion. The first innovators are too far apart from the next adopters to be influencing them. The fact that they take an innovation into use, however, increases visibility of the innovation to others. Horizontal communication with people who are equal, can speed up innovation in that group. Communication between unequal groups is needed to assert vertical diffusion between layers of people in society. In such networks, people seek advice from opinion leaders having a higher socioeconomic status, being more cosmopolite and innovative, better educated and better connected with change agents. Therefore, opinion leaders are the most important early users.

Cities are in general more innovative, having universities and contacts that are more international. More people are available so that the number of innovators taking new technology into use will be higher, and the interpersonal communication networks are larger (Pan et al 2012). Other aspects are higher average incomes, increased EV visibility with more people seeing the EV in use, and trialability as one EV dealer can serve more people.

II:2.5 Nature of the social system

The social system consists of institutions with various interests, norms, habits, values and laws. Crucial societal framing factors for EVs are clear *political goals* supporting the use of the actual technology, and the prevalence of a political and economic system suitable for supporting the goals with incentives. The latter is especially important for environmental innovations. Figenbaum & Kolbenstvedt (2013) present

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the technological development of BEVs as well as the political goals and tools established to stimulate the use of BEVs in Norway. They illustrate how the societal role for EVs was transformed from an industrial to a climate protection instrument. Other framing conditions are related to *geography*, climate, travel distances and electricity mix, chapter II:5.

II:2.6 Different users in different phases

Diffusion of innovations normally follows a s-shaped curve with five adopter groups successively adopting the innovation, c.f. figure II:2 showing the main characteristics of the adopter groups. After 10-20% market adoption is reached, further adoption is self-sustaining, i.e. critical mass is reached. Successful innovations follow the s-curve. Incentives and other framing conditions can cause some to adopt earlier than expected or result in setbacks i.e. the experience with EVs may be negative if range is marginal for user needs.

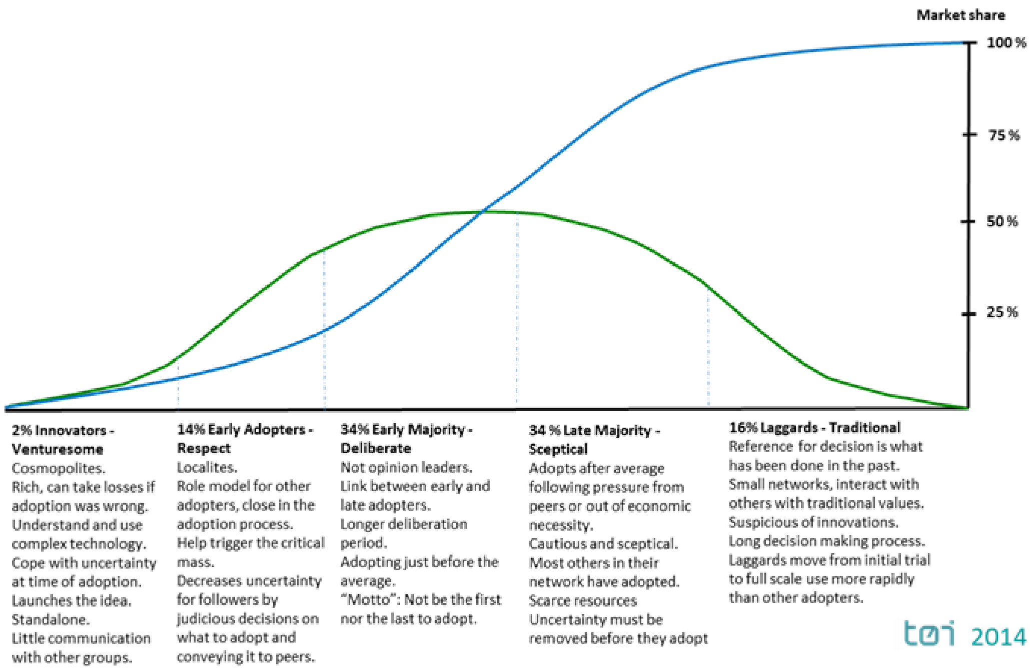

Figure II:2 Adoption curve for innovations and the typical role of different user groups, adopted from Rogers (1995).

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II:2.7 Expected diffusion

The hypotheses are that diffusion of EVs will be more successful when:

- *Cars* that can meet *user needs* (individual and societal) and give relative advantages are available
- *Society can speed up* diffusion with *incentives* reducing barriers or giving compensatory assets
- *Communication channels* are in function, and may be supported by *change agents.*

Diffusion of EVs can be measured at the model level, as the number of vehicles sold of an EV model compared with ICE vehicle models in the same segment, at the segment level, as the share of vehicles sold by a particular brand or as the share of total sales of passenger vehicles at local, regional and national level. The expected diffusion pattern is shown in figure II:3, based on Rogers (1995) five adopter groups and the authors' assessment of what the diffusion model would translate into on a national level. In principle, three processes occur at the same time, adoption within a region, expansion of adoption to new regions and an expansion in the supply of models in increasing number of segments from increasing number of automakers.

First step of diffusion - Innovators

The diffusion is expected to be slow at first. The first adopters are the innovators (2% of market) who make the decision to adopt individually with little influence from social networks. They are cosmopolites and rich enough, i.e. adoption of a product that later fails does not cause too high risk. The innovators can be in different parts of a country with no contact between them. More adoption is expected in cities. Innovators get their information from media, but also from international travels. Few vehicle models, brands and segments will be available. Geographical availability may be limited due to the producers not having or wanting a nationwide dealer network.

Second step of diffusion – Early adopters

The diffusion picks up in speed when early adopters start buying. They are well connected, richer than average and acting as intermediates between innovators and later adopters. Adopting opinion leaders have large social networks and a high esteem among peers, a situation leading to faster adoption. They are in contact or proximity with the innovators, i.e. typically living in cities or suburbs. The number of models and brands will be larger in more segments and will be available from nationwide dealers. Diffusion spreads out radially from initial areas and within each area. New areas start adopting as users are influenced through communication networks, across groups, i.e. friends, families or social media.

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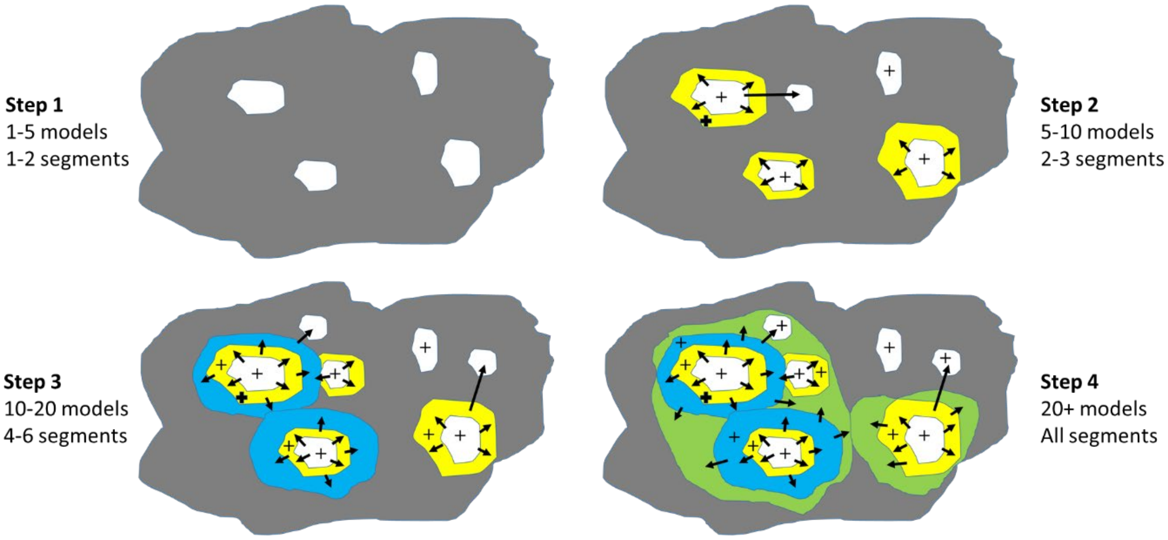

Figure II:3 Expected pattern of market diffusion, the first four steps taken into account. White are initial areas, + signs illustrates a deeper diffusion within areas where EVs have been taken into use. Arrows mark diffusion to new areas with increasing distance to the original areas with yellow, blue and green colour.

Third step of diffusion – Early majority

The early majority starts adopting and diffusion speeds up. Vehicles will be available in the main volume segments from the market leaders nationwide so that the early majority is reached at a national level. Diffusion should now spread to all regions, and growth should be large in all areas in increasingly larger, overlapping circles.

The fourth step of diffusion – Late majority

The late majority starts adopting. EVs are now seen as a regular option alongside gasoline and diesel vehicles. All brands sell EVs in different segments catering for brand and segment preferences. The diffusion circles around cities have become so large that the overlaps create large adoption regions. Diffusion is now high in all parts of the country.

The final step of diffusion - Laggards

In addition, laggards adopt, and more remote regions starts adopting. The diffusion growth rate slows down, and diffusion eventually reaches its maximum potential as all potential adopters have adopted.

II:3 Material and method

The actual diffusion pattern is analysed using statistics from the national vehicle register, NPRA and the EV Association (2008-2014), Statistics Norway (2013, 2014) and other sources. The EV diffusion in the fleet is analysed by municipality and over several years. New vehicle sales of EVs per model, brand and segment, are compared with ICE vehicles sales, providing further insights into the market dynamics.

Results from the surveys and interviews described in the chapter on common material in the beginning of the report have also been used.

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White papers, propositions and national plans have been used to find the regional patterns (see i.e: The Norwegian Climate Policy Settlement (2012), The national Transport plan (NTP 2014-2023)).

II:4 Actual diffusion patterns

The process of EV diffusion in Norway has been a combination of centralized and decentralized. Deciding that adoption of EVs will contribute to reduction of emissions of Green House Gases (GHGs), the government put incentives into place to stimulate the market. The decision to adopt is entirely decentralized to the buyers. The international automakers' decisions on adoption are a framework for the consumers, affecting their ability to adopt the technology.

II:4.1 National EV fleet

Prior to 1998, no regular diffusion of EVs occurred, and the number of EVs in the fleet only reached 146 in that year (Asphjell et al 2013). The fleet of EVs increased slowly through the 2000s, as consumers became the main buyers. In May 2006, 25% of the total 1316 EVs registered in the national car fleet were owned by consumers (ECON 2006). In the beginning of 2010, the number of EVs in Norway reached 3000 (Figenbaum & Kolbenstvedt 2013). The EV fleet increased rapidly from 2011 as the traditional vehicle manufacturers launched their models one by one, reaching 39 000 EV, or 1.6% of the total Norwegian passenger car fleet in 2014, see figure II:4. In Norway 80% of EVs are sold to and owned by consumers (Gronnbil 2014). Sold to legal entities, parts of the remaining 20% are leasing vehicles used by consumers.

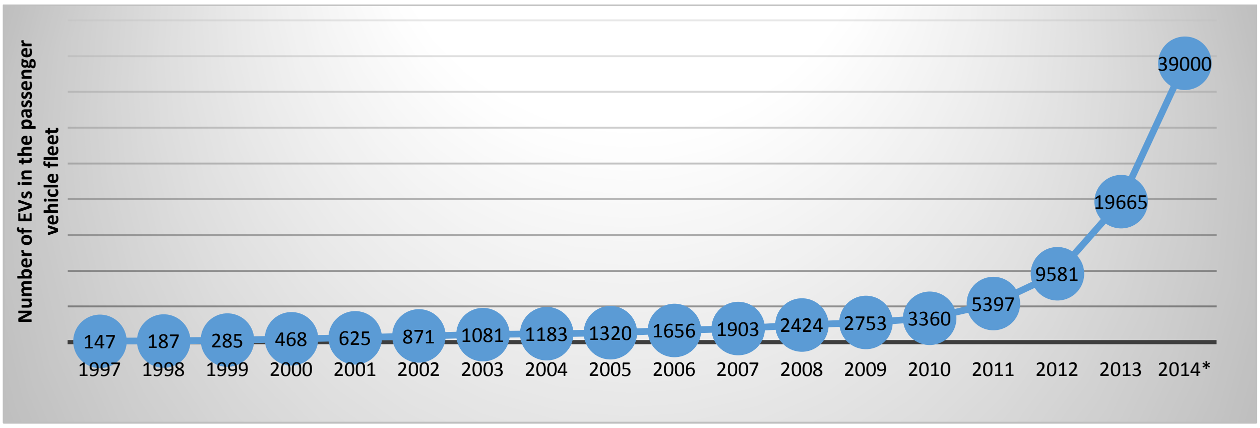

Figure II:4 Number of EVs in Norway 1997-2014. Source: Asphjell et al, 2013, OFVAS (2014), NPRA and the EV Association (2008 -2014).

II:4.2 Regional diffusion

After 2010, the diffusion of EVs started in cities and their neighbouring municipalities spreading further out radially. An increase in the adoption rate has also occurred within each municipality, se figure II:5. A second group of early adopters have been municipalities with expensive toll roads such as Finnøy, the first municipality with more than 10% adoption where owners save up to 30 000 NOK per year.

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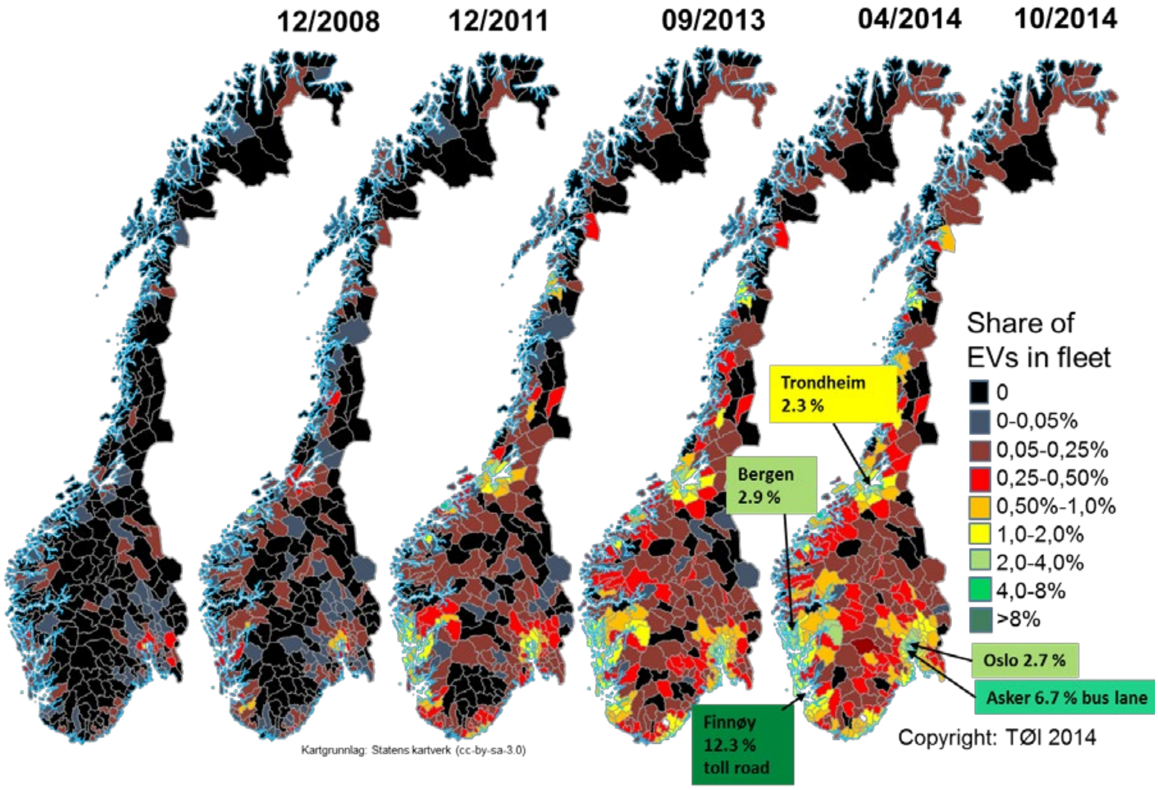

Figure II:5 Geographical diffusion of EVs in Norway's 428 municipalities 2008-2014. Share of EV in total fleet 1st of January each year. Made by authors with data from the Norwegian Public Roads Administration and the EV association, OFVAS (2014), Statistics Norway (2013).

The number of municipalities without EVs has gone down dramatically over the years. Only 13% of the municipalities had no EVs registered in October 2014, c.f. figure II:6. In 2008, none had more than 2% EVs in the fleet. In October 2014, the share was 10%. The change in EV density of the municipalities in the greater Oslo region is shown in figure II:7. The diffusion of EVS is clearly visible with increasingly larger circles of higher EV density of municipalities around Oslo and increased density in adopting municipalities.

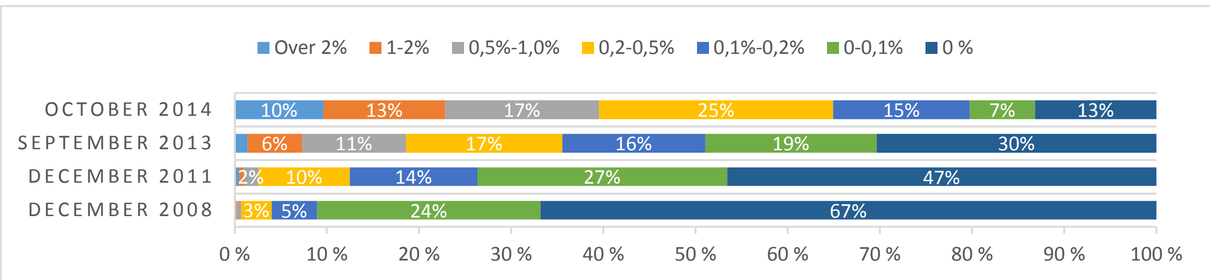

Figure II:6 The expansion of EVs within 428 municipalities in Norway 2008-2014. Share of EVs of total fleet 1st of January each year in intervals. Data from the NPRA and the EV association (2008 – 2014), OFVAS, Statistics Norway (2013).

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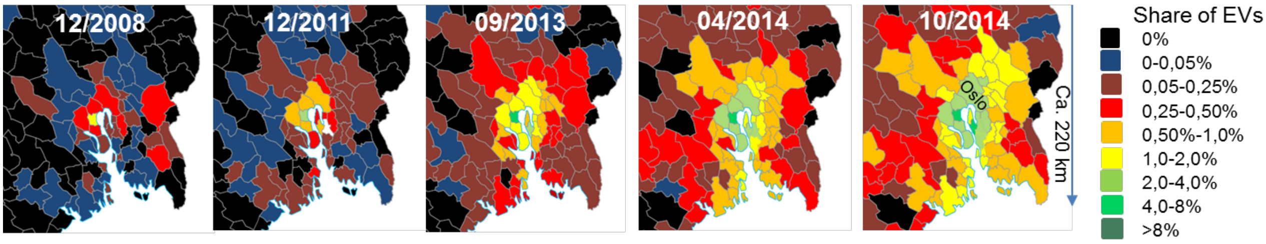

Figure II:7 The change in EV density (share of EVs of total fleet) of the municipalities in the greater Oslo region 2008-2014. Percent of total fleet. Data from the NPRA and the EV association (2008 – 2014, *OFVAS (2014), Statistics Norway (2013).*

II:4.3 Market shares from 2011

Diffusion measured in new vehicle sales and market shares must take into account the number of models available in various segments and the supply being limited or not. The first model in unlimited supply, the Mitsubishi I-Miev (Mitsubishi 2010), became available in Norway in 2011 thus selected as the starting year in this chapter. Second hand vehicles also lead to increased total adoption when imported from other countries as some consumer groups will not adopt until second hand vehicles are available The statistics of the vehicle fleet presented earlier also include second-hand imported vehicles. The market share of EVs of total passenger vehicles for Norway has been 12.6% in 2014 with some 16500 new vehicles sold. 2800 second-hand EVs were imported, see figure II:8.

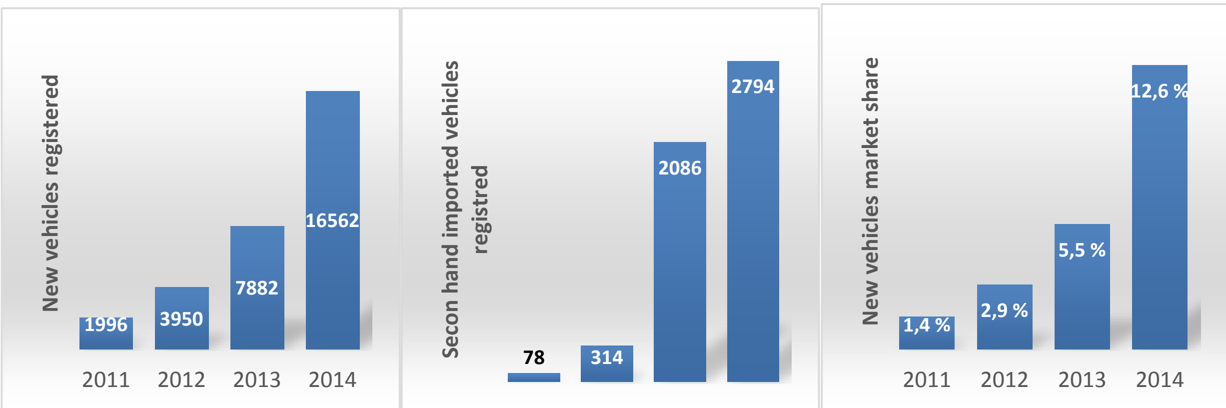

Figure II:8 Total sales of new EVs, second hand imports and new EV market share 2011-2014. Source: OFVAS (2014).

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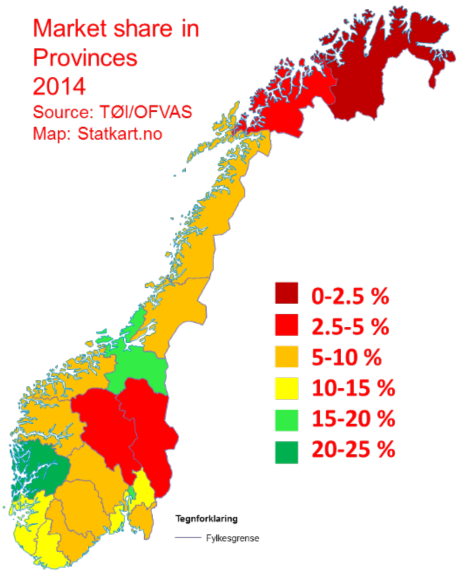

The market shares by counties are shown in figure II:9, showing that the three most populous counties in Norway, Oslo, Trondheim and Bergen, have market shares in the interval 15-25%.

Figure II:9 Market share of EVs by province, January to September 2014 in Norway. Data source: OFVAS (2014).

II:4.4 Diffusion by brand

Mitsubishi (2010) launched the small 4-seater I-Miev into the market through their nationwide dealer network in 2010/2011 followed by Peugeot and Citroën launching Ion and C-zero through most of their dealers. In late 2011, Nissan rolled out Leaf in the five largest Norwegian cities, expanding the dealer network nationwide a year later. In 2013, more vehicles became available, Ford Focus, Tesla Model S, BMW i3, and VW started selling the E-up followed by E-Golf (VW 2013) and then Kia Soul EV (KIA 2014) in 2014. In the last quarter of 2014, Mercedes started selling the B-class and Nissan E-NV200. Smart ForTwo will be the next model coming into the market in 2015. Market shares are shown in figure II:10, and the number of dealers and models available 2011-2014 in figure II:11.

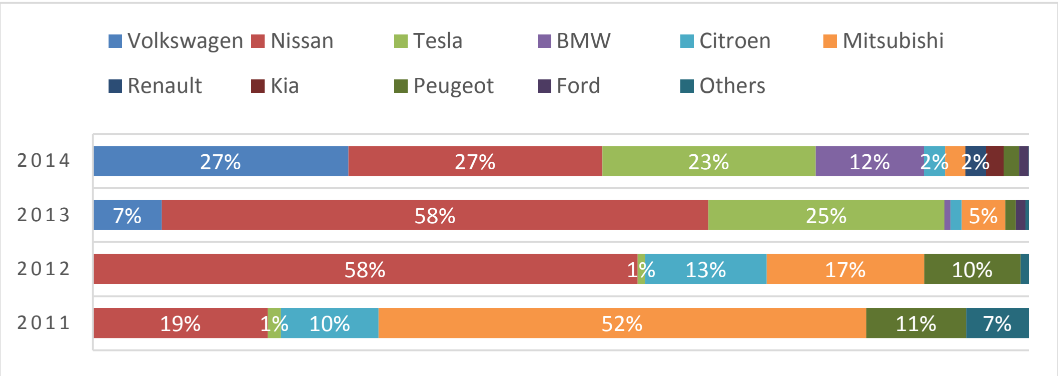

Figure II:10 Brands share of EV market 2011-2014. Data sources OFVAS (2014), Figenbaum & Kolbenstvedt (2013).

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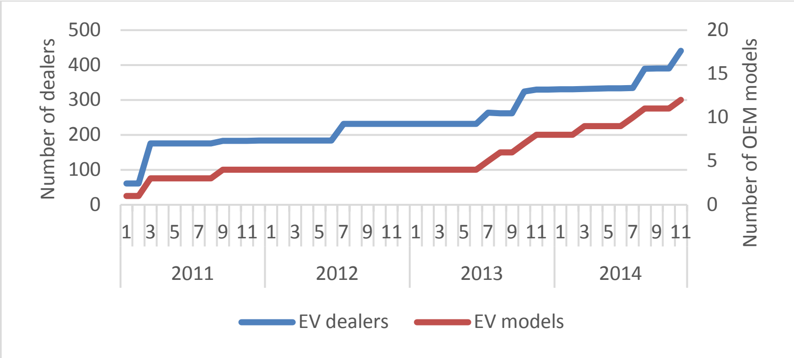

Figure II:11 The number of dealers and models available in Norway 2011-2014. Sources: Compiled from the importer websites. OEM=Original equipment manufacturers.

The development of the EV fleet over time is shown in figure II:12, illustrating the dominance of the Norwegian brands, Think/Kewet/Buddy up to 2010 and the very rapid expansion with new models thereafter. Figenbaum and Kolbenstvedt (2013) presented more information on the market prior to 2011.

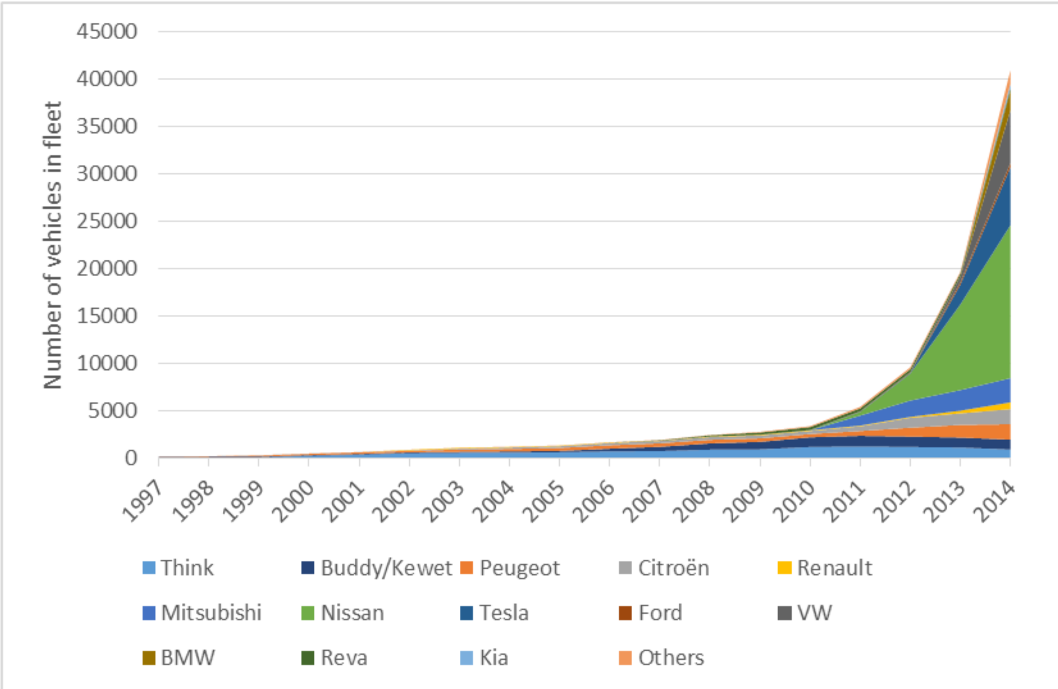

Figure II:12 EV fleet development in Norway 1997-2014. Data sources: The Norwegian Public Roads Administration, the EV association, OFVAS (2014), Asphjell et al (2013).

Share of manufacturers' sales 2014

Manufacturers of EVs get a large part of their current sales volumes in Norway from EVs, exceptions are Ford and Peugeot, see figure II:13. For Nissan, Leaf accounted for 52% of total sales in 2014. The Volkswagen share is lower than its potential due to delays in deliveries of E-Golf.

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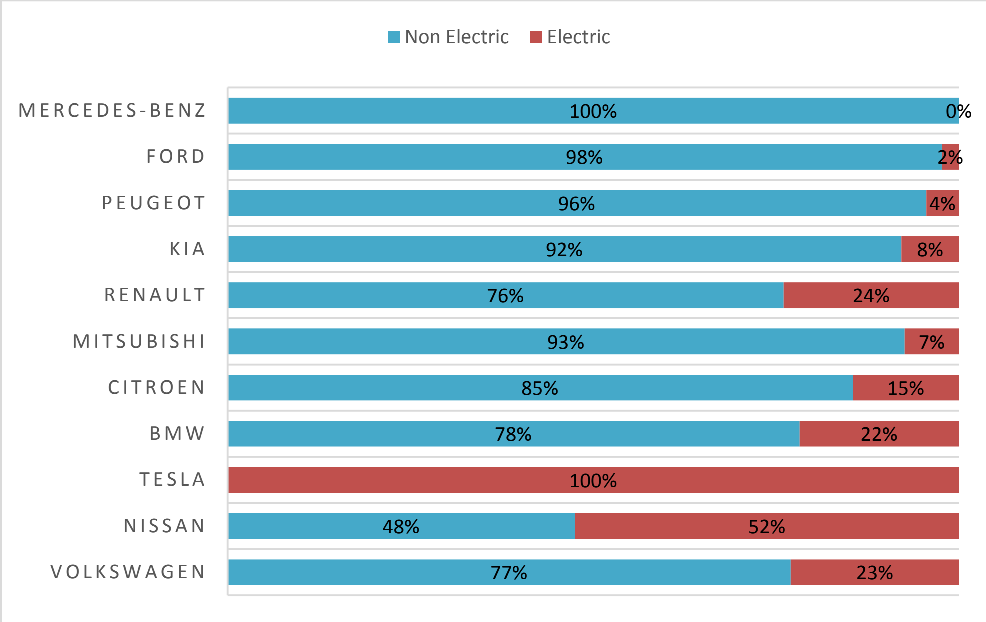

Figure II:13 Shares of EVs and ICEs by manufacturers supplying EVs in Norway 2014. Source OFVAS (2014).

Figure II:14 shows that new EV models led to decreases in sales of some existing models. This is seen for the Mitsubishi I-Miev, Peugeot Ion and Citroën C-zero in mid-2013. Nissan Leaf sales have been somewhat reduced in 2014 compared to the last months of 2013. However, the total numbers sold in 2014 was higher than in the same period of 2013. The low Tesla sales in late 2014 may be influenced by a factory shut down whereas the high sales in March was deliveries of pre-orders. The general tendency is that, contrary to intuition, the existing models keep sales volume when new models enter the market, significantly contributing to the rapid diffusion of EVs. Nissan has (Assum, Kolbenstvedt & Figenbaum 2015) a high percentage of conquest vehicle sales that seems to hold even when competitors enters the market.

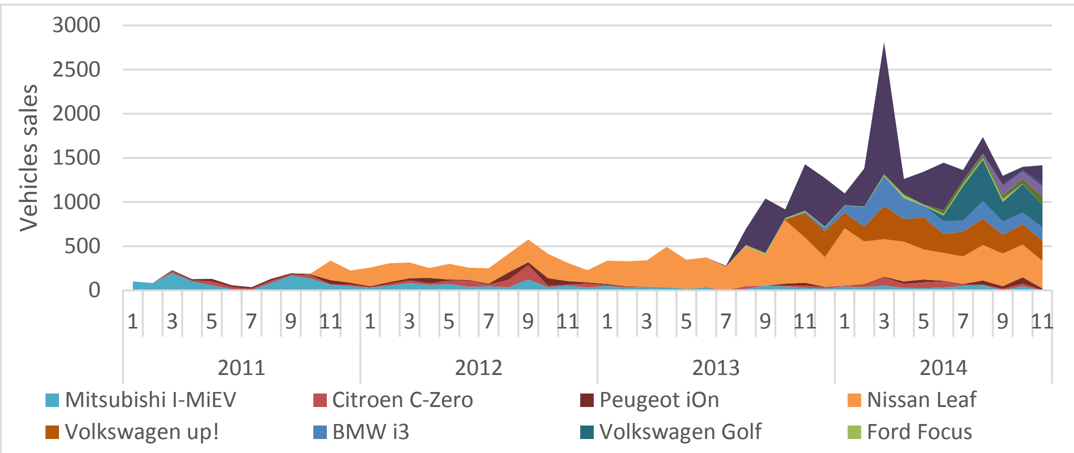

Figure II:14 EV sales of models sold per year and month. Source: Mitsubishi (2010), WW (2013), Asphjell et al (2013), OFVAS (2014).

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Shares by model 2014

In 2014, six models have been sold both in electric and in ICE versions, see figure II:15. Ford Focus and E-up has been available the whole year. Ford Focus has a high price and little luggage space explaining the small EV share. A shipment of VW E-Golf was somewhat delayed, but the pre-sales have been high so that the future registrations of E-Golf will increase.

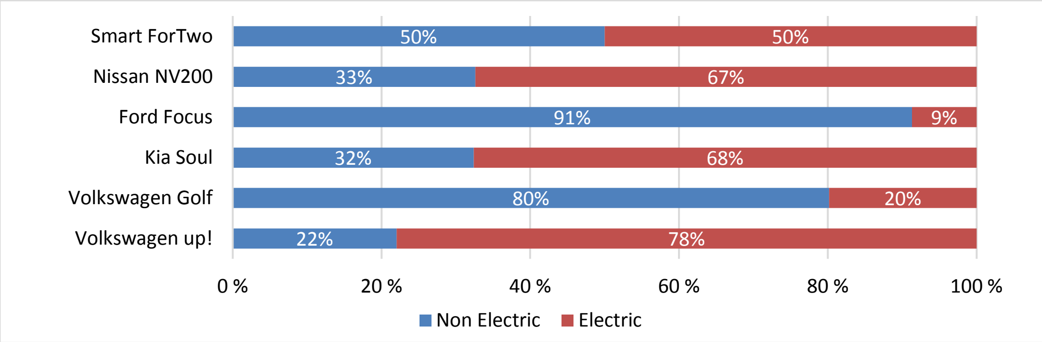

Figure II:15 EV shares of sales in 2014 of models available both as EVs and as ICEs. Source: OFVAS (2014).

The electric version mostly adds volume to the ICE versions of the same vehicle as seen in figure II:16. The volume of ICE versions of Golf was unchanged when E-Golf became available. For E-Up some of the ICE volume seems shifted to the electric E-Up version.

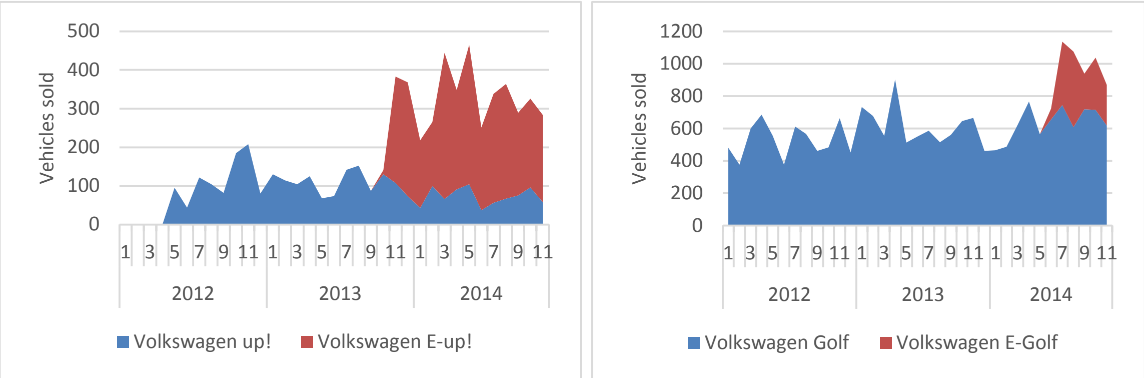

Figure II:16 EV shares in VW models Up and Golf sold in both EV and ICE versions by year and month. Source: OFVAS (2014).

II:4.5 EV segments' market share

The diffusion of new vehicle technologies is mostly top down, starting with the larger and luxury vehicles being used as primary cars, moving down to smaller and cheaper vehicles (Figenbaum 2010). The EV diffusion differs from this pattern, being both top down (Tesla) and bottom up (VW E-Up, Nissan Leaf).

Another difference between ICE vehicles and EV diffusion is the lack of a second-hand car market. Normally, a large part of vehicles sold new are bought by legal entities and used in fleets or as company cars. Two or three years later, they are sold second hand to private consumers not affording new vehicles. For EVs, the pattern is different, most cars being bought new by consumers and entering the household

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fleet directly, mainly as secondary vehicles, see figure II:17. In 2014, 47% of all new vehicles and 20% of EVs were bought by legal entities (OFVAS 2014).

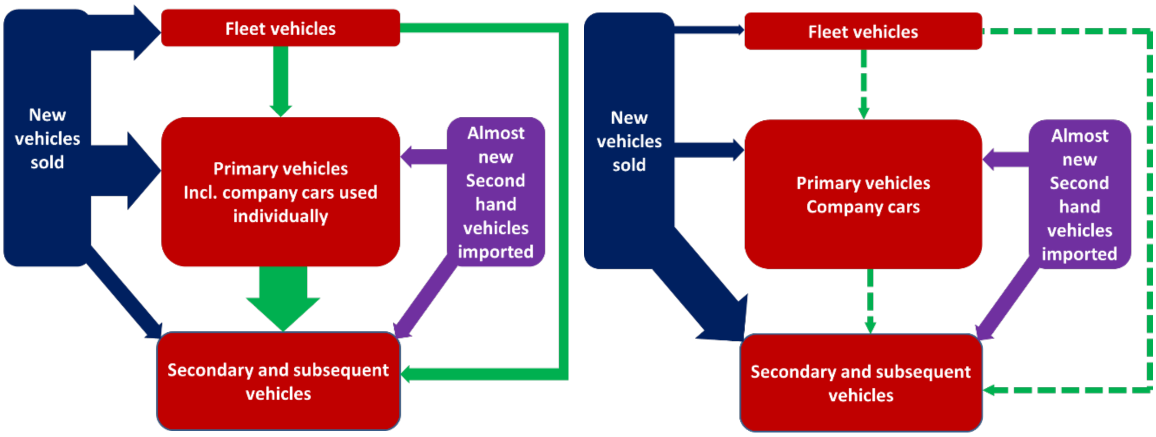
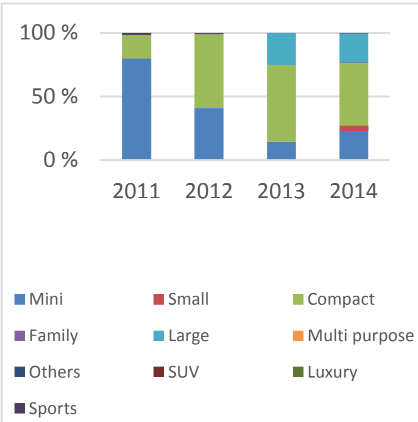


Figure II:17 The flow of new vehicles into the general car market (left) and EV market (right).

In 2011, the mini segment made up 80% of EV sales in Norway. In 2012, this share was halved, and the compact segment became the most important. In 2013, the mini segment share was 15% as Tesla Model S captured 25% of the total EV market, while the compact share was 60%. In 2014, the compact segment made up 50%, large and mini vehicles 23% each, and small vehicles 4%, see figure II:18.



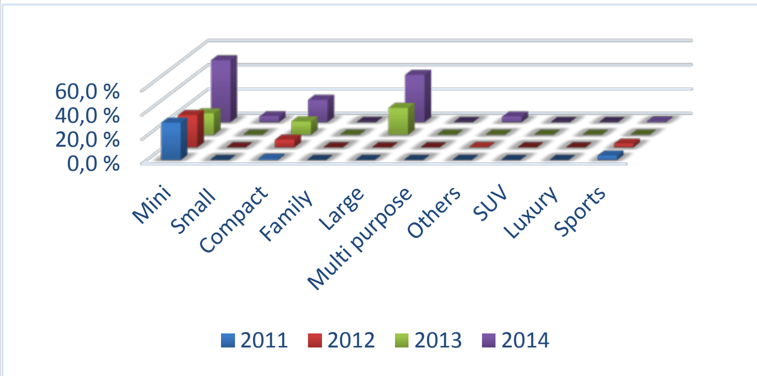


Figure II:18 EV sales by segment share of total EV sales (left) and EVs share of sales by segment (right). Norway 2011- 2014. Source: OFVAS (2014).

EVs captured 50% of the mini segment in 2014 following the popularity of E-up, after a downturn in 2013. Tesla's share of the large vehicle market was 39% in 2014 up from 22% in 2013. Nissan Leaf and E-Golf combined captured 18% of the large-volume, compact vehicle segment in 2014. Renault and Kia EVs captured 5% of the small vehicle segment.

II:4.6 EV owners, coming buyers and non-buyers

Studies of early adopters of EVs indicate common socio-demographic characteristics across countries (Hjorthol 2014, Figenbaum & Kolbenstvedt, 2013). The early adopters are relatively young, a majority are men, having high education and income

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belonging to households with more than one car and live in or in vicinity of larger cities (see summary in Hjorthol 2013).

Most EV owners in Norway belong to multi-vehicle households (75%) with large transportation needs, having children under age 18 and longer than average distances to work. Working, highly educated, and well off, they have a positive perception of EV technology. Playing down the disadvantages, they see the advantages of EVs. In total, they do not differ much from other multi-vehicle households in socio-demographics (Figenbaum, Kolbenstvedt & Elvebakk 2014).

ICE car owners stating that they will not buy an EV, are older, have lower education, fewer children, lower income, and a lower employment rate. Fewer are multi-vehicle owners, and they have a negative perception of EV technology compared to car owners at large. Those stating that they will consider buying an EV the next time, are somewhere between the EV owners and those who will not consider EVs in socio-economic background (Figenbaum, Kolbenstvedt & Elvebakk 2014). Evaluating the Norwegian EV market COMPETT surveys (ibid) found that the largest potential for further diffusion lies in the early majority, which considers buying an EV next time or have not, made up their minds, and in the late majority, who still do not consider the EV option.

II:5 Factors affecting diffusion rate and pattern

To determine the parts of the Norwegian experience that may be relevant for other countries, knowledge of factors affecting the EV diffusion rate is necessary. This chapter present some such factors. The discussion of relevans for others is sett in the following chapter II:6.

II:5.1 National characteristics

In Norway, electricity is produced almost exclusively by hydroelectric power plants with annual production typically around 130 TWh. Norwegians consider electricity as emission free, easily available at moderate prices, used for heating houses. The typical household's available electric power is thus substantial enough to easily accommodate normal charging of vehicles from 16-20 A outlets. Four of ten ICE vehicles in Norway are equipped with engine block heaters (Bilnorge 2010), plugged to the grid to facilitate cold starts in cold regions. Thus, many Norwegians are used to plugging vehicles into the grid, a situation leading to electric vehicles being a less complex innovation to take into use compared with other countries.

No total European statistics exist on the availability of electricity in garages, carports or parking spaces. Foller (2014) has showne that in Denmark 58% of these parking facilities have electricity available, and 19% can make it available.

The cold climate influences EV adoption in two ways. The cold winter causes range to be reduced by 30%, (Figenbaum, Kolbenstvedt & Elvebakk 2014), even up to 50% in severe cases (Haakana et al 2013). The relatively cool summers are positive for the life of Li-Ion batteries used in EVs.

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Between the major cities (Oslo, Bergen and Trondheim) drivers have to drive through mountain passes. The weather conditions can be rough, and road closures with long waiting times can occur in the winter, causing potential challenges for EV owners. The regional diffusion described in chapter II:4 shows that municipalities with no EVs are located in the coldest areas and/or areas with low population density, see figure II:19. These factors, however, also covariate with household income.

The general speed limit on Norwegian roads is 80 km/h with motorways rated at 90, 100 or 110 km/h. City speed limit is 50 km/h, and 30 km/h in residential areas. Higher speed limits in other countries lead to higher energy consumption per km, resulting in range being a bigger barrier to EV adoption.

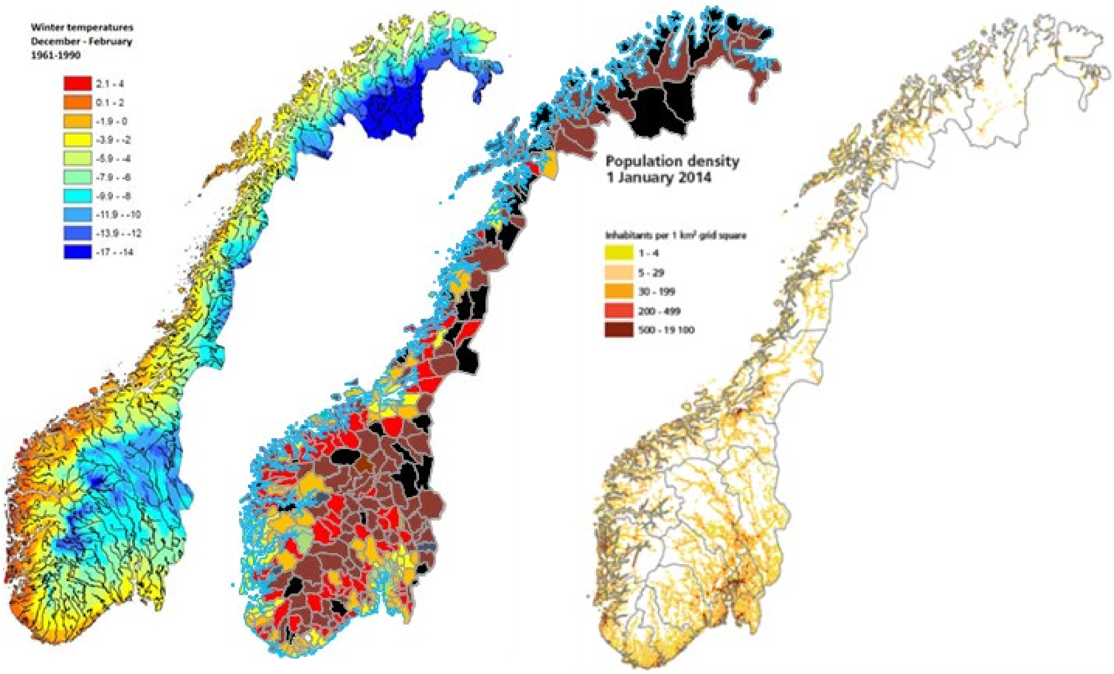

Figure II:19 Winter temperature (to the left), EV density (in the middle) and population density (to the right) in Norway. Source: Left map: Haakana et al (2013), Middle map: Authors, based on data from the Norwegian Public Roads Administration and the EV association, OFVAS (2014), Statistics Norway (2013). Right map: Statistics Norway (2014).

II:5.2 Norwegian EV incentives

The incentives lead to other and more adopters than the theory of diffusion of innovation predicts. The motivation to continue adoption may be reduced when the incentives are downsized or removed. The sustainability of the innovation and the quality of diffusion may be lessened. Incentives may, however, make people buy vehicles that they may discover are useful for more of their transport needs than initially thought. Thus, the incentives can contribute to increased environmental consciousness.

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The rate of diffusion in Norway indicates that the incentives and policies have addressed many of the barriers to EV adoption, creating several niche markets to grow from, i.e. bus lane users, areas with toll roads, users looking for parking spaces in crowded city centres etc. The policies and incentives have societal costs that are redistributed between owners of EVs and owners of other vehicles. The reductions in several duties lead to loss of government revenue that must be recovered elsewhere. The Norwegian case proves, however, that incentives are not enough. Prior to 2010 almost all incentives were in place; yet adoption was low due to lack of attractive vehicles and poor dealer coverage.

Fiscal incentives in Norway include tax exemptions that can give socioeconomic equality of adoption, see table II:1. In principle, everyone buying a new vehicle can afford EVs in Norway. The early adopters can be located anywhere in the country as incentives are nationwide and not limited to certain volumes per year.

Direct user subsidies such as free toll roads, access to bus lanes and reduced ferry rates are local or regional in their effects, but regulated by national laws. In addition, local and regional authorities have supported the establishment of normal and fast charge stations, the most notable being Oslo and some of the other counties. Some municipalities have targets for introducing EVs into their own municipal (Assum, Kolbenstvedt & Figenbaum 2014).

Table II:1 National incentives, policies and initiatives. Source: Figenbaum, Assum and Kolbenstvedt (2014).

Incentives	Introduced	Benefits for users
Fiscal incentives - reduction of purchase price/yearly cost gives competitive price		
Exemption from registration tax	*1990/1996*	The tax is based on emission and weight. Example taxes on ICE vehicles: VW Up 3000 €. VW Golf: 6000-9000 €. The tax makes the vehicles competing with EVs more expensive
VAT exemption	2001	Vehicles competing with EVs are levied a VAT of 25% on sales price minus registration tax.
Reduced annual vehicle license fee	1996/2004	Three rates apply for private cars. EVs and hydrogen vehicles have the lowest rate of 52 € (2013-figures). Conventional vehicle rates: 360-420 €.
Reduced company car tax	2000	The tax on having a company car is lower for EVs. Most EVs are not company cars.
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 €/year for commuters. Some places have tolls exceeding 2 500 €/year
Reduced rates on ferries	2009	Similar to toll roads saving money for those using car ferries frequently. Not important up to 2013, but the value of the incentive can be high in some areas.
Financial support for charging stations	2009	Reduces the economic risk for investors establishing charging stations. Contributes to reduced range anxiety, expand the EV market, and get more EV miles out of every EV.
Financial support for fast charge stations	2011	More fast-charging stations become available increasing the EV miles driven and the total EV market including fleets. Fast charging does not void vehicle battery warranties.
Reduction of time costs and giving relative advantages		
Access to bus lanes	2003/2005	EV users saves 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.
Free parking	1999	The benefit for users is to get a parking space where these are scarce or expensive and time saved looking for a space. Impact depends on the number of spaces available.

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Municipalities having commuters travelling to Oslo, are divided by *proximity to Oslo,* including the presence of physical barriers (no roads) and high-speed roads reducing travel time, see figure II:20. The closer to Oslo, the higher the EV density is in general with some exemptions caused by local incentives.

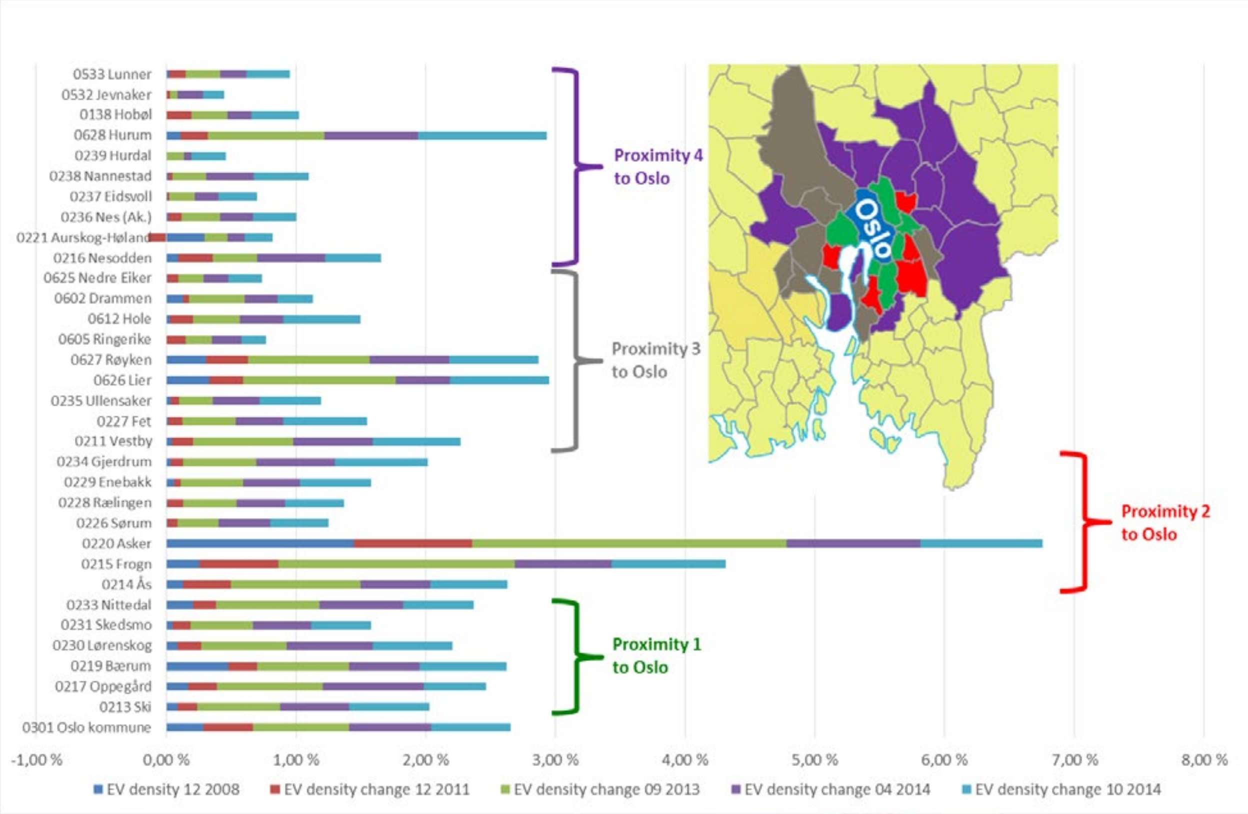

Figure II:20 EV density (EVs per 1000 vehicles) in municipalities surrounding the capital Oslo up to October 2014. Proximity is defined as 1) Border with Oslo, Green in the map 2) Borders to those that border with Oslo, Red in the map 3) Situated further out, Brown in the map and 4) Municipalities farthest away, Lila in the map. Data from Norwegian Public Roads Administration, the EV association, OFVAS (2014) and Statistics Norway (2013).

EV drivers living in municipalities from where they can benefit from driving a the bus lane between the regions and Oslo, can avoid rush hour delays averaging 35 minutes each day. (Examples are Asker, Hurum, Røyken, Lier and Frogn). In the closest municipalities, commuters have better public transport, shorter travelling distances and less to gain. The municipalities where users had advantage of bus lane access in 2008, had higher EV density than Oslo, suggesting that this incentives influence diffusion. Diffusion is also influenced by the availability of private parking allowing home charging, which is lower in cities than in surrounding municipalities.

Aurskog is a special case, being the home of the EV producer Think, explaining the high EV density in 2008 with negative growth to 2011 a result of Think moving out of Norway.

EV density by postal code zone is shown for Oslo, Bærum and Asker in figure II:21. The average distances to work for EV owners are 19 km, 19 km and 23 km, respectively (Figenbaum 2014). The postal zones with the largest EV densities, 45% and higher, are those where there are EV dealers owning many demo-vehicles and few households. EV densities are high also in areas with high income, long distances to Oslo, where driving in the bus lane is an advantage, outside the toll-road ring or

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far away from metro or train lines. Low EV densities are seen where households have metro or train closely available, where there is no bus lane and inside the toll-road ring. Close to Oslo centre availability of private parking facilities, may be a limiting factor. Further discussion on the EV incentives influence on market share is found in Figenbaum et al (2014).

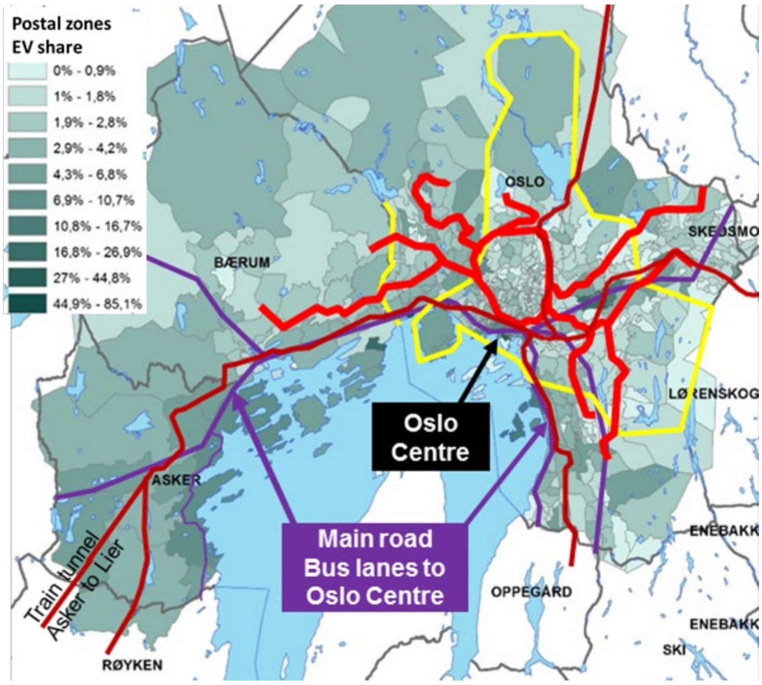

Figure II:21 EV density (EVs per 1000 vehicles) by postal code zones in Oslo, Asker and Bærum. Yellow lines mark the toll ring around Oslo and the toll gates between Oslo and Bærum. Red lines are the metro network, dark red the main train lines, purple is main roads. Data from the NPRA and the EV association (2008-2014).

II:5.3 Diffuser incentives

The diffusers in the international EV market are the vehicle manufacturers, the vehicle importers and the dealers. The consumer incentives including the charging-station support make EVs easy to sell for dealers, attractive to import for importers. In addition vehicle manufacturers may prioritize the Norwegian market over markets with fewer incentives. Economic incentives shifting the initial cost burden of EVs away from the producers and early adopters and into society, are thus diffuser incentives.

On a European scale, the most important diffuser incentive is the European Union law (Regulation (EC) No 443/2009 of the European Parliament and of the Council) requiring vehicle manufacturers to reduce average CO_2-emission of new vehicles to 95 g/km in 2020. Non-fulfilment of this target leads to fines of 95 Euros per vehicle sold for each g/km above target. The fines could lead to manufacturers subsidizing some of the costs of EVs, such as development costs. The Norwegian target is 85 g/km, used as guidance for the vehicle tax policy, but there are no sanctions if it is not met.

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Standardisation of vehicles, charging systems and payment systems for charging, research and demonstration support programs are other examples of diffuser incentives reducing complexity, costs and uncertainty and contributing to technology improvements and market facilitation. The incentives globally available in different markets affect the manufacturers' possibility to reach profitable volumes and the price they can charge for the products.

II:5.4 Attributes changing over time

Technological advances

In the early days of EV development around 1995, EVs were considered different from other vehicles. Driving classes were established in La Rochelle in France, to teach users a new driving style (Studytrip La Rochelle 1995). Nowadays the Original Equipement Manufacturers (OEMs) train their regular workshops to do service and repairs on EVs, and the operation of EVs closely resembles that of the traditional ICE vehicles. The instrumentation is different as is the process of recharging the vehicle. The user must still be aware of the available range of the vehicle to avoid being stranded.

The EV technology has improved over time. In the early 2000s, the on road range of EVs (what the users experience over the seasons) was typically 40-80 km. In 2009-2011 vehicles with ranges of 100-150 km appeared, still dominating the market. In 2012, Tesla launched the Model S, the first EV with an on-road range resembling that of ICE vehicles with 300-450 km (author's estimates). The range improvement is due to several factors; Li-Ion batteries with higher energy density, components with lower energy consumption such as LED lights, heat pumps, better thermal management, lower drag forces, lighter weight and increased energy recovery.

Battery technology changed from Ni-Cd in the early 2000s with two years warranty. This battery was expensive yet robust, requiring maintenance every six months, to Li-Ion batteries with up to eight years/160 000 km warranties. Nissan has revealed the replacement cost of an entire battery pack for Leaf to be 6916 € including VAT. Only three batteries have been replaced in the 30 000 EVs in Nissan's European Leaf fleet (Insideevs 2014) providing owners and potential buyers with a figure that can be used to assess risk. The life of batteries is better than expected with the consequent worries over battery replacement costs being reduced (Assum, Figenbaum & Kolbenstvedt 2015).

The speed of charge (limited by the domestic 10-16 A sockets) at home, have resulted in 12-20 km of usable driving range per hour of charging, for vehicles consuming 160 Wh/km (Figenbaum 2010). Fast charge at 50 kW typically result in up to 4 km of usable driving range per minute of charge. A small network of about 100 (Gronnbil.no) fast chargers are located along main roads and in cities. The Tesla Model S, consuming 200 Wh/km can be recharged up to 9 km of usable range per minute of charge at Tesla's super charge stations. Actual charge speed is influenced by the state of the battery, the temperature and start-up and shut down times. In cold climates, the charge speed could be up to halved, as batteries cannot handle such high power charging when they are cold. In addition, the energy consumption of the vehicle will be higher. Both factors contribute to fewer km of driving per minute charged.

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The safety of EVs has improved (Høye & Figenbaum 2015). In the early 2000s, ICE-vehicles experienced a revolutionary development in the safety level, as measured by EuroNcap (2014). EVs remained small, simple vehicles with few safety features and would have had poor crash test results. EuroNCAP tested no EVs. EVs now achieve 4-5 stars in EuroNcap as do gasoline and diesel vehicles.

Economic advances

It is not likely that many people would have bought the first expensive and rather primitive vehicles of the early 2000s without substantial incentives. Figure II:22 shows the development of the price of the cheapest EVs in each segment compared with the price of similar ICE vehicles. EVs had much less equipment than the gasoline vehicle up to 2009. Between 2003 and 2008, only a few very small and basic models were available. EVs became comparable to the cost of vehicles in the same or in the closest segments in 2013. The price parity is, of course, influenced strongly by the taxes on ICE vehicles and exemption for EVs. Figure II:23 shows that E-Up has a price on par with the ICE version most comparable in performance. In other countries, VAT in absolute terms is higher on EVs than on other vehicles. In France, the ecological bonus compensates for the VAT and some of the extra costs.

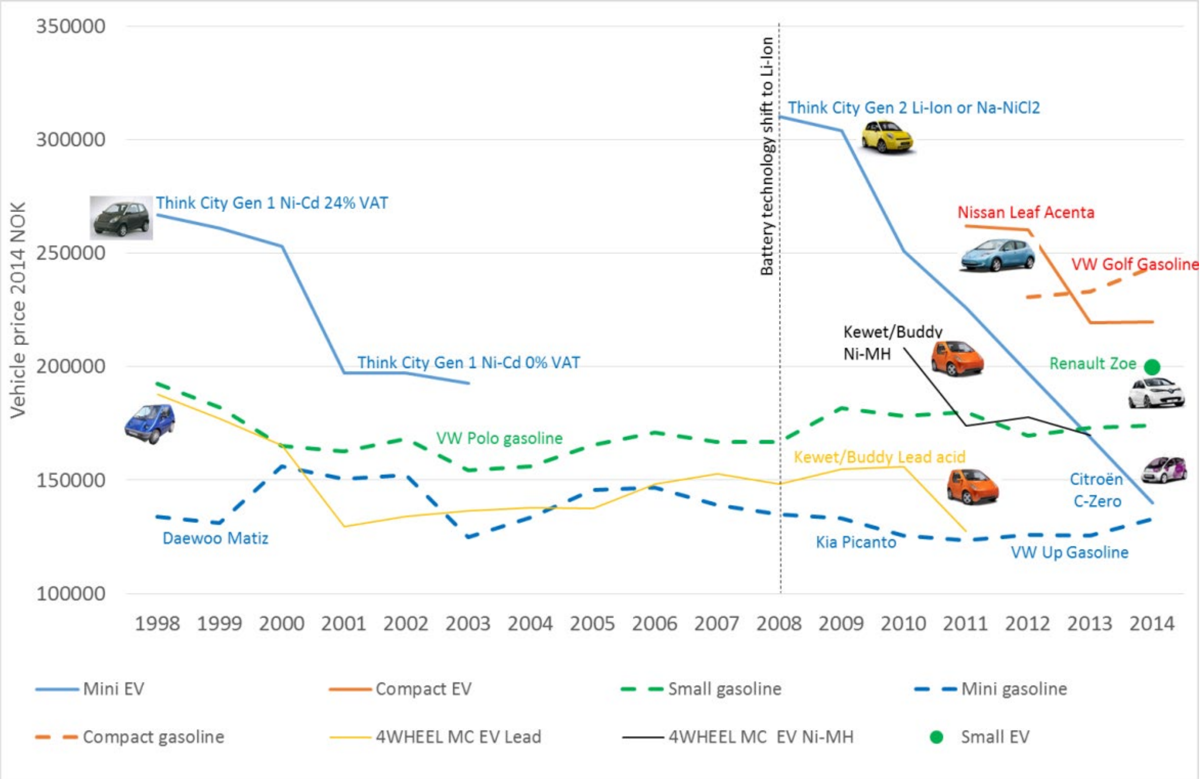

Figure II:22 Sales prices of EVs in Norway compared with gasoline vehicles. EV prices are without all taxes according to the incentives. ICE vehicle prices include all registration taxes and VAT. Sources: Taxnorway 2015, Bilpris (2008-2014) various webpages, news articles, historical sales material.

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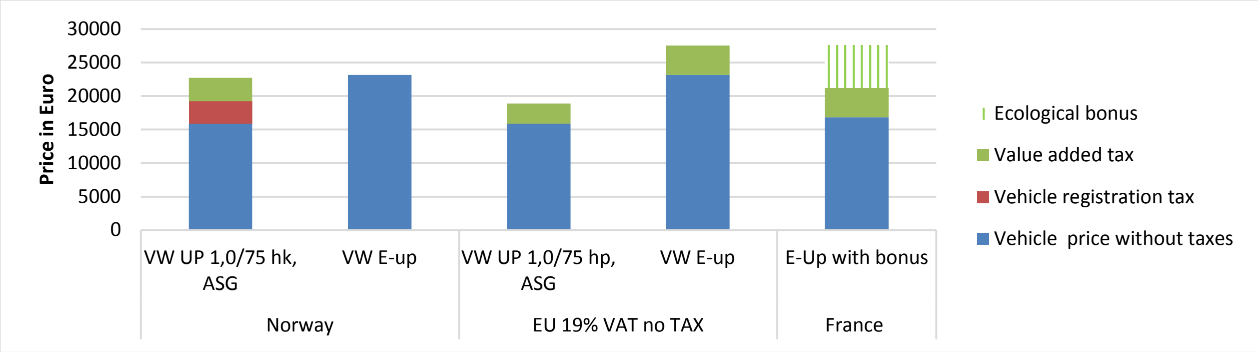

Figure II:23 Price comparison between Volkswagen cars - EVs or ICEs in Norway 2014. Euro. Source: Importers price lists. EU: Assumed Norwegian pre-tax prices plus 19% VAT. France: Bonus Ecologique 6300 Euros (2014-2015).

II:5.5 User perception

Relative advantage

The relative advantage is the most important factor in the diffusion process where prospective EV buyers consider the benefits and costs of taking EVs into use. The most important factors are shown in table II:2. The incentives turn EV ownership into an advantage already for the first owner of the vehicle, thus being the key to the EV success story in Norway.

Table II:2 Elements of Relative advantage. Assessment of first owners' evaluation of the potential of each element without and with the Norwegian EV incentives.

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	EVs are more expensive than ICEs. Value added tax on top expands the cost gap.	Equalizes the price in smaller vehicle segments. EVs are cheaper than ICE vehicles for larger vehicles
A decrease in discomfort	Discomfort due to range limitations although many users are compatible with range limits. Not available with 4 wheel drive	User advantages result in increased comfort and EVs are in accordance with societal environmental goals. People can afford buying it. Concerns of second-hand value are reduced as the owner potentially saves more each year on low operative costs and incentives than what is risked. Not available with 4 wheel drive
A saving of time and effort	More effort 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 saving using bus lanes and time to find 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 and reduced ferry rates and free parking
Social Prestige	Teslas and BWM i3s give prestige, but basic EVs may have so poor value proposition that prestige could be negative?	Possible for everyone to buy an EV, democratizing EV diffusion, but also reducing social prestige.
Environmental prestige	Not a dominating motive initially	Increasing as a motive after buying EVs. A possible negative factor is that it becomes easier (morally) to justify buying a second household car.

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Compatibility

The EV is compatible with regular vehicles and is driven and controlled as an ICE vehicle with automatic gear. EVs are sold and serviced through regular OEM dealers. The process of refilling energy is different. Short range and long charging times are the main incompatibilities with ICEs. The technology is compatible with the needs of households having access to more than one vehicle, in Norway 42% (Vågane, Brechan & Hjorthol 2011). In the 43% of households with one vehicle, range will be more of a challenge (Figenbaum, Kolbenstvedt & Elvebakk 2014) but can be handled, see chapter II:5.6. Users need to be able to recharge EVs at home over night so that as much as possible of the range is utilisable each day. Households in Norway in general have good access to parking, see table II:3. The biggest exception is Oslo, where only 55% of the households have access to parking compared with the average of 83% for the whole country. Multicar households have the best parking availability.

Table II:3 Parking facilities in households in Norway. Source: SSB 2001.

Number of cars	Has access to own garage or carport	No access to garage carport, but available parking space	No access to garage, carport or parking space	Total	Percentage with parking available
No car	201 943	170 815	209 809	582 567	64%
1 car	577 931	224 826	105 840	908 597	88%
2 or more cars	358 600	88 130	23 654	470 384	95%
Total	1 138 474	483 771	339 303	1 961 548	83%

Complexity

By 2015 EV diffusion is so far advanced in Norway that friends and family provide information to users prior to buying the vehicles, thus leading to Norwegians being better prepared than early adopters elsewhere are. In other countries when people adopt EVs, there is an increase in range utilization over the initial ownership period (Franke & Krems 2012, Franke 2014). In the COMPETT user survey, some users found the range more limited than expected, while others had the opposite experience. Anyway, the majority (85%) are comfortable using 80% of the cars range limit (Figenbaum, Kolbenstvedt & Elvebakk 2014). The range trust doesn't vary with driving length, see figure II:23.

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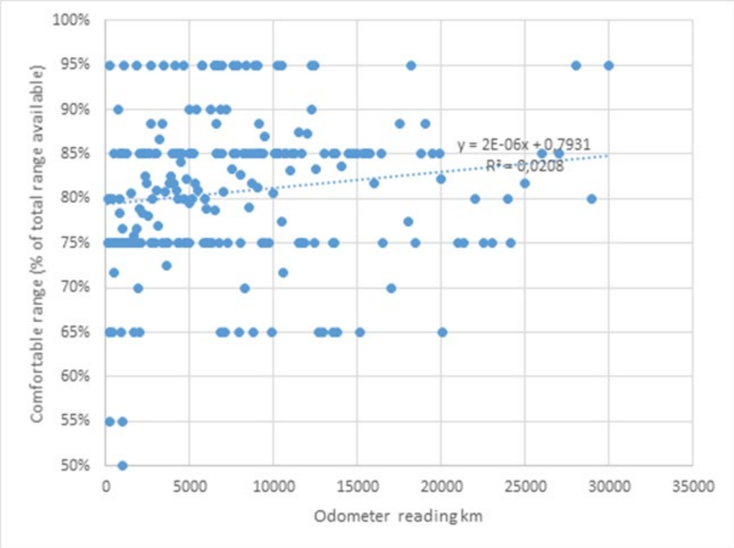

Figure II:23 Range utilization as a function of odometer reading, first time EV owners having owned EVs less than a year. Source: Figenbaum (2014).

The availability of fast charge stations is one of the factors influencing EV adoption allowing charging on the go and in emergencies. The average EV owner uses fast chargers about 14 times per year (Figenbaum, Kolbenstvedt & Elvebakk 2014). A chaos of different payment systems for fast charging makes usage more complex than needs be. The first buyers of fast charge capable vehicles had no fast chargers. For them the first fast chargers improved the situation. EV sales may, however, outpace the expansion of charge stations, so that available charge stations per EV is reduced, c.f. figure II:24. More users would normally mean more fast chargers and a critical mass of users must be reached to eventually make charging business profitable. Everyone thus profits on more users joining the market.

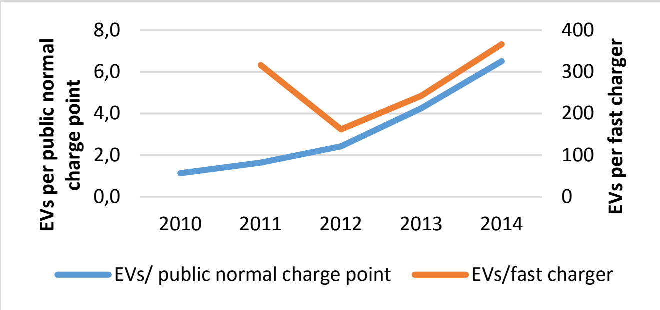

Figure II:24 Development of charging structure. EVs per public chargers, normal and fast chargers 2010 – 2014 in Norway. Data sources: Gronnbil.no, OFVAS (2014).

Trialability

In the early phases, trialability is an important aspect of diffusion of innovations. The first adopters have no peers who have adopted already. Therefore, they need to try an EV to see if it works for them. The bus lane access from 2003 allowed more early adopters to use EVs to drive to work as they could better utilize the short ranges of the early EVs. The import of second-hand vehicles from 2003 up to 2009 kept the EV market alive, allowing EVs to be tried out in some of the cities in Norway. Dealer availability as shown in figure II:11, increases trialability as does the presence of EVs in employers' fleets. As diffusion catches on, more potential adopters will

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have peers providing reliable information on EV functions, reducing the trialability issue.

Observability

The visibility of EVs is larger in Norway than other countries. EVs have been equipped with EL number plates since 1999, and EVs in the bus lane pass a large number of vehicles during the rush hour. Norwegians living in cities see EVs in real traffic situations every day. They now constitute 2-3% of the vehicle fleets in cities and 5-7% in suburban areas. In the user survey, Nissan Leaf owners stated a driving length of 14 900 km/year and in 2014, Nissan recorded an average of 16 484 km for Leaf owners in Norway (Nissan 2014), this being longer than the average 11 300 km/year (OFV 2012). Cities such as Oslo have put up charging stations for EVs in city centres also improving visibility. The large increase in EV-dealers, as seen in figure II:11, has increased visibility and exposure in arenas where people look for vehicles to buy. The second-hand market is picking up speed as dealers import second hand EVs.

The EV association and the Norwegian Automobile Federation arrange events increasing EV visibility such as EV parades and races, international conferences as well as ride and drive events.

II: 5.6 Meeting user needs

EV uptake and growth depend on the early adopters and future diffusion into the rest of the market and on the share of daily trips and trip chains that can be made within EVs' limited range and charge time.

Range anxiety (the fear of being stranded due to a depleted battery) is ubiquitous, but the range of new EVs keeps increasing. Studying the total distance as a car driver on an average day, Hjorthol et al. (2014) found that as many as 88% of drivers will have no need for recharging an EV during an average day, assuming summer/winter ranges of 120/80 km. Related to range, trips need to be analysed in connection, in *trip chains.* 4% of the trips, 6% of the trip chains and 12% of the days during a year exceed the range limit. In a year, the EV range (without recharging) is exceeded 43 days. On these days, it is necessary to recharge during the day. Recharging can be done when stops are long enough and conditions are suitable (typically home or work). Of those who exceed the range limit per day, 24-29% stop at home 1-5 hours during the day, sufficient for some charging. In addition, about 10% can park at a designated parking, and have a potential for recharging there. 20-40% have stops that exceed five hours with a potential for recharging at work.

Finding that 84% of the EV owners use their EV for commuting to work, the COMPETT survey (Figenbaum, Kolbenstvedt & Elvebakk 2014), support this picture. However, some trips or trip chains cannot be made, and the EV owners must take other measures i.e. saving energy while driving, borrowing or renting vehicles or swapping cars within the household, see figure II:25.

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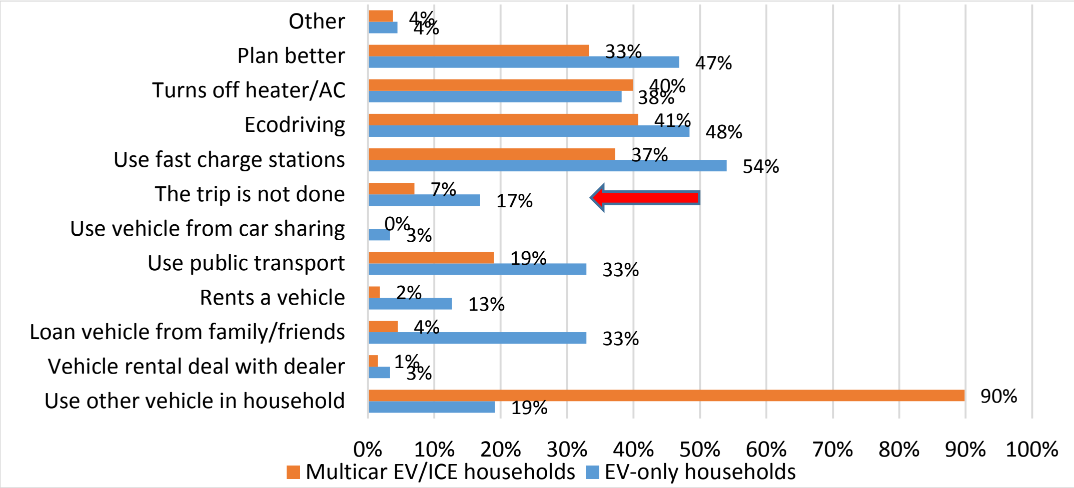

Figure II:25 Different adaption strategies to avoid range challenges in multicar EV/ICE and EV-only households. Source: Figenbaum, Kolbenstvedt and Elvebakk (2014).

A strong indication of the EVs ability to meet user needs is that a large majority, 87% of the current EV owners, say they *will buy* an EV next time they buy a car (Figenbaum, Kolbenstvedt & Elvebakk 2014). The corresponding figure for the average car owner is that 30% *will consider buying* one.

II:5.7 Communication channels

Social networks

Figure II:26 shows the share of EV owners having friends who bought EVs after they had told them about their experiences and the share that considers buying, for municipalities with different proximity to Oslo. The tendency is that those who live in the city or close to the city have more friends who have bought EVs after they told them about their experience compared to those who live further away. For those considering buying, the tendency is opposite, indicating that the interpersonal communication started earlier in the municipalities closest to the city: The potential growth is now higher further from the city as the interpersonal communication seems to be at an earlier stage. The sum of the two is varying much less indicating that *there is not a more negative attitude* to EVs further from the city.

The EV owners were asked how they heard about EVs *the first time*. Of those answering friends, there is no apparent geographical trend in the Oslo area, figure II:27.

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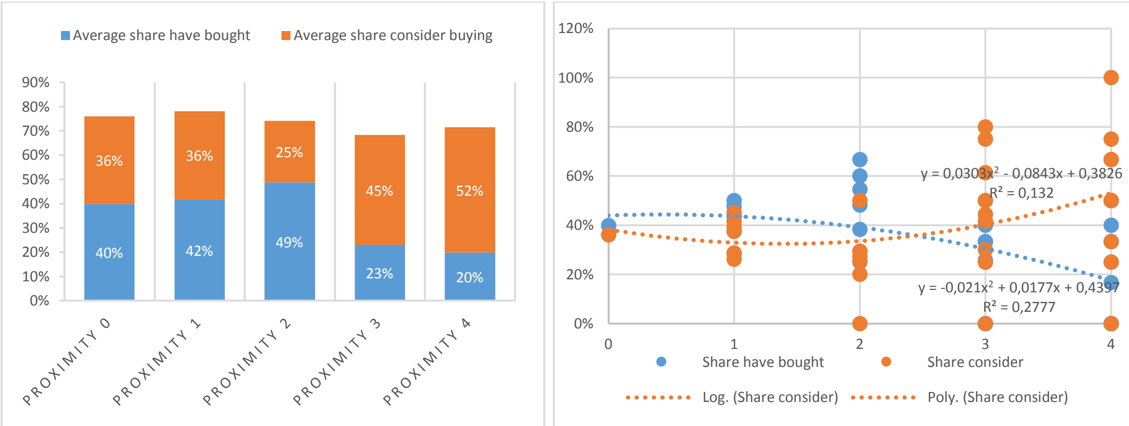

Figure II:26 Share of owners having friends who have bought or are considering buying EVs after they told them about the experience with EVs by proximity to Oslo. Source: Figenbaum (2014).

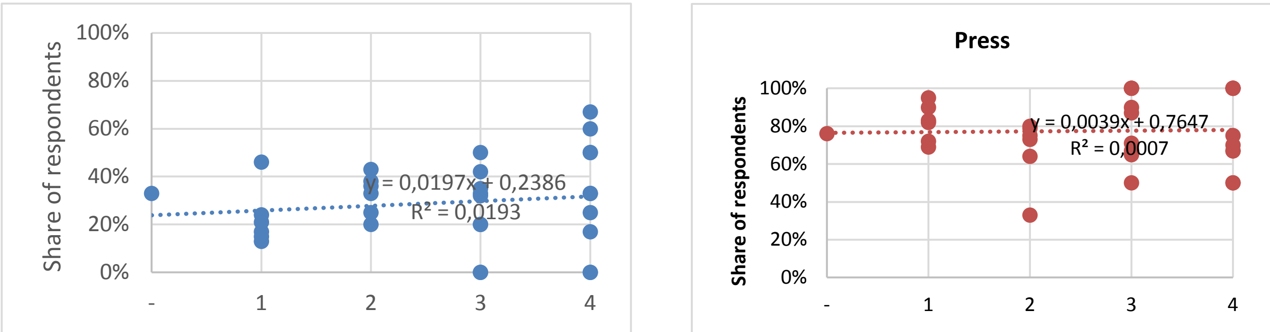

Figure II:27 Share of respondents in Oslo area who answered "friends" (left) and "press" (right) respectively to question: Where did you first get the information from that prompted you to consider buying an EV? by distance to the city. Proximity is defined as 1= Border with Oslo, 2= Borders to those that border with Oslo, 3= Situated further out, and 4= Municipalities farthest away, cf map in figure II.20. (n=1720). Source: Figenbaum (2014).

Press and Media

Figure II:28 presents the yearly press coverage of EVs together with the growth in the EV fleet. The press coverage was low until 2007, when a rapid increase lead up to a higher level from 2009 to 2012. 2013 and 2014 have seen another large increase in press coverage. The three-year gap between increase in press articles and the increase in the fleet between 2007 and 2010 is potentially linked to EVs being high on the agenda while very few vehicles were available at dealers. The press is important regardless of how far from Oslo the EV owner lives according to figure II:27, right.

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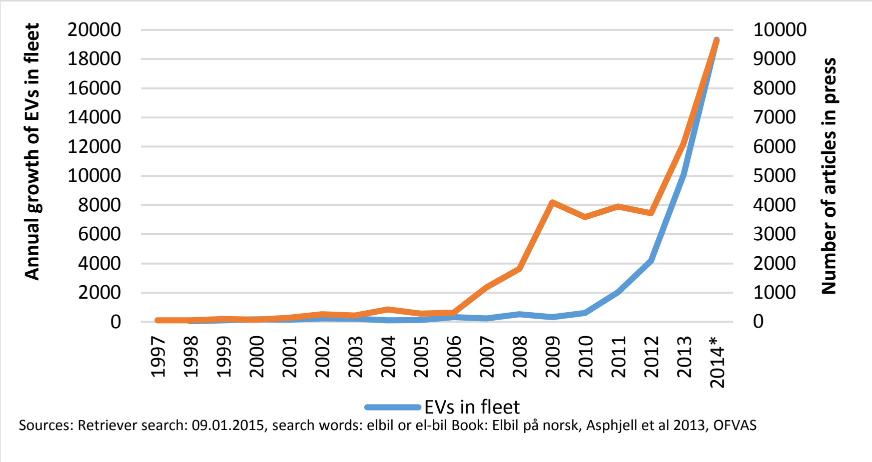

Figure II:28 Press coverage of EVs (red line) and annual growth of number of EVs (blue line) in Norway between 1997 and 2014. Sources: Figenbaum. Kolbenstvedt and Elvebakk (2014) and Retriever (2014).

II:5.8 Role of change agents and change aids

Change agents influence the rate of adoption of innovations (Rogers 1995). In Norway, several types of change agents have been active in targeting increased EV adoption

Transnova was established in 2009 as a general governmental change agent contributing to transforming the transport sector from fossil fuel dependency to sustainability by promoting cleaner energy, improved modal mix and reduced transport. The budget was 50 to 100 million NOK /year. Transnova supported infrastructure deployment (charging stations, hydrogen and biofuel stations) and demonstration programs of technologies and concepts. The activities have been transferred to Enova from 2015.

Green car (in Norwegian: Grønn bil) was an organization tasked with nudging fleets to adopt EVs. It was funded by Transnova, and provided statistics about the uptake of EVs and PHEVs and charging stations coverage by municipality. The organisation visited a large part of the Norwegian Municipalities from 2009-2014 (Assum, Kolbenstvedt & Figenbaum 2014). The organisation had mainly an impact in awareness raising where the effect on EV adoption of fleets had been modest. The activities are now transferred to Enova and the environmental NGO Zero.

The EV association (Elbilforeningen) is a change agent and a change aide. As a change agent, it promotes EVs on their website (elbil.no) and in meetings with stakeholders or authorities. It lobbies politicians directly and uses its web site to set the agenda on EVs. It keeps guard over incentives, aiming at establishing a better framework for EVs (Assum, Kolbenstvedt & Figenbaum 2014).

The NGOs Zero, Bellona and EVU are acting as change agents, partly on behalf of vehicle importers. Bellona managed to get registration tax exemption for the first EV imported to Norway in 1990. With other actors, they succeeded in lobbying for exemption from toll road charges in Oslo in 1997 (Figenbaum & Kolbenstvedt 2013). *The municipalities Oslo and Stavanger* acted as change agents lobbying the government to change the law on parking to allow free parking for EVs from 1999 (Asphjell et al. 2013).

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Change aides contribute in the diffusion process. In the web forum of the EV association, "elbilforum.no", EV owners can discuss technology, challenges and opportunities. The association gives EV owners updates on charging services and technology. It established a database of charging stations (nobil.no) that can be used in navigation systems. It negotiates membership advantages and buys renewable energy certificates for members (Assum, Kolbenstvedt & Kolbenstvedt 2014). Together with the Norwegian Automobile Federation, they developed a guide with basic information about EVs helping new buyers.

Several of the vehicle importers cooperate with the above organizations (Assum, Kolbenstvedt & Figenbaum 2014), and all dealers give buyers one-year membership in the EV association. There is thus a network of business and change agents all pulling in the same direction.

II:6 Discussion

II:6.1 Norway as a European Test site

Part II of the report started with some questions concerning the pattern and rate of EV diffusion as well as possible explanations to the Norwegian story, see chapter 1 (Background). We have also presented the Norwegian framework in more detail in chapter II:5 to make possible the discussion of the lessons learnt in Norway can be of interest for others.

A main point is that Norway has developed and introduced a broad spectre of incentives, see table II.1, resulting in the largest electromobility diffusion in the world. This situation, however, does not mean that other countries should copy this package. Since the prices of EVs have been reduced, the batteries improved and more brands are selling EVs, using so many incentives to promote EVs should not be necessary now. What can be learnt from the Norwegian test site is how the different incentives work and how various frame conditions influence diffusion, thus having an option to choose what is most adquate to stimulate the initial diffusion phase in different countries. Each country should find incentives fitting with its transport policies, and identify and utilize windows of opportunity when they open up.

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II:6.2 EV diffusion in accordance with the theory

The available statistical data on the EV fleet, share of the total fleet, available models and regional distribution have been used in the analysis.

From data on *regional diffusion,* it is evident that:

- EVs were first taken into use in cities wide apart by innovators more prone to be located in cities, being cosmopolites getting information from media, not needing to be in contact with each other.
- EVs spread out radially from the initial municipalities to neighbouring municipalities. At the same time expansion occurred within each municipality through interpersonal networks. The spread of EVs through interpersonal networks is measurable at the municipal level. Adoption picks up when visibility and trialability increases, i.e. when EVs move around in people's mobility space.
- In addition, municipalities with particularly large local incentives stood out as early adopters.
- The technology takes time to spread out from initial areas given the time delay between hearing about an EV from peers to deciding to buy an EV and then to actually do it. This effect could explain the slow market introduction followed by the very rapid expansion from early 2014.
- EVs are in 2014, four years after the regular diffusion started, present all over the country, and 87% of Norway's municipalities have EVs in the fleet. The remaining municipalities, with low winter temperatures and low population densities, are the least likely to house early adopters.

The *automotive EV market diffusion* however, in some aspects complies with and in other aspects differs from theory:

- Contrary to the general picture of diffusion of innovations in the car business, the EV fleet evolved from being dominated by small domestically produced Thinks and Buddies to be pluralistic in terms of models, makes and segments. Diffusion of luxury cars first came when Tesla launched the Model S whereas most other EVs still are small or compact in size.
- Being the starting point of EV diffusion, the mini vehicle market has now passed through early majority and is moving into the late majority buyers. The large/luxury and compact markets are into early majority. The latter segment is much larger than the others in terms of models and volumes.
- Some provinces have reached EV market shares around 20%, theoretically beyond critical mass indicating a self-sustaining further diffusion given current framework. In real life, these regions are too small to influence the rate of diffusion or to drive a process by themselves.
- EVs make up a substantial part of total vehicle sales for manufactures with attractive EVs available, and models with EV and ICE versions have high EV shares mostly additional to the ICE volume, i.e. indicating a segment of buyers looking particularly for EVs.
- When new EVs are launched, most of the market for the new models are made up by new EV customers. Existing models loose little sales. EV sales volumes depend strongly on the popularity of a few EV models, making the diffusion process vulnerable to changes in customer preferences.

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The communication process has supported EV diffusion:

- The process is characterized by the development of new types of organisations helping users, the car industry and the introduction of channels for cooperation between organisations, public authorities and car industry.
- The rapid development in the market and the technology have been leading to a large media exposure that have grown parallel to the market.
- A large share of EV owners indicate that they got information from friends or family, which has higher “quality” in the diffusion process than information from the press. To thirds of EV owners state that their experience is influencing their friends or family to buy or consider buying EVs.
- Diffusion agents have been successful in getting incentives established and keeping guard over their continuation. Change agents who have tried to increase EV usage in municipal fleets have managed to raise awareness and initiate some tests and initial adoption.

The diffusion seems to have gone at maximum speed over the past four years given the availability of makes and models as well as the regional diffusion pattern. The *users’ needs are thus met*:

- Prices are now competitive, and local user incentives give EV owners relative advantages over other vehicle owners. Operative costs are lower as energy costs much less for EVs than ICEs.
- The majority of users find that an EV is the best car for their need.
- Meeting daily travel needs, EVs are driven as much as other vehicles per year.
- People cope with range limitations. Multi-vehicle households have minor problems adapting, whereas single vehicle households may have to drop a journey or use more effort borrowing an ICE vehicle.
- EV owners say they will continue to buy EVs.

The radial diffusion pattern around cities with new buyers attracted over the years could be the result of cost reductions leading to EVs becoming increasingly attractive to subsequent lower income groups. Being higher in cities, income is reduced e further into the rural areas as housing costs are lower further out. This is an inherent issue with the theory of diffusion of innovations as the cost of innovations goes down over time.

II:6.3 Changes in key elements influencing diffusion

During the diffusion period, important changes in crucial decisive factors have occurred. These changes make the basis of our understanding of the Norwegian success.

The EV technology changed. Batteries last longer, range is increased, and EVs now cover most daily trips. An EV in 2014 is not the same as those available earlier years. The EV characteristics now resemble ICE vehicles in comfort, purchase price, quality, durability, safety and reliability, though deviating when it comes to range and recharge. EVs are now sold by well-known brands.

The support given by political goals and incentives *has increased immensely* during the latest twenty years, making Norway an arena for testing the effectiveness of electromobility incentives. Most incentives were in place before the EV market share

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took off. The earlier market was limited by lack of available models and high cost, making it challenging to evaluate each incentive. Some conclusions can be made:

- *Incentives were necessary to bridge the cost gap* between EVs and ICEs. EVs now are on par with ICEs purchase price in the mini- and small vehicle segments, and cheaper in the other vehicle segments.
- *Incentives supporting charging structures* have been important to reduce range anxiety.
- *Incentives have given EVs the necessary relative advantages* motivating a purchase. The motivation has evolved from predominantly achieving advantages to buying a general means of transport. EVs have become competitive through cost reductions and incentives are nudging buyers to opt for EVs.

The users' needs have not changed, but their attitudes have become more positive over time, helped by interpersonal communication with peers, their own experiences and improved technology. EV owners' environmental motivation increases over time as well as the willingness to stay with EVs, which now is the case for nearly all of them.

II.7 Conclusions - challenges and opportunities

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

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 diffusion of EVs started, cities should be targeted, for reasons of avoiding increased traffic they should not. This dilemma is not easy to handle but the diffusion pattern does shows that EVs spreads to rural areas from the cities, suggesting that this issue is temporal.

The improved technology and reduced costs combined with the incentives have resulted in Norwegian EV buyers experiencing that EVs have many relative advantages over ICE vehicles. The limited range is not a hindrance to adoption. Reward is immediate as the EVs cost the same or less than ICEs, and their operative costs are lower due to their energy efficiency available from day 1. It is thus an evident opportunity to position EVs both as a climate friendly car and as a car with low variable cost used for daily travel needs.

There is potential for future growth supported by diffusion through interpersonal networks and the availability of new longer-range models attracting new customer groups. Further expansion probably requires the availability of EVs 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 EV models possibly causing some to opt for

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PHEVs, although incentives for PHEVs are few. The company and public-body fleet markets are underdeveloped, but they should grow more quickly in the future as fleet owners get used to EVs being available and able to meet transportation needs.

The diffusion of EVs in Norway closely resembles what is expected from diffusion theory. An achievement of the EV policy is that national, regional and local governments, businesses and NGOs have been motivated to move in the same direction. The actual rate of diffusion will be heavily influenced by possible modifications to the societal and economic framework and cooperation. The Norwegian EV market is, however, depending on the other automotive markets. If diffusion does not catch on globally or in Europe, the diffusion of EVs in Norway may slow down.

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Part III: Learnings from Norway based on part I and II

The two perspective in this report complement each other and provide a good understanding of how the EV policies in Norway came into being and how they influenced the market actors and the vehicle buyers.

The EV policy has consistently been pro EV 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 EV communication might have inspired a larger share of the general vehicle owners to be positive to consider buying an EV than in countries were the communication is more ambivalent.

From the experience of EVs in Norway it is evident that incentives are needed to speed up diffusion as long as EVs are more expensive than ICEs. These incentives came about through a series of unique events were stakeholders took advantage of windows of opportunity. Other countries will need to find their own way of supporting EVs as other windows of opportunity may appear and they will have their own framework of vehicle policies to start from. Incentives that address and improves on the perceived relative advantage of EVs as seen by the potential buyers will be most effective to speed of adoption of EVs. In Norway it is seen that purchase incentives have been particularly effective in speeding up adoption in combination with user incentives that give EVs a relative advantage not available to others.

When the price is right and vehicle buyers are aware of and see advantages of EVs, the diffusion pattern will be similar to other innovations.

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