TØI report 1627/2018

Erik Figenbaum

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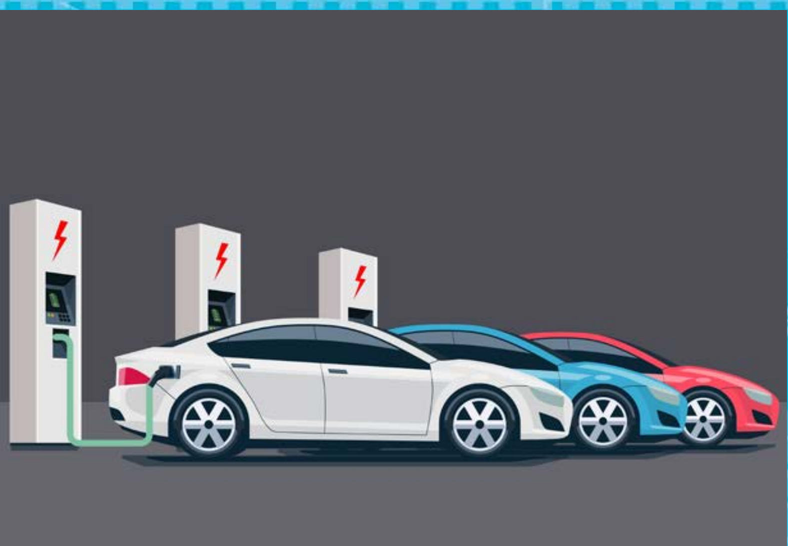
Norwegian Centre for Transport Research

Electromobility status in Norway

Mastering long distances – the last hurdle to mass adoption



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Elbiler hadde en markedsandel på 20% og nådde en andel av bilflåten på 5,1% i 2017. Denne imponerende utviklingen er resultatet av en elbilpolitikk som har vært stabil over lang tid, men er ikke på langt nær nok til å nå Stortingets mål om at bare nullutslippsbiler skal selges fra 2025. Fram til 2018 har flerbilshusholdninger tatt i bruk elbiler til lokaltransport. Skal 2025 målet nås må også enbilshusholdningene ta i bruk elbiler, det vil si at elbiler må kunne erstatte all bilbruk. En flom av nye modeller som kommer på markedet vil gjøre dette enklere, men langdistansekjøring vil være en stor barriere. Det er ikke sikkert at ladeinfrastrukturen kan bygges ut til å dekke ladebehovene på store utfartsdager fullt ut. Elbilkjøpere vil stå overfor en avveining mellom spart tid og kostnader i hverdagen og økt tidsbruk og ladekøer på lengre reiser.

Summary:

Battery electric vehicles (BEVs) reached in 2017 a market share of 20% in Norway, and a fleet share of 5.1%. This impressive development is the result of large incentives and a stable long term BEV-policy, but not nearly enough to meet the Parliaments target of only selling zero emission vehicles by 2025. Up to 2018, the main BEV user group has been multi-vehicle households replacing one vehicle. After 2025 all single vehicle households must buy BEVs, and BEVs must replace all vehicles in multi-vehicle households. A flow of new BEVs with longer range coming on the market the coming years will aid, but traffic on peak travel days can become a major barrier. It may not be economic to build out charging infrastructure capacity to absorb these peaks. Users will thus confront a trade-off between daily cost and time savings and longer stops and charging queues on long distances.

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Preface

This report is part of the work in the Electromobility Lab Norway (ELAN) research project. ELAN is led by the Institute of Transport Economics and is financed by the Research Council of Norway.

The objective of this report is to provide a status on the development of the Battery Electric Vehicle (BEV) market in Norway up to the end of 2017. This status includes identification of knowledge gaps that needs to be filled to be able to assess whether Norway can reach the Parliament (Stortinget) target that only zero emission passenger vehicles shall be sold in Norway from 2025.

The report draws on and elaborates on previous works done at the Institute of Transport Economics. This work has established that BEVs are well suited as the local transport vehicle in multi-vehicle households. A special focus of the ELAN project is on the prerequisites for replacing also the "primary" vehicle of multi-vehicle and single-vehicle households with BEVs. The "primary vehicle" in this sense is the vehicle households use for long distance driving on weekends and for vacations. The more demanding transportation tasks that needs to be accomplished for this usage pattern leads to a need to overcome other and more severe barriers to adoption of BEVs.

The report has been written by Erik Figenbaum. Quality assurance has been done by Research Director Michael W. J. Sørensen. Trude Kvalsvik has been responsible for the final finish of the report.

Oslo, March 2018
Institute of Transport Economics

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Content

Summary

Electromobility status in Norway

Mastering long distances – the last hurdle to mass adoption

TØI Report 1627/2018
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Battery electric vehicles (BEVs) reached a market share of 20% in Norway in 2017, and a fleet share of 5.1%. This development is the result of very large incentives and a long term stable BEV-policy. In addition, another 20% bought a Plug-in Hybrid Vehicle (PHEV) that make up another 2.6% of the fleet. These results are impressive compared to any other nation, but not nearly enough to meet the Norwegian Parliaments ambitious target of only selling zero emission vehicles by 2025. The main BEV user group has been multi-vehicle households replacing one vehicle. However, after 2025 also single vehicle households must buy BEVs, and BEVs must replace all vehicles in multi-vehicle households, not just one. A flow of new BEVs with longer range coming on the market the coming years will aid the transition. If the charging infrastructure is built out concurrently with the increase in the fleet, then more users will find BEVs attractive and easy to use. Data from main-road toll road stations reveals that peak travel days can become a major barrier. Building out charging infrastructure capacity to absorb these peaks completely may not be economically viable. Users will thus confront a trade-off between daily cost and time savings and longer stops and more queues on long distance trips, or they must buy BEVs with range long enough to get them to the final destination on peak travel days.

Higher electric vehicle share of the fleet than anywhere else

Battery electric vehicles (BEVs) reached a market share of 20% in Norway in 2017, and a fleet share of 5.1%. Norway's large incentives and the long term stable BEV-policy have been essential in achieving these impressive results not seen anywhere else in the world. They are, however, not nearly enough to meet the Norwegian Parliaments target of only selling zero emission vehicles by 2025. Zero emission in this sense is defined as zero tailpipe emissions. The main option for achieving that target seems to be BEVs. Fuel Cell Electric Vehicles (FCEVs) running on hydrogen may be another option, but so far no car manufacturer has started full series production of these vehicles. Plug in Hybrids are only part-time zero emission. In this report the focus is on BEVs ability to contribute to the target.

The main BEV user group has up to 2018 been multi-vehicle households. Earlier research has shown that this user group has had few challenges taking BEVs into use. To be able to reach a target of only selling BEVs from 2025, also single vehicle households must start using BEVs, and BEVs must replace all vehicles in multi-vehicle households. New barriers will thus emerge.

Long distance driving (trips, sum of trips or total driving over a day), exceeding the range of BEVs, lead to a need for owners to charge during the trip or the day, or to adapt their driving behavior. Combined with long charge time this will be the remaining main barrier to adoption of BEVs in Norway. The charging process of BEVs is more time consuming than filling fuel in an Internal Combustion Engine Vehicle (ICEV). Fast charging can give 3-5 km of range per minute of charge. Some vehicles can be fast charged about twice as fast. If charge queues also occurs, then long distance driving could become impractical on peak travel days. Users will also need larger BEVs as these trips often are done with vehicles full of luggage and with all household members in the vehicle.

These issues are the remaining major barriers to adoption of BEVs as primary vehicles (the vehicle used for long distance driving) in Norway.

Price is not a barrier to consumer adoption of BEVs. The Norwegian incentives even out the cost of a BEV and an ICEV. In many cases the BEV will be the cheapest option. Battery life is still a barrier although the batteries seems to hold up capacity well under Nordic conditions. Surveys indicate that users are less worried about the second hand value of BEVs than they were earlier in the diffusion process.

BEV technology improve and model availability increase

Most automakers announced in 2017 major and concrete investment and production programmes for BEVs, and other types of electrified vehicles such as PHEVs and hybrids. Some of the announcements even specified which assembly plants the BEVs will be produced and the associated investment costs. There will therefore be a huge increase in the availability of BEVs with longer range designed for the mass market in the coming years. There are three potential game changers in the pipeline. Longer range will be possible with larger battery packs and more energy dense lower cost battery cells. These larger packs will also allow at least three times faster charging. The time spent on fast charging will thus become more comparable to filling fossil fuel at a gas station. A larger pack will also increase battery life as fewer charge cycles will be needed for a given mileage. If the purchase cost barriers continue to be repressed through incentives, there is every reason to believe that the market will continue to expand in the coming years.

The market has been cooled down by delays in vehicle deliveries, or too low production capacity, for models such as Tesla Model 3, VW E-Golf and vehicles from Hyundai and Kia. Nissan on the other hand seems to have the ability to deliver large volumes of the new Nissan Leaf. The delivery situation is likely to be subject for delays until the next wave of models designed for the high volumes enters the mass market between 2019 and 2022. The range for these new types of vehicles will be 400-600 km, with fast charge power of 100-150 kW, and up to 350 kW for the largest luxury vehicles.

National policies influence markets

Norway is in many ways an ideal place to introduce BEVs. The population is rich, a large share of households owns more than one vehicle, the access to home parking is good, speed limits are low (leading to longer range), and the electricity is cheap and supplied by a robust grid. The cold winters will however give large reductions in range, whereas temperate summers are ideal for longevity of batteries.

The Norwegian BEV market is fuelled by incentives that eliminates the price difference of BEVs and ICEVs, and in many cases make the BEV option the cheapest. Ownership costs are also lower due to the largest annual energy cost savings of using BEVs instead of ICEVs of any country in Europe. Further cost savings are available many places due to local incentives such as the exemptions from toll road and parking charges. These policies have been in place for a very long time leading to opportunities for vehicle importers to profitably and quickly introduce BEVs into the market in large volumes, which they all have grabbed as soon as their brands started offering BEVs. The market will continue to expand as long as these benefits and incentives continue to be available to new user groups.

The user benefits are also available to buyers of second hand vehicles, leading to a strong second hand market demand. The depreciation rate of BEVs launched after 2013 has therefore been more or less the same as that of similar ICEVs. Earlier BEVs have however suffered higher value losses, mainly due to the rapidly decreasing new vehicle prices early in the diffusion process.

Will BEVs meet enough vehicle user's needs?

A small share of early BEV users only own the BEV and have no other vehicles at their disposal unless they rent, loan or use car sharing vehicles in addition. An even smaller share of households owns more than one BEV, with no ICEVs in the household, but these are people that have taken a special interest in the technology. Most BEVs are however owned by multi-vehicle households also owning an ICEV. These households keep the flexibility to effortlessly do long distance driving with the ICEV.

Meeting mass market demand for general purpose vehicles will be very different. People have very different usage patterns and some users need large vehicles capable of rooming much luggage, or have a need to haul heavy trailers or caravans. It will thus be much more difficult to replace the last 20% of ICEVs in the fleet than the first 20%. Long distance driving, such as vacations and weekend trips will be most difficult to replace, especially if the range is less than the distance to be covered for large share of vehicles. It is unlikely that it will be economically viable to build out charging infrastructure to completely cope with the total travel demand on peak travel days. On some roads the demand on peak days can be more than five times larger than that of a normal day. Another challenge could be the ability to charge at the destination, for instance at vacation homes and huts, due to lack of electricity where the vehicle is parked.

Charging infrastructure is lagging fleet increase but improving

Home charging capability is seen as a main attraction of BEVs, and a prerequisite for BEV ownership. 94% charge their vehicle at home. Up to 75% of all households can park on own land, a further 14% less than 100 meters from their doorstep. It can be estimated, based on results from user surveys, that about 42 000 BEV and PHEV owners had installed homechargers (EVSE wallbox) at the end of 2017. A further 142 000 use domestic type Schuco sockets for charging. There were about 7 500 public "slow" chargers available. Additional electric sockets that can be used for charging are however available outdoors in numerous locations without being termed "charging station". Home charging supports most of the local driving, but when fast chargers are installed in cities they are quickly fully utilized, indicating that some users stretch their vehicles range capability also in daily day traffic.

Fast charging was non-existent in 2010. Today more than 1000 fast chargers are available in Norway. These fast chargers are distributed in more than two hundred physical locations. The rapid expansion of the fast charger network has been the result of a deliberate government policy of supporting the installation of fast chargers since 2011, and various private initiatives. A general support program got the first chargers installed (Transnova), and public tenders resulted in a basic network of chargers every 50 km along all major transport corridors in southern Norway up to Tromsø. A new program will from 2018 support the installation of fast chargers in municipalities that have none. Increasing private investments also leads to more fast chargers being installed in cities and outside shops and restaurants. Life with a BEV has thus become easier in cities, although range anxiety seems to gradually be morphing into a charge queue anxiety. Long distance driving has been enabled across most of Norway, but has so far not often been undertaken by the majority of BEV owners.

Fast charging has been limited to 50 kW, apart from Tesla Superchargers operating at 60-120 kW. That is about to change in 2018. Several operators will install chargers capable of 150 kW charging and some even 350 kW. Vehicles capable of fully utilizing the charging power of these stations will not come on the market until 2019-2020.

Everyone knows the technology and the market will expand

While the BEV diffusion and market introduction started in cities, the market is now rapidly increasing also in rural areas, supported by increased availability of fast chargers, and a knowledge transfer in the population.

All importers offer BEVs across their entire national dealer network, and new models are introduced as soon as they are available in the market. BEVs are thus no longer a city phenomenon, but a real option for most vehicle buyers in most places.

A survey of the general population in early 2018 revealed that 89% of the population of Norway knows someone owning a BEV, 66% have been a passenger in a BEV, and 34% have driven a BEV. Only 22% have never been inside a BEV. The survey also revealed that in the general population the main barriers to sales are range, a lack of sufficient charging infrastructure and uncertainty about battery life. Twice as many respondents believe that ICEV cars will be less attractive in the second hand market than BEVs, as those that believe the opposite. Using purchase intentions of different types of vehicles from the 2018-population survey and splitting it into shares of the total market, it seems to be a potential to sell about 40 000 new BEVs in Norway in 2018, 25-30% of the expected total sales of passenger vehicles.

The range that will be available on future models will meet the needs of larger shares of vehicle buyers. 300 km all year range was seen as sufficient by up to half of ICEV owners and 80% of BEV owners, in a 2016 vehicle owner survey. Short range and long range vehicles will potentially co-exist in the market to cater for different user needs at different cost levels. Another market booster will be an increase in the number of available models, both from a wider range of brands and for user segments currently lacking BEV offerings. One can also expect higher future growth when users that currently own BEVs, trade in their older BEVs for models with longer range and other improvements.

BEV owners spend much less money on energy than ICEV owners do. This advantage comes however at the cost of having to spend more time than ICEV owners when undertaking long distance trips. The reason is that the charging occur at a much slower energy transfer rate than when filling liquid fuels. This trade-off is reduced the longer the range of the vehicle is, and the faster the charging it can accept.

Transportøkonomisk institutt
Stiftelsen Norsk senter for samferdselsforskning

Sammendrag

Status for elektromobilitet i Norge

Lange reiser – den siste barrieren for videre ekspansjon

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Forfatter: Erik Figenbaum
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Elbiler (batterielektriske) nådde en markedsandel i nybilmarkedet på 20% i 2017, og utgjorde over 5,1% av bilflåten på slutten av samme året. Dette ekstraordinære resultatet sett i internasjonale sammenheng er resultatet av kraftige insentiver som har vært stabilt tilgjengelige i lang tid. Ladbare hybridbiler har ikke like store insentiver men med færre brukerbarrierer nådde også disse en markedsandel på 20% i 2017 og utgjør nå over 2,6% av bilflåten. Selv om dette er imponerende resultater sett fra andre lands ståsted er det langt fra nok til å nå Stortingets mål om bare å selge nullutslippsbiler (uten avgassutslipp) fra 2025. Elbiler er foreløpig den eneste teknologien som kan anvendes for å nå et slikt mål. Elbilene har slått an i flerbilshusholdningene som har hatt få utfordringer med bruken, men nå må de i økende grad tas i bruk av enbilshusholdninger og erstatte også den andre bilen i flerbilshusholdningene. Flommen av nye modeller med lenger rekkevidde og raskere ladning som kommer på markedet vil gjøre dette enklere, men ladeinfrastrukturen må også henge med slik at elbiler oppleves som attraktive og enkle å bruke. Data fra bomstasjoner langs hovedveiene viser store variasjoner i antall biler som reiser på ulike dager. Det vil dermed bli vanskelig å dekke alle behov for ladning på dager med ekstra stor trafikk fullt it. Brukere vil dermed stå overfor en avveining der de sparer tid og penger i hverdagen på hjemmeladning, men bruker mer tid på lange reiser.

Høyere andel elbiler i bilflåten enn noe annet sted i verden

Elbiler hadde en markedsandel av nybilsalget på 20% i Norge i 2017. Andelen av den totale personbilflåten passerte 5,1%. Det er kombinasjonen av store insentiver og en stabil elbilpolitikk som har skapt disse unike resultatene, som ikke ses noe annet sted i verden. Dette er imidlertid langt fra nok til å nå Stortingets mål om at det bare skal selges nullutslippsbiler fra 2025 i Norge. Med nullutslipp menes null avgassutslipp fra selve bilen i bruksfasen. Hovedopsjonen for å klare dette ser ut til å være elbiler da den andre kategorien nullutslippsbiler, brenselcellebiler som går på hydrogen, fremdeles ikke er industrialisert og derfor bare kan anvendes til begrenset uttesting. Ladbare hybridbiler kan kjøre elektrisk deler av tiden men også med forbrenningsmotor og kvalifiserer dermed ikke som nullutslippsbil. I denne rapporten fokuseres det derfor på elbilenes muligheter for å bidra til det nasjonale målet.

Hovedbrukergruppen for elbiler har fram til 2018 vært flerbilshusholdningene. Tidligere studier har vist at denne brukergruppen kan enkelt ta elbiler i bruk uten å møte store brukerutfordringer. Skal det nasjonale målet for 2025 nås må imidlertid også enbilshusholdningene gå over til elbiler og den andre bilen i flerbilshusholdningene må også skiftes ut. Dette vil medføre at nye barrierer må overvinnes.

Den viktigste barrieren vil være langdistansekjøring. Langdistansekjøring enten det er enkeltreiser eller total reise over en dag, som overskrider elbilenes rekkevidde vil medføre behov for oppladning av batteriene underveis, eventuelt endringer i bilbruksvaner. Kombinert med lange ladetider og begrenset tilgang på ladeinfrastruktur, vil denne type kjøring utgjøre den gjenværende barrieren mot økt elbilbruk i Norge. Elbiler kan hurtiglades. Hurtigladehastigheten ligger typisk på 3-5 km kjørelengde per minutt ladetid, men noen biler kan lades dobbelt så hurtig. Hvis det i tillegg oppstår lange ladekøer kan langdistansekjøring på dager med stor utfart bli upraktisk for biler med kortere rekkevidde. I tillegg vil denne type reiser ofte gjennomføres med bilen full av husstandsmedlemmene og bagasje.

Kostnader er ikke lenger en barriere for elbiler i Norge. Kjøpsinsentivene (avgiftsfritak) utjevner prisforskjellene, og i mange tilfeller ender elbilen opp som det billigste alternativet. Batterilevetid kan fortsatt være en barriere men det ser ut til at batterikapasiteten holder seg bra under nordiske forhold. Befolkningen er mindre bekymret for elbilers andrehåndsverdi enn de var tidligere i elbilintroduksjons-prosessen.

Elbilteknologien forbedres og antall modeller øker

De fleste bilprodusentene annonserte i løpet av 2017 store og konkrete beslutninger om investeringer i utvikling og produksjon av elbiler med lenger rekkevidde, og andre elektrifiserte biltyper som ladbare hybridbiler og vanlige hybridbiler. Enkelte av disse var detaljert ned til modell og investeringsbeløp i navngitte produksjonsanlegg. Det er derfor ingen tvil om at det vil bli en stor økning i tilgjengeligheten av masseproduserte elbiler med lang rekkevidde de kommende årene. Det er tre potensielle gjennombrudd på gang. Lenger rekkevidde muliggjøres av større og mer energitette batteripakker, som igjen muliggjøre raskere oppladning (i km rekkevidde per minutt lading) og lenger batterilevetid (færre ladesykluser over bilens levetid).

Hvis kostnadsbarrieren fortsatt holdes nede av insentivene i Norge (avgiftsfritakene) så er det all grunn til å anta at markedet vil fortsette å ekspandere i de kommende årene.

Markedet har blitt kjølt ned av forsinkelser i leveranser av nye biler og som følge av for lav produksjonskapasitet. Førstnevnte gjelder særlig Tesla Model 3 som mange nordmenn venter på. Sistnevnte gjelder nå de fleste elbilprodusentene, herunder VW, Hyundai og Kia. BMW og Nissan er eksempler på produsenter som er leveringsdyktige. Men også Nissan har i starten av 2018 økende ventetid på nye Leaf som har en enorm etterspørsel og ligger an til å bli Norges mest solgte bilmodell i 2018. Denne situasjonen vil nok vedvare inntil den neste bølgen av nye elbiler designet for massemarkedet fra starten av kommer på markedet mellom 2019-2022. Disse bilene vil få rekkevidde på 400-600 km og ladehastigheter på 100-150 kW for vanlige elbiler og opp mot 350 kW for luksuselbiler.

Nasjonal politikk og særegenheter påvirker markedet

Norge er på mange vis et ideelt land å introdusere elbiler i. Befolkningen er rik og en stor andel av husholdningene eier mer enn en bil. Tilgang til parkering hjemme er god. 75% av husholdningene kan parkere på egen tomt og vil ha derfor ha gode lademuligheter. Strøm er billig mens bensin og diesel er dyrt. Norge er derfor det land i Europa der energikostnadsbesparelsen ved å gå over til elbiler vil være størst. Kraftnettet er stabilt og husholdningene har en kraftig kobling til elnettet i og med at de fleste husholdninger bruker el til romoppvarming. Hastighetene på veinettet er forholdsvis lav, noe som reduserer elbilenes energiforbruk og dermed gjør at rekkevidden er lenger enn i land med høyere hastigheter i trafikken. Milde sommertemperaturer er en fordel for å oppnå lang batterilevetid, mens de kalde vintrene gir betydelig rekkeviddereduksjon og kan også negativt påvirke levetiden til batteriene.

Elbilmarkedet drives særlig fram av kjøpsinsentivene, det vil si avgiftsfritak, som gjør at prisforskjellen mellom en elbil og en vanlig bil i realiteten elimineres, og i mange tilfeller medfører at elbilen blir billigste alternativ.

Elbileiere nyter godt av kostnadsbesparelser som følge av lokale insentiver som gratis passering av bomstasjoner og gratis parkering. Disse insentivene har vært tilgjengelig siden 1997. Dette har sammen med kjøpsinsentivene gjort at bilimportørene som tar inn elbiler har kunnet spre elbilene i markedet profitabelt og raskt i store volumer. Denne muligheten har alle bilimportører som har hatt muligheten benyttet seg av. Markedet vil fortsatt ekspandere så lenge disse insentivene og fordelene fortsetter å være tilgjengelig for nye brukergrupper.

Bruksinsentivene er også tilgjengelige for kjøpere av bruktelbiler, noe som har ledet til en høy etterspørsel etter brukte elbiler. Verditapet for elbiler som har blitt lansert etter 2013 har derfor vært omtrent som for tilsvarende diesel- og bensinbiler. De som kjøpte elbiler tidligere har imidlertid opplevd et større verditap enn normalt fordi nybilprisene falt raskt de første årene spredningen av elbilene kom i gang for alvor.

Vil elbilenes egenskaper tilfredsstille nok brukeres behov?

En liten andel elbiler eies av enbilshusholdninger. De har ikke tilgang til andre biler med mindre de leier eller låner en bil eller benytter delebilordninger. En endra mindre andel av elbileierne eier mer enn en elbil uten tilgang til biler med forbrenningsmotor. Dette er stort sett bileiere med en spesiell interesse for elbiler. Langt de fleste elbilene er imidlertid eid av flerbilshusholdninger som også disponerer en bil med forbrenningsmotor. Disse husholdningene opprettholder dermed fleksibiliteten til enkelt å dra på lange turer.

Å klare kravene til egenskaper for biler som brukes på de lange turene vil bli en større utfordring. Bilkundene har veldig ulike bruksmønstre og bilstørrelse er av betydning når husstandens medlemmer skal på langtur med bagasje og sportsutstyr. En del brukere har også behov for å trekke tilhengere og campingvogner. Mens det har gått raskt og smertefritt å erstatte de enkleste 20% av bilmarkedet med elbiler vil det bli betydelige utfordringer med å erstatte de siste 20% av markedet. Langdistansekjøring vil bli den store barrieren, spesielt også fordi denne ofte foregår i samme tidsperiode for mange bileiere, store utfartsdager som det vil være ulønnsomt å bygge ut en tilstrekkelig ladeinfrastruktur til å håndtere fullt ut. På noen veier kan det på de verste dagene være mer enn fem ganger så mange som reiser som på vanlige dager. En annen utfordring kan bli manglende muligheter for å lade på destinasjonen hvis elektrisitet ikke er tilgjengelig der.

Ladeinfrastrukturen ekspanderer saktere enn bilflåten

Hjemmeladning er sett på av brukerne som en av hovedfordelene med elbiler, og ser også ut til å være en forutsetning for elbileierskap, da 94% av dagens eiere lader hjemme. Hele 75% av alle husholdninger parkerer på egen tomt, og ytterligere 14% mindre enn 100 meter fra dørstokken. Om lag 42 000 husholdninger som eier elbiler eller ladbare hybridbiler har installert hjemmeladere, mens ytterligere 142 000 lader fra vanlige «Schuko» støpsler. Det er ca. 7 500 offentlige «normalladere» installert i Norge men elektrisitet fra vanlige «Schuko» støpsler er tilgjengelig på utallige steder. Hjemmeladning muliggjør det meste av lokaltrafikken, men hurtigladere som sette opp i byene tas raskt i bruk og indikerer et behov for å supplere med strøm underveis på enkelte turer.

Hurtigladning eksisterte ikke i 2010 i Norge. På slutten av 2017 var det over 1000 ladepunkter installert, fordelt på mere enn 200 lokasjoner. Denne raske utbyggingen har skjedd som følge av en villet politikk der Transnova og senere Enova har støttet utbygging av hurtigladere. I de seneste årene har private initiativer fått økt betydning og utbyggingen i byene skjer kommersielt uten offentlig støtte. Enova har gjennom fire anbudsrunder støttet utbyggingen av et nettverk av hurtigladere hver 50 km langs de viktigste transportkorridorene mellom de norske byene opp til Tromsø. Markedet nord for Tromsø har vært for lite utviklet til at noen har villet bygge ut hurtigladere der. Et nytt Enova støtteprogram går til utbygging av hurtigladere i kommuner som så langt ikke har fått støtte til hurtigladere. Livet med elbilen har således blitt enklere, både i byene og på reise mellom byer. Rekkeviddeangst kan bli til ladeangst hvis infrastrukturen ikke holder tritt med bilflåteutviklingen. Det er foreløpig få som kjører mellom byer med unntak av Tesla-eierne.

Hurtigladning har vært begrenset til 50 kW ladeeffekt, som gir ca. 3-5 km rekkevidde per minutt opplading, men dette vil endres i 2018. Flere ladestasjonsoperatører bygger ut hurtigladere som kan levere 150 kW ladeeffekt, og helt opp til 350 kW. Elbiler som kan lade med slike effekter kommer ikke på markedet før i perioden 2019-2020.

Alle kjenner til elbiler og markedsekspansjonen fortsetter

Introduksjon av elbiler i bilflåten startet i byene men spres nå i rask fart til resten av landet, støttet av økt tilgjengelighet av hurtigladere og en rask kunnskapsspredning i befolkningen. Alle bilimportører, der bilmerket de representerer har elbiler, har introdusert biltypen i hele sitt landsdekkende forhandlerapparat. Elbiler er dermed ikke lenger et byfenomen men en biltype som er aktuell også for de som bor på spredtbygde steder.

En representativ spørreundersøkelse i befolkningen i februar 2018 avslørte at 89% kjenner noen som eier en elbil, 66% har vært passasjer i en elbil og 34% har kjørt en. Bare 22% har aldri vært inni en elbil. Samme undersøkelse viste at i den generelle befolkningen er hovedbarrierer mot økt elbilsalg; rekkevidde, utilstrekkelig ladeinfrastruktur og usikkerhet knyttet til batterilevetid. Spørreundersøkelser fra 2014 og 2016 hadde tilsvarende resultater. I 2018 undersøkelsen sa imidlertid dobbelt så mange respondenter at forbrenningsmotorbiler vil være mindre attraktive i bruktmarkedet enn elbiler, som de som sa det motsatte. Markedet for elbiler i 2018 kan basert på spørreundersøkelsens spørsmål om kjøpsintensjoner i framtiden og egne vurderinger, estimeres til å kunne nå ca. 40 000 elbiler, som vil være 25-30% av det forventede totale bilmarkedet.

Året rundt rekkevidden vil for mange tilgjengelige elbilmodeller bli minst 300 km, noe som vil møte forventningene og behovene til langt flere. Denne rekkevidden mente halvparten av eierne av forbrenningsmotorbiler og 80% av elbileierne i en 2016 spørreundersøkelse at er tilstrekkelig til at flere vil bli interessert i å kjøpe elbil. Elbiler med kortere rekkevidde og lavere pris vil nok fortsatt være tilgjengelig i markedet da ikke alle trenger lang rekkevidde. En annen faktor som vil bidra til å øke markedet vil være at det kommer flere modeller på markedet fra flere bilprodusenter i flere markedssegmenter. En tredje faktor vil være at de nye attraktive modellene vil gjøre det interessant for eksisterende eiere å bytte bil til en modell med lenger rekkevidde og andre forbedringer.

Elbileiere har mye lavere energikostnader enn bensin- og dieselbileiere, men må akseptere at lange reiser tar lenger tid. Dette skyldes at hurtiglading er mye langsommere enn tiden det tar å fylle flytende drivstoff. Tidsulempen avtar med elbiler med lenger rekkevidde og økende ladehastighet, men kan kanskje ikke elimineres fullstendig. På dager med mye trafikk over lengre avstander kan etterspørselen etter hurtiglading overstige kapasiteten.

1 Introduction

Battery electric vehicles (BEVs[1]) reached a market share of 20% in Norway in 2017 and a fleet share of 5.1%, a result of very large incentives and a long term stable BEV-policy. The main user group has been multi-vehicle households. In addition, another 20% bought a Plug-in Hybrid Vehicle (PHEV) that run roughly half the time on electricity, and making up another 2.6% of the fleet. By the end of 2018 close to one out of ten vehicles will have a plug and run on Norway's clean grid electricity, and thereby reducing national greenhouse gas emissions and pollution.

These are impressive results compared to other nations, but not nearly enough to meet the Norwegian governments ambitious target of only selling zero emission vehicles by 2025. This goal has been set in the Norwegian national transportation plan (NTP 2017b) and approved by the parliament (NTP 2017a). To be able to reach that target also single vehicle households must start using BEVs, and BEVs must replace all vehicles in multi-vehicle households. The main question will be how existing BEVs, and the longer range BEVs coming on the market now and in next 1-4 years, can meet the needs of Norwegian households as a replacement for their "primary vehicle". The primary vehicle is in this report defined as (1) the vehicle owned by single vehicle households, and (2) the vehicle that is used on long distances and vacations in multi-vehicle households. The secondary vehicle is the other vehicle(s) in multi-vehicle households, but may, as it is most often the case for BEVs, be the most used vehicle in daily traffic.

Understanding the travel behaviour of vehicle owners will be a key factor in the analysis of how BEVs can meet these user needs, and how policies, incentives and infrastructure must work together in a drive to fully electrify the Norwegian vehicle market and fleet.

A detailed account of the characteristics of existing BEV owners and their travel pattern, and how they deviate from other vehicle owners, can be found in Figenbaum and Kolbenstvedt (2016). Some of the results from that report will be presented and further elaborated upon in this report. In the COMPETT (COMpetitive Electric Town Transport) project, funded by the Electromobility+ ERA-NET program undertaken 2012-2015 (Figenbaum et al 2014, Figenbaum and Kolbenstvedt 2015), and in the follow up survey of vehicle owners in 2016 (Figenbaum and Kolbenstvedt 2016), the major conclusion was that BEVs were already suitable as a replacement for one of the vehicles in multi-vehicle households and for local travels. Few single vehicle households had however taken them into use, and they were rarely used for long distance trips such as vacations.

Long distance driving combined with long charge times is the main remaining barrier to adoption of BEVs in Norway. Such trips involve moving all or some of the household members from home to a hut, a vacation destination, or for visits to friends or family. Other long distance targets could be multimodal terminals (car ferries, airports etc.), shopping and leisure destinations and work related destinations. The km driven to cover these long distance trips, trip chains and days of driving can exceed the available range of most of the BEVs that were on the market up to 2018, leading to a need to charge during

[1] Acronyms used in the report: BEVs=Battery Electric Vehicles, PHEVs=Plug-in Hybrid Electric Vehicles, ICEVs=Internal Combustion Engine Vehicles, ICE=Internal Combustion Engine, FCEVs=Fuel Cell Electric Vehicles.

the trip or day, unless driving habits are adapted. The charging process is more time consuming than filling fuel in an Internal Combustion Engine Vehicle (ICEV). Queues to charge will have more severe impacts for BEV drivers due to typical fast-charges lasting 20-40 minutes, than for ICEV owners filling liquid fuels in minutes. The vehicles size is important on these trip types as substantial amounts of luggage is brought along on the trips, and the owners may want to mount bicycles or skis on a roof rack or on a tow hook. Some vehicle users pull large caravans or boats on trailers, others use smaller trailers for transporting goods, garden waste etc. The result is that drag forces are substantially increased, and the range of BEVs decreases. These issues are barriers to adoption of BEVs as primary vehicles.

With longer range and faster charging of future and newer BEV models, more people may find that BEVs functions for their primary vehicles usage pattern. No one knows, however, how long range different users really need for summer and winter driving. Drivers are accustomed to ICEV vehicles having over 800 km range, and the ability to refill in minutes, but most vehicle owners never drive that long on a single day. Refueling is something the average ICEV owner would do about twice a month for an annual driving distance of about 15 000 km. Although BEVs will have much shorter range than ICEVs in real traffic in the winter, they nevertheless cover a very large share of drivers needs with the energy that can be charged into the battery overnight at home (Figenbaum and Kolbenstvedt 2016).

Fast charging is used for the occasional long distance trips, or when the user has miscalculated range or forgot to recharge the vehicle (Figenbaum and Kolbenstvedt 2015, 2016). Fast charging would likely be used to provide just enough electricity to be able to get to the destination, given that the cost of fast charging is four times as expensive as charging at home or at the destination. More powerful fast charging will become possible with larger batteries, and charge time can then be substantially reduce measured in km of driving per minute of charge. There are other options to solve longer distance trips. Users may have the ability to swap vehicles within families and use an ICEV for long distance trips, thus creating a virtual multi-vehicle fleets, or combine single vehicle ownership with car sharing/rental solutions (Figenbaum et al 2014, Figenbaum and Kolbenstvedt 2016).

A key question for the expansion of the BEV market, can thus be summed up to:

What is the range, charge time, model availability in vehicle segments, and infrastructure availability, that will cover a wide range of consumer needs and wants for transportation, and how can the market potential be unlocked to reach the 2025 target of only selling BEVs?

A first step in the process of answering that question in the ELAN project (2017-2020), has been to write this report on the present status of BEVs in the Norwegian passenger vehicle market. The report thus complements the earlier works on the situation up to 2016 (Figenbaum and Kolbenstvedt 2013, 2015, 2016a, 2016b), Figenbaum et al 2015a, 2015b, Fearnley et al 2015 and Figenbaum 2017).

The report starts off with chapter 2 presenting the status of BEV technology, and providing an overview of the current and future marketed vehicles. Chapter 3 provides an update on Norwegian BEV policies and incentives currently in place, and the usage and value of these incentives. Chapter 4 presents some basic facts about the Norwegian vehicle market, whereas Chapter 5 presents the characteristics of users and usage patterns. Chapter 6 goes through the status of the charging infrastructure. Chapter 7 discusses how the findings in chapter 2-6 influences the future BEV diffusion and provides a market outlook. Chapter 8 gives a short overview of how the transition to BEVs might impact Norwegian business opportunities. Chapter 9 contains the conclusions of the report.

2 BEV technology prospects

This chapter provides an overview of the characteristics of vehicles currently available in the market, and the prospects for improved technology of new vehicles coming on the market in the period up to 2020.

The BEV technology is under constant and rapid development. BEVs range has increased from 80 km in the 1990s to 160 km by 2010, to over 500 km for some models after 2013. Slow charging from domestic plugs was standard up to 2010, although some French BEVs produced in the period 1998-2003 could be fast charged at 20 kW power. Today 50 kW fast charging capability is standard on most BEVs, while Tesla BEVs can charge at 120 kW.

2.1 Characteristics of available BEV models in 2017

Available models by introduction year

Figure 2.1 shows the BEV models that were available (with known price) through the official vehicle importers in the Norwegian market 2016-2018. Some models are listed with 2-3 lines because they are, or have been available, in old and upgraded versions were battery sizes and charging options have changed. The Peugeot Ion and the Citroën C-Zero are listed separately, but are essentially the same vehicle as the Mitsubishi I-Miev.

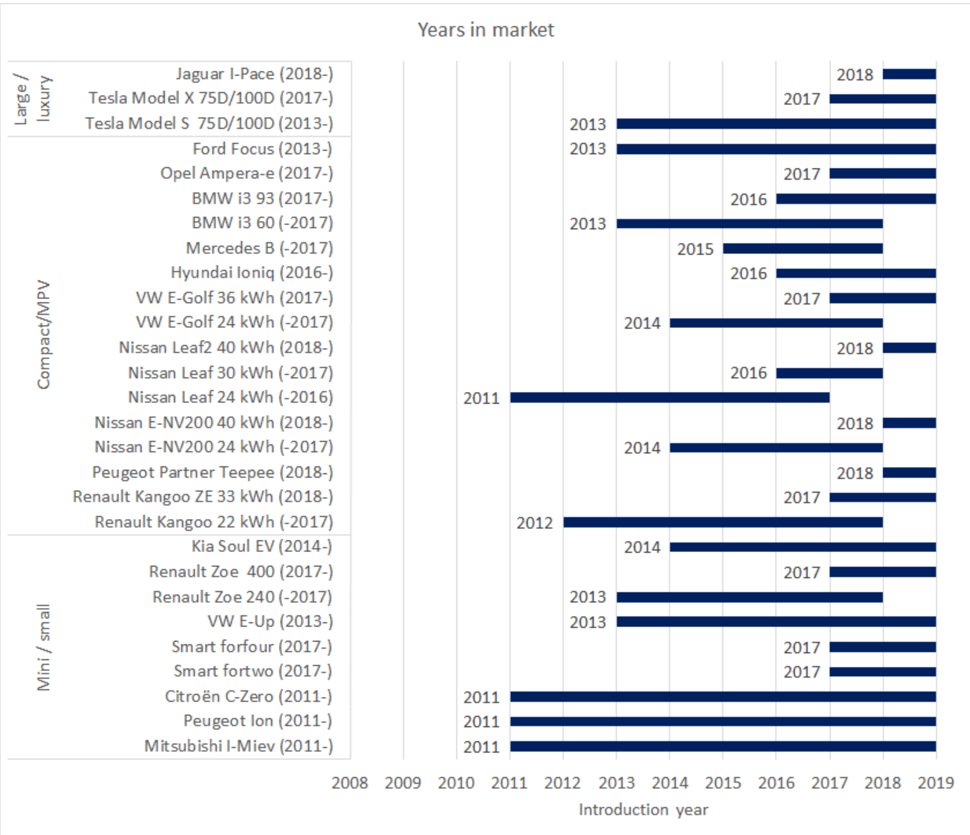


Figure 2.1: Available BEV models for delivery in 2016-2018 by year of introduction in the Norwegian market.

Four models became available in 2011. Three of these have more or less the same specifications in 2018 as when introduced. The fourth, the Nissan Leaf, has been upgrade several times. Four more models became available from 2013, two more from 2014, one in 2015 and three in 2016. One model was discontinued in 2017, four new were introduced and three were improved. The remaining nine models are new in 2017. One model was reworked for 2018 and two new introduced. The biggest offering is in the compact/small vehicle segments. Tesla Models S and X are the only larger vehicles available in the market. Tesla Model 3 deliveries will not commence until 2019 and is therefore not on the chart.

Price

The base vehicle price is for most BEVs 150000-350000 NOK[2] as seen in figure 2.2. A large share of new ICEV purchases are in that price interval in Norway. Some vehicles only come in one main variant, others have up to three different equipment levels. These prices are competitive with ICEVs in the same vehicle segments in Norway, due to BEVs exemptions from registration tax and the Value Added Tax (VAT), as explained in chapter 3. The Opel Ampera price increased by 18% from 2017-2018, and the VW E-Golf and BMWi3 by 9%. The prices have been more stable for the other BEVs.

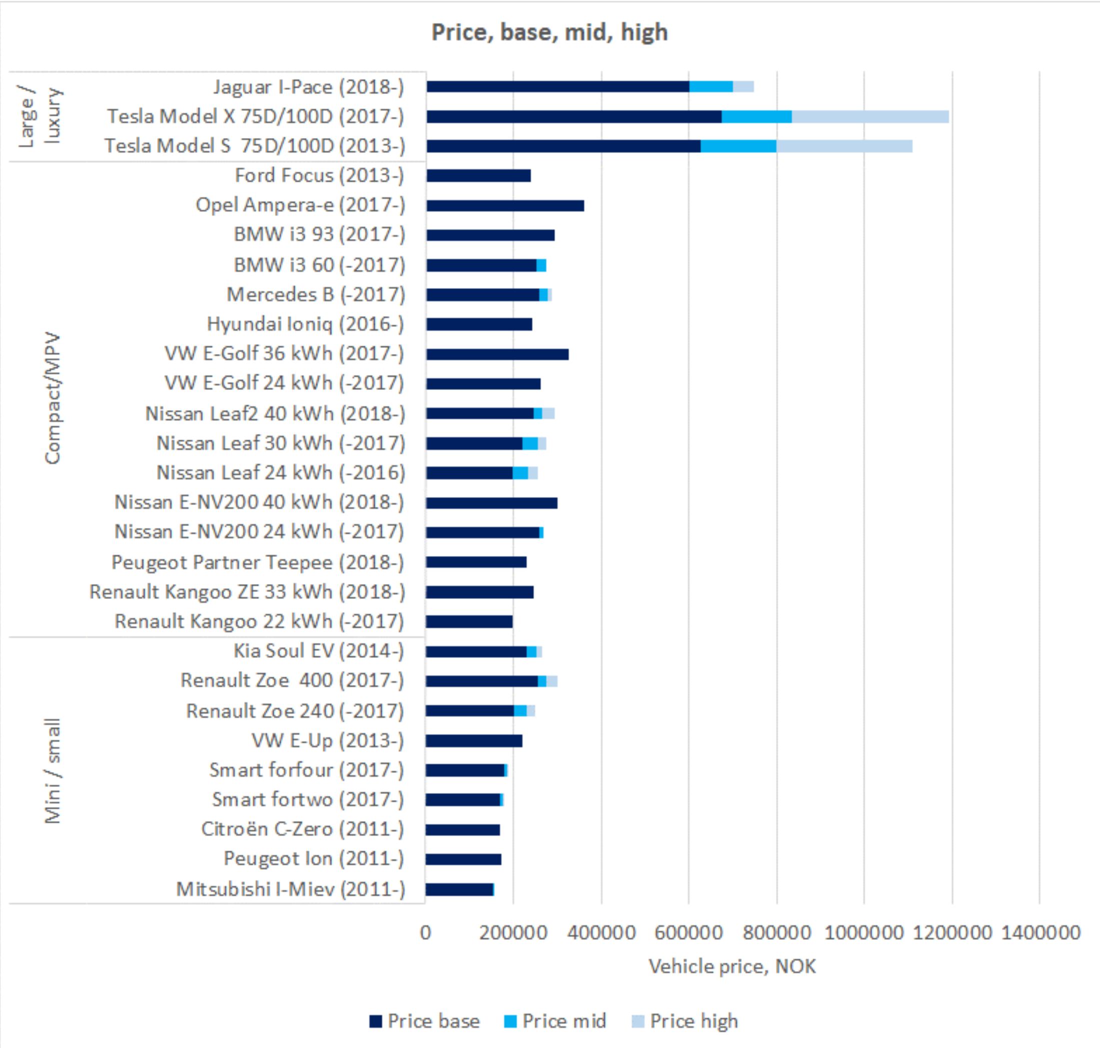


Figure 2.2: Vehicle prices by base, mid or high equipment variant in various segments 2016-2018. NOK.

[2] 1 Euro was 9.8 NOK in February 2018.

Range

BEVs range was up to 2016 rather uniform. Small and mini vehicles had a range of 150 – 230 km and compact vehicles 160-280 km. Tesla was in a league of its own with 400-550 km range in the large/luxury segment up to 2016. The spread of ranges within the vehicles segments expanded substantially in 2017, as seen in figure 2.3, with longer range vehicles available in all three segments. The Opel Ampera-e compact BEV has for instance a longer range than the base versions of the Tesla Model S and X vehicles, at a much lower cost. Existing models range increased substantially in 2017-2018, such as the E-Golf and the i3.

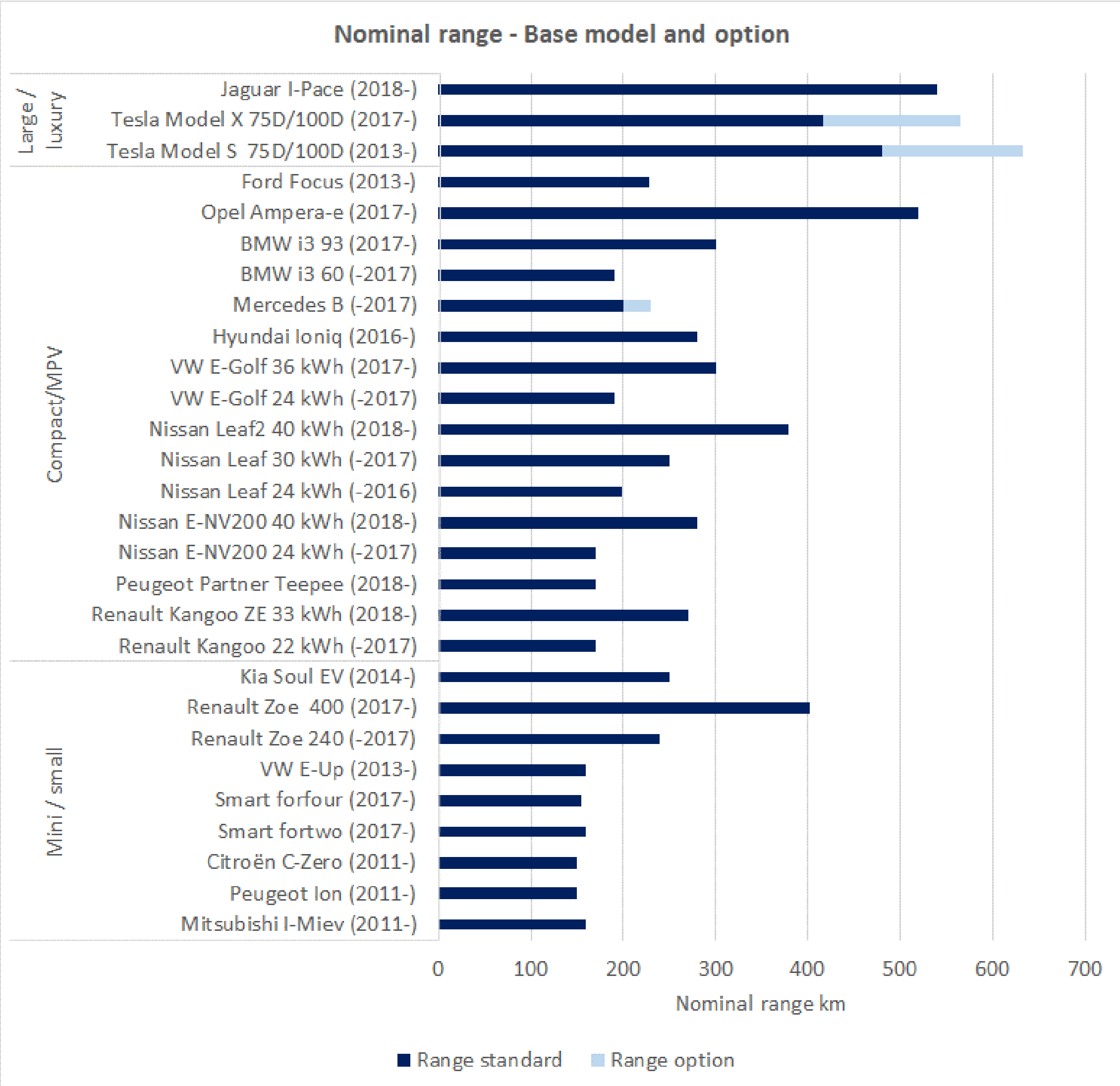


Figure 2.3: BEVs official range in km according to the type approval NEDC test, 2016-2018[3].

Cost of range, i.e. vehicle price divided by the range, varies from 633-1 619 NOK/km, as seen in figure 2.4, and has gone down when the range increases as seen for the Leaf, the i3 and the E-Golf. Nissan Leaf seems to offer the best overall package, having low cost per km of range, a roomier interior, larger luggage capacity than other BEVs of the same size and a low purchase price. When the Leaf was introduced in 2011 the price was 255 000 NOK which is 288 000 NOK in 2017 money. The range was 160 km of the 2011 model

[3] Jaguar I-Pace range is 480 km in the new cycle WLTP. Jaguar has stated that NEDC range (shown here) exceeds 540 km (Motoring 2018).

and the cost of range was then thus 1 800 NOK/km of range, illustrating the rapid improvements in the technology. The Ampera E has longer range than the leaf at almost the same cost per km of range. It also the same roomy interior as the Leaf, but the purchase price is higher while the range is longer. These vehicles have a cost per km of range which is almost half that of a Tesla Model S. The increased range and reduced cost per km of range in all vehicle classes is positive. The cost of long range has gone down substantially with the availability of small and compact vehicles with long range. The spread of range between models within segments could make consumers vehicle selection process more complicated.

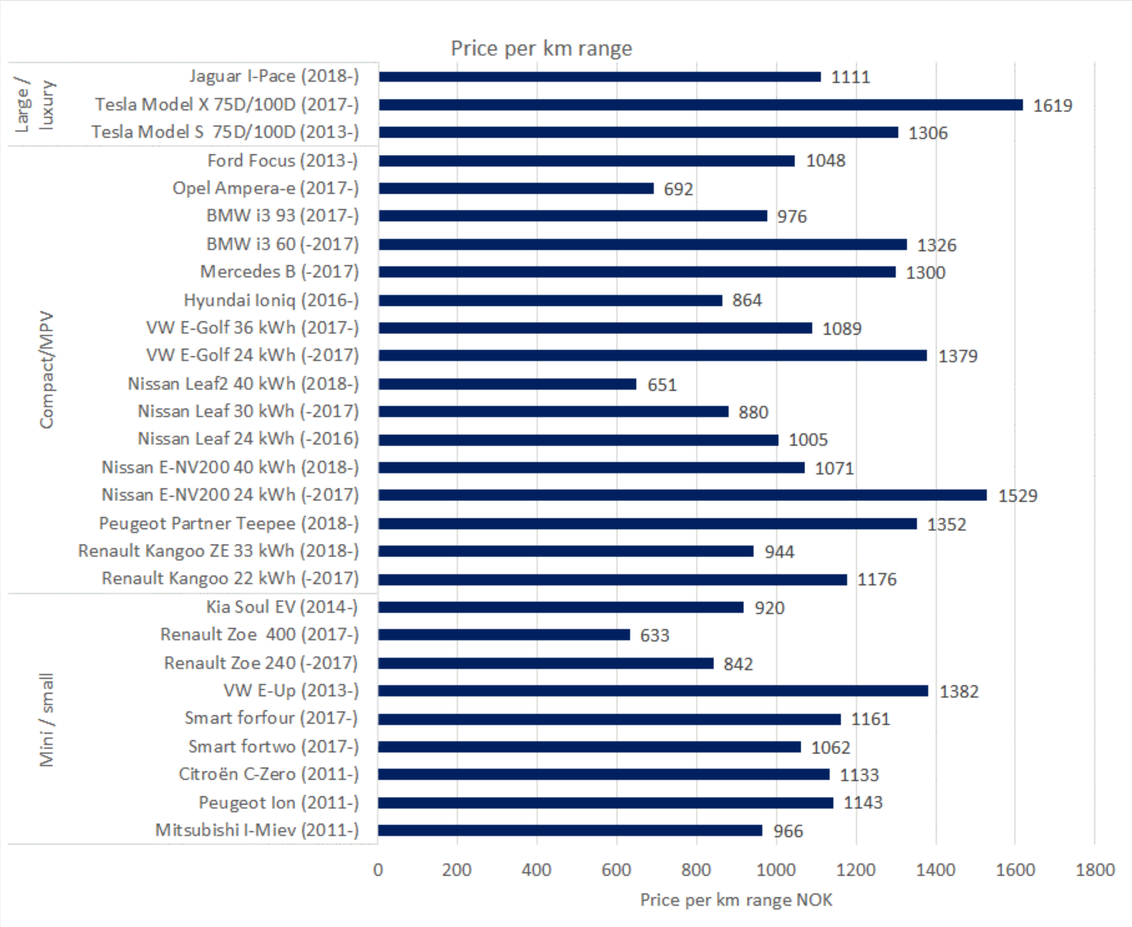


Figure 2.4: Cost of range in NOK/km, calculated from purchase price divided by range, 2016-2018 vehicles.

Charging capabilities

The vehicles charging capabilities have evolved substantially. None of the vehicles on the market were fast charge capable prior to 2010, and normal charge was limited to 2.3-3.2 kW. BEVs come in 2018 with 7.2 or 11 kW chargers as standard or option and can be fast charged at 50 kW or for some vehicles even faster, as seen in figure 2.5. There are still two different types of fast charge inlets on these vehicles, the Chademo inlet on vehicles from Japanese manufacturers, and the CCS on vehicles from European manufacturers. One European manufacturer has its own system of fast charging using 43 kW AC power. While it is positive for buyers that charging power increases, it does make the selection of vehicles, vehicle options and charging solution at home, more complex. Charging infrastructure providers face challenges in providing solutions for all these different specifications. Multi standard fast chargers are for instance more expensive and complex.

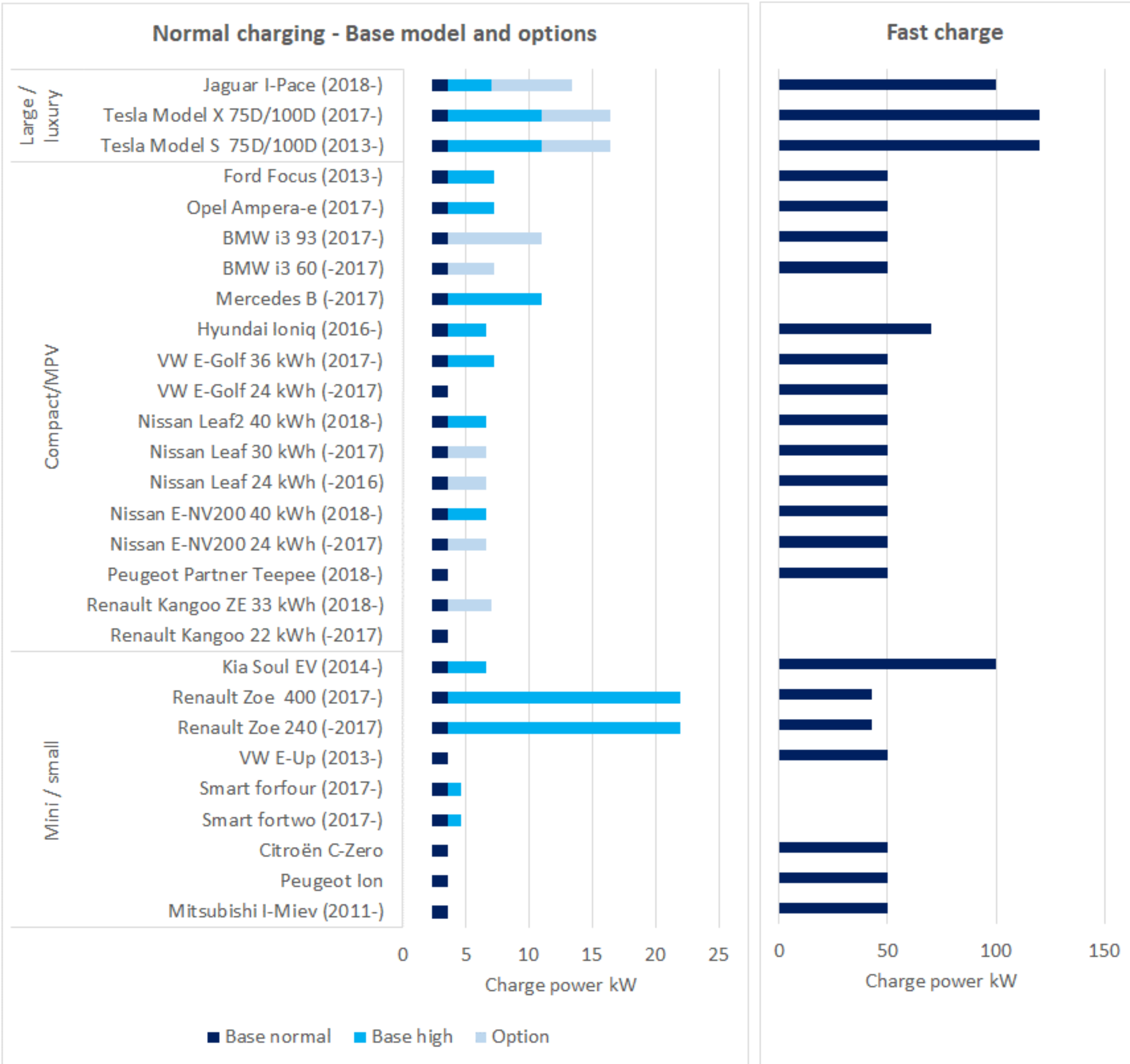


Figure 2.5: Normal charging power, fast charge capability and charging options for BEVs. Norway 2016-18. Sources: Manufacturers Norwegian web sites.

2.2 Other technical developments

Towing of trailers and caravans is an important feature for Norwegians. It will be technically feasible also on BEVs in the future. Initial tests in the US revealed that fast charge stations layout may not allow charging vehicles with trailers or, as a driver using the Tesla Mode S to tow a trailer and charging at Superchargers found out, the trailer needs to be unhooked to get the vehicle close enough to the charger (Edmunds.com 2016). This US based driver travelled 1614 km towing a trailer weighing 572 kg with an average energy consumption of 380 Wh/km. A Norwegian driver found a similar increase for the Model S, as seen in figure 2.6. These tests are not scientific or repeatable, but provides an indication that towing trailers over long distances will be a challenge. The increased aerodynamic drag is the biggest issue. Towing trailer locally and regionally will become feasible, with tow hooks available on SUV such as the Tesla Model X, and will cover the need to transport goods between shops and home and waste to dumpsites, or a boat from the garden to a nearby boat harbor. The users will find it challenging to get access to fast chargers in addition to the short range. Towing caravans on vacation or materials to mountain huts over long distances therefore seems challenging and will require that fast charge stations are designed to allow vehicles with trailers to charge.

Changes in user practices could reduce the challenge. For instance, people can hire professional transporters for long distance transports of goods or other articles, rent or borrow vehicles fulfilling these needs, or use home waste collection and delivery services.

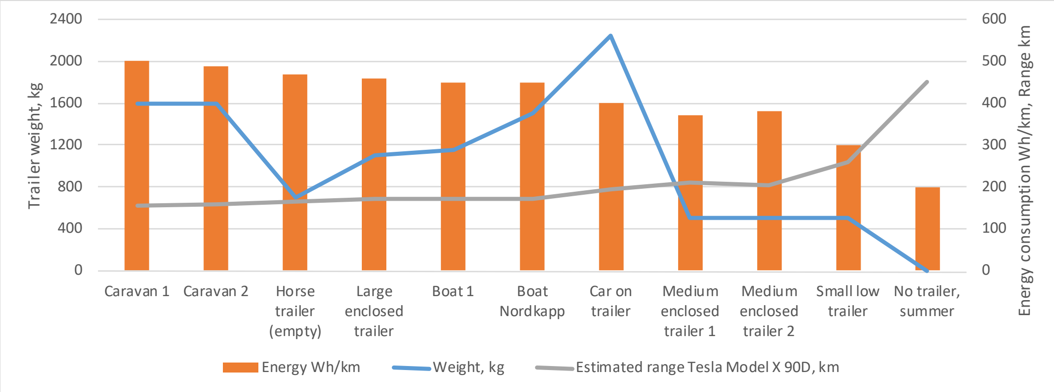


Figure 2.6: Energy consumption Tesla Model x when towing. Source: Insideevs.com (03-2017).

2.3 Future BEV technology and vehicles

BEVs will evolve from mainly being a short distance smaller vehicle replacing one of the vehicles in multi-vehicle household, into a more general purpose vehicle available in most vehicle segments over the next five years.

Battery technology will evolve rapidly

Battery prices is expected to decrease further, allowing long range batteries to be installed with moderate or no price increase. UBS (2017) tore apart a Chevrolet Bolt and estimated the cost of the 60 kWh pack to be about 200 USD/kWh (145 USD/kWh for the cells). The vehicle is designed for an annual production of 30 000 vehicles. IEA expects that increasing battery pack production volumes from 25 000 per year to 100 000 per year, reduce battery pack costs per kWh by 17% (IEA 2017). Such volumes will be achieved by Tesla for Model 3, and Nissan for the 2018 revised Leaf model (Nissan 2017). In 2018 battery pack cost could thus be as low as 170 USD/kWh. Increasing the pack size from 60 to 100 kWh might reduce battery pack cost per kWh a further 13% (IEA 2017). The marginal cost of going from a 60 kWh pack to a 100 kWh pack in a volume of 100 000/year would then be as low as 115 USD per extra kWh[4].

High volume BEVs will therefore likely have large batteries and it seems reasonable that 2018-2020 battery pack cost could be 150-200 USD/kWh at the pack level, for high volume vehicles with ranges above 400 km. A 40 kWh battery pack could therefore cost about 6 000-8 000 USD to put into the hands of a customer, without taxes and warranty costs. The rest of the vehicle will likely cost less than a diesel vehicle when both are produced in high volumes, due to the avoidance of emission control systems, and a simpler design of the motor. The net additional vehicle cost is thus likely to be about the same as the battery pack cost, potentially less.

[4] (100•170•0,87- 60•170)/40=115 USD/kWh

Additional improvements in the battery cells and pack layout will result in further reductions. IEA (2017) thus estimate battery pack cost to drop to 100 USD/kWh by 2030 for an average BEV having a 350 km range.

Characteristics of future models

BEVs has become a mature technology in the sense that it has migrated from technology development departments to the regular product development teams of the major car manufacturers. BEVs are now designed for high volume production. This move results in new groups of engineers, designers and marketing managers becoming involved in BEV designs. A more customer demand oriented engineering process will lead to new more exiting products. Designers are for instance no longer limited by the space available to shoehorn in a battery into an existing vehicle. These new vehicles will also be able to take advantage of the added vehicles space available in vehicles without an Internal Combustion Engine (ICE). The batteries are placed under the floor between the axles, not limiting the volume inside the vehicle, and the motor and associated electronics is more compact than ICEs. In high volumes, this design approach will enable more range for the same cost, also leading to longer range vehicles, and enable different range options. The vehicle manufacturer will however face higher risks in case of market failure.

Although the technology allow longer range, up to 600-700 km for premium vehicles, will vehicle manufacturers still optimize range to minimize cost. VW for instance plans for a range of 400-600 km (Senger 2017) for mass marketed BEVs, while targeting a sales price matching that of a diesel vehicle. Real world ranges of 230-400 km in the winter (-7°C) and 320-480 km in the summer is expected (Ibid). Small and mini vehicles, do not need that long range. The travel demand of their owners can be met with shorter range, so they will likely continue to have limited range.

On board chargers are likely to increase in power. 7.2 kW could become the new standard for normal chargers, with optional chargers that can handle up to 22 kW. This development will be an advantage as 7.2 kW could be available in private houses, and 22 kW in larger buildings, or can be established at low cost. Some compact and medium sized BEVs introduced in 2018-2019 will be able to fast charge at 100-150 kW. Large and luxury vehicles introduced after 2019 could be capable of up to 350 kW fast charging.

More models will come with traditional optional equipment, such as tow hooks, further increasing the versatility of BEVs. New and unique features such as Augmented Reality Head Up Displays is possible to introduce in BEVs because more volume is available in the cabin (Senger 2017). BEVs will be offered in variants with different equipment levels.

BEVs can, based on the discussion above, be divided into the technology generations seen in table 2.1. Some of these technology generations may co-exist in the future. Smaller vehicles intended for local use and for fleets, may not need long range that larger vehicles need. There will be an interaction between the development of the charging infrastructure, as discussed in chapter six, and the development of new vehicle generations.

Table 2.1: Main characteristics of BEV generations. Authors assessment.

	Year	Nominal range	Typical real world range in Norway	Battery size	Max fast charge power	Typical fast charge speed km/min Win-Sum	Sizes and segments
		km	km	kWh	kW	Km/min	
Pre Li-ion	- 2010	60-85	40-70	8-12	NA	NA	Micro, Mini
Gen 1	2010-18	150-230	70-140	16-24	50	3-6	Mini, Small, Compact
Gen 1 Tesla	2013-18	375-594	250-500	60-95	120	6-10	Large/Luxury
Gen 1+	2016-18	250-300	120-180	28-30	50	4-6	Mini, Small, Compact
Gen 2	2017-18	400-520	250-400	40-60	80	6-9	Mini, Small, Compact, Medium
Gen 3	2018-	400-600	300-500	50-90	150	10-18	Compact, Medium, Large, Luxury, SUV, MPV, Crossover, Sport
Gen 4	2020-	500-650	400-600	>90	350 kW	23-35	Large, Luxury, SUV, Sports

2.4 PHEVs a competing or a supplementary technology

BEVs is not the only technology that improves over time. Mercedes is developing plug in hybrid vehicles capable of 100 km range (Mercedes 2017a), while BMWs new vehicle platform can accept any powertrain, thus allowing also for larger PHEV batteries (BMW 2017a). The PHEV market has expanded rapidly since 2014 and seems to appeal to a different type of customers than BEVs (Figenbaum and Kolbenstvedt 2016), being much more popular with single vehicles households and older owners, than BEVs are. The most popular vehicles are the Mitsubishi Outlander SUV, the compact vehicles VW Golf GTE and Audi A3 E-Tron, as well as the VW Passat GTE. There is a direct competition between BEVs and PHEVs in the compact vehicle segment. A number of large plug-in hybrid SUVs entered the market in 2016-2017, competing with Tesla's Model S and X.

BEVs will be much cheaper to own and use than PHEVs, given the incentive structure. Those that choose a PHEV in Norway are therefore those that likely cannot use a BEV, due to size, short range and long charge time, or are uncertain about BEVs, or their preferred brand has no BEVs.

Toyota is still pursuing Fuel Cell Electric Vehicles (FCEVs), and plan for an FCEV produced in somewhat larger volumes by 2020. Toyota is however also industrializing BEVs and more PHEVs will come on the market in the first years after 2020 (Toyota 2017). Other manufacturers such as Mercedes also develop FCEVs.

2.5 Implications for future research

The accelerated development of new models and improved technology will quickly make research results out of date. The BEVs that come on the market the next five years reduce or remove many of the user barriers of the first generation BEVs. Range will increase to more than 300 km under winter conditions and up to 500 km in the summer for compact and larger BEVs. Even longer range is feasible according to BMW. The next generation Tesla Roadster will for instance get a range of 1000 km with a 200 kWh battery. Range is not as big a barrier for smaller and mini vehicles as these are used less for long distance driving. But also these vehicles will get longer range, such as the Renault Zoe did in 2017 when the range increased from 230 to 400 km. The range barrier is thus quickly built down, but there is no knowledge on what range consumers really need or want, and how the needed range is influenced by different levels of infrastructure. The long distance driving patterns of consumers need to be explored further to see how these needs will match with the characteristics of future model offerings, and the expanding charging infrastructure.

The charge time barrier will be reduced by a combination of more powerful on-board "slow chargers" (increased from 3.6 kW to 6-11 kW) for home charging, and ultra-fast charging up to 150-350 kW along national main roads.

The new purpose built BEVs will offer opportunities to introduce new features that cannot fit in an ICEV. VW for instance plans for a Head Up Display on their BEVs that essentially makes the windscreen a display, a technology they claim is to roomy to fit in ICEVs. Researchers could investigate the value to consumers of such features to see how this development might boost the BEV market.

The competition and market appeal differences between BEVs and PHEVs also warrants more research. What will be the situation if FCEVs are industrialized sometime around 2020? Which factors gives one technology an edge over the other? Will the technologies co-exist and appeal to different segments of consumers?

3 National characteristics, policies, targets and incentives

The development and the effectiveness of the Norwegian EV policy and incentives over the period from 1990-2015 has been analyzed in several research articles (Figenbaum 2017, Figenbaum et al 2015a and 2015b, Fridstrøm and Østli 2017, Bjerkan et al (2016) and reports (Figenbaum and Kolbenstvedt, 2015, 2016, and Figenbaum et al 2014). The conclusion has been that these incentives have been effective in promoting BEVs. This chapter will present the current status of targets, policies and incentives and some new insights into their effects.

3.1 Facts about Norway

Norway consisted of the 19 provinces (Svalbard is not a province), shown in figure 3.1 in 2017. From 2018, Sør and Nord-Trøndelag merged into Trøndelag. Some basic facts about the provinces are shown in table 3.1. There were 428 municipalities in Norway in 2017.

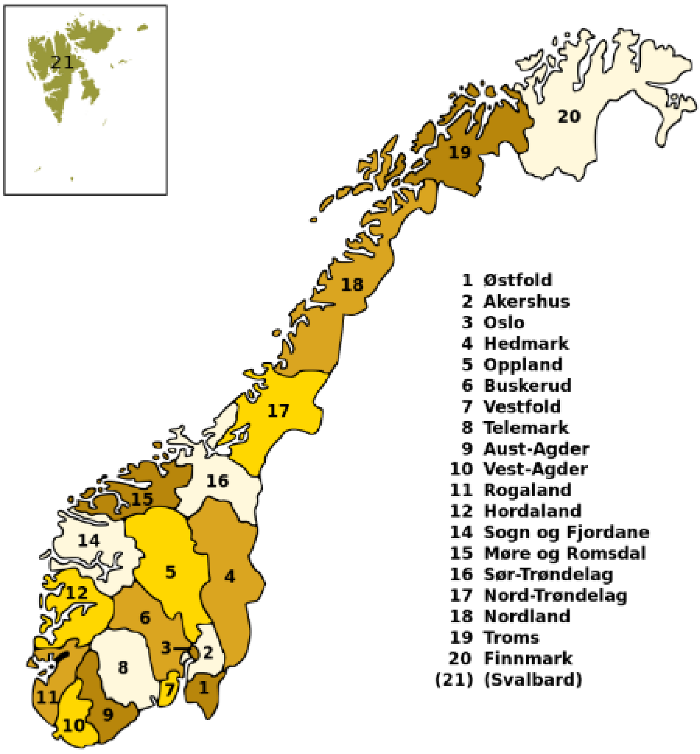


Figure 3.1: Norwegian provinces in 2017. The colors are intended to increase readability.

Table 3.1: Basic facts about Norwegian provinces, 2017. Source: Statistics Norway (www.ssb.no).

	Population	Vehicles	Households	Land area km^2	Municipalities	Vehicles per household	City areas >40000 inhabitants
01 Østfold	289867	149058	129094	3888	18	1.15	Fredrikstad/ Sarpsborg, Moss
02 Akershus	594533	331895	248153	4579	22	1.34	Oslo
03 Oslo	658390	288314	332568	426	1	0.87	Oslo
04 Hedmark	195356	116310	90513	26086	22	1.29	
05 Oppland	188953	110783	87184	23777	26	1.27	
06 Buskerud	277684	160746	122840	13778	21	1.31	Drammen
07 Vestfold	244967	128902	110212	2149	12	1.17	Tønsberg, Sandefjord
08 Telemark	172494	91302	79249	13832	18	1.15	Porsgrund/Skien
09 Aust-Agder	115785	60879	50924	8307	15	1.20	Arendal
10 Vest-Agder	182701	87200	80617	6679	15	1.08	Kristiansand
11 Rogaland	470175	228952	197654	8585	26	1.16	Stavanger/Sandnes, Haugesund
12 Hordaland	516497	235008	230616	14502	33	1.02	Bergen
14 Sogn og Fjordane	109530	56902	46289	17666	26	1.23	
15 Møre og Romsdal	265290	140859	115095	14569	36	1.22	Ålesund
16 Sør-Trøndelag	313370	150838	149931	17833	25	1.01	Trondheim
17 Nord-Trøndelag	136399	75857	58993	20781	23	1.29	
18 Nordland	241906	125162	109444	36087	44	1.14	Bodø
19 Troms	164330	83848	75688	24869	24	1.11	
20 Finnmark	75758	37898	33733	45755	19	1.12	
Total	5213985	2660713	2348797	304148	426	1.13	

The climate varies substantially across the north south axis and between inland and coastal zones as seen on the map of average winter and summer temperatures in figure 3.2.

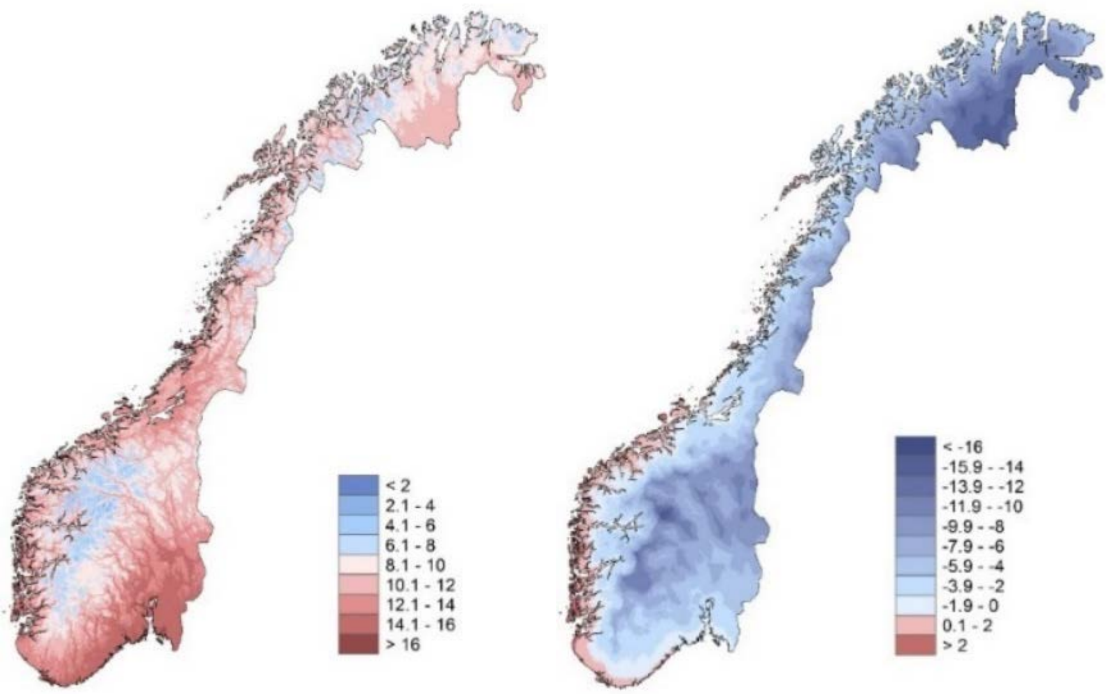


Figure 3.2: Average temperature summer and winter in Norway.

Speed limits in Norway are BEV friendly. The regular main road speed is 80 km/h. Motorways have speed limits of 100-110 km/h. Norway extends 2000 km north-south. Electricity is among Europe's cheapest, and fossil fuels among the most expensive. The energy cost saving of running a vehicle on electricity instead of fossil fuel is the largest in Europe, twice that of Germany (Figenbaum and Kolbenstvedt 2015), as seen in figure 3.3.

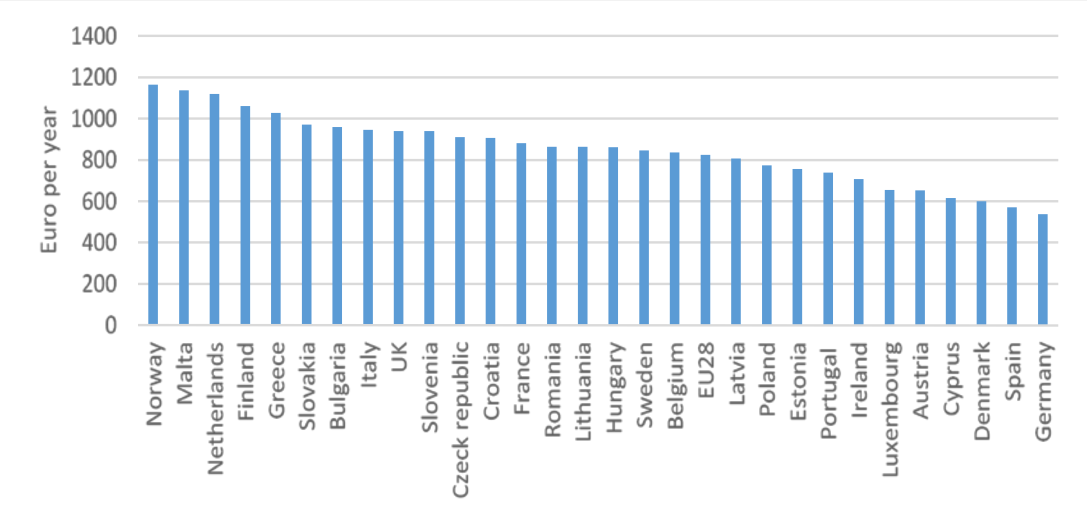


Figure 3.3: Annual energy cost savings of driving a BEV compared to a gasoline vehicle 15 000 km per year.

3.2 National climate policy and BEV targets

Figenbaum (2017) found that the BEV policy has developed over time. In the period 1990-1998 the focus was on allowing testing of BEVs, through the removal of tax barriers to adoption, targeting improved air quality in cities. From 1999-2002 the focus was on creating a BEV industry as Ford Motor Company owned the Norwegian BEV producer Think, and set up a factory for production in Norway. These efforts had largely failed by 2003 when Ford sold Think, which later went bankrupt. Also international BEV development collapsed around this time.

In the period from 2003-2007 the BEV incentives nevertheless remained in place, as they did not cost the government anything. Niche market developments could thus continue through import of second hand vehicles that was used in bus lanes now opened for BEVs. Since 2008 BEVs is seen as a means to reduce transport greenhouse gas emissions, with a renewed industrialization focus when Norwegian investors re-established Think (although later bankrupt). BEV policy and incentives have since been part of the climate policy.

The overall target for the transportation sector is to reduce the CO_2-emissions, so that the Norwegian obligations of the Paris agreement on climate gas emission reductions for 2030 can be met. A target of reducing the CO_2-emission of new vehicles to less than 85 g/km by 2020 was reached in 2017. A new target is that all new passenger vehicles sold shall be zero-emission from 2025, i.e. electric or fuel cell hydrogen powered (NTP 2017a, 2017b). The sales of ICEVs cannot be banned due to the EEA agreement with the EU. The target must therefore be met by a combination of incentives for BEVs and disincentives for ICEVs. The government has stated that it shall always be more economical to choose zero-emission vehicles over fossil fueled ones. PHEVs also have tax reductions that from mid-2018 will be differentiated according to the range in E-mode (Lovdata 2018). A further climate policy target is that the growth in passenger transport in cities shall be covered by public transport, walking or cycling (NTP 2017a, 2017b). Therefore, increased BEV ownership should lead to a decrease in ICEV ownership.

3.3 Incentives

Table 3.2 provides an overview of the current status of BEV incentives in Norway.

Table 3.2: Relative advantages of different BEV incentives in Norway in 2017 and future plans.

Incentives	Introduction year	BEV buyers - relative advantage	Future plans (NTP 2017a, 2017b, Stortinget 2017, Lovdata 2018)
Fiscal incentives: Reduction of purchase price/yearly cost gives competitive prices			
Exemption from registration tax	1990/1996	The tax is based on ICEV emissions and weight. Example taxes: VW Up 3000 €. VW Golf: 6000-9000 €,	To be continued until 2020.
VAT exemption	2001	Vehicles competing with BEVs are levied a VAT of 25% on sales price minus registration tax.	To be continued until 2020.
Reduced annual vehicle license fee	1996/2004	BEVs and hydrogen vehicles 52 € (2014-figures). Diesel rate: 360-420 € with/without particulate filter.	To be continued indefinitely
Reduced company car tax	2000	The company-car tax is lower but BEVs are seldom company cars.	This incentive may be revised in 2018
Exemption from the re-registration tax	2018	A tax is levied on the change of ownership of ICEVs and PHEVs. 0-3 year old vehicles above 1200 kg: 610 Euros, 4-11 years 370 Euros. Older: 160 Euros. BEVs have an exemption.	Will be introduced from 2018
Direct subsidies to users: Reduction of variable costs and help solving range challenges			
Free toll roads	1997	In Oslo-area saved costs are 600-1 000 € per year. Some places exceed 2 500 €	Law revised so that rates for battery electric vehicles in toll roads and ferries will be decided by local governments, up to a maximum rate of 50% of the ICEV rate.
Reduced fares on ferries	2009	Similar to toll roads saving money for those using car ferries.	
Financial support for normal charging stations	2009	Reduce investors risk, reduce users range anxiety, expand usage.	A national plan for charging infrastructure shall be developed.
Financial support for fast charge stations	2011	More fast-charging stations influences BEV km driven & market shares.	ENOVA support programme to establish fast charging along major transport corridors. City fast charging is left to commercial actors.
User privileges: Reduction of time costs and providing users with relative advantages			
Access to bus lanes	2003/2005	BEV users save time driving to work in the bus lane during rush hours.	Local authorities have given the authority to introduce restrictions if BEVs delay buses.
Free parking	1999	Users get a parking space where these are scarce or expensive and save time looking for a space.	Local authorities will be given the authority to introduce rates up to 50% of the ICEV rate.
Free charging (some places)		Not regulated by national law, but often bundled with free municipal parking	Local authorities and parking operators decides whether this incentive will continue.

The most important incentives are the exemptions from VAT and toll roads. The exemption from registration tax was important in earlier years, but now the impact is small. Most BEVs would not be taxed anyhow. Further incentives are the low annual tax, free parking, access to bus lanes, reduced ferry rates on national roads, and a lower benefit of the perceived value of company cars. There was a decision in 2015 to introduce half annual tax from 2018 and full from 2020, which was reversed by the Parliament in 2016 deciding to introduce a full exemption from annual tax for BEVs, which was reversed again in 2017 (Stortinget 2018). The Parliament also stated in 2016 and 2017 (Stortinget 2017) that the zero rates for VAT and registration tax (Lovdata 2018) for BEVs will be kept until 2020, which was approved by ESA in December 2017 (ESA 2017), as not infringing the EEA agreement with the European Union. The parliament approved an exemption from the re-registration tax for BEVs from 2018 (Lovdata 2018). It was also decided that BEV owners will pay a maximum of 50% of the rates of conventional vehicles on toll roads, ferries and municipal parking spaces in the future (Stortinget 2017).

The national policy is to continue to allow BEVs in the bus lane, but local authorities have been given the authority to remove the incentive if buses are delayed. When that happens access could still be granted on the condition that there are at least two persons in the vehicle. The parking regulation was revised from 01.01.2017 (Lovdata 2017). In the old regulation it was specified that all BEVs are to be exempted from parking charges on municipal roads. The new regulation opens up for the possibility that the municipality can offer free parking. The new regulation also contains a requirement that sufficient charging facilities shall be offered for electric vehicles (BEVs and PHEVs), regardless if the owner of the parking area is a municipality or a private parking operator. The maximum requirement that owner must fulfill according to the regulation, is limited to 6% of the total number of parking spaces in each area (Ibid). The parking law will be revised to reflect that the maximum rate for BEVs shall be 50% of the rates for ICEVs.

3.4 Value of economic incentives

An example of the value of the purchase incentives is shown in figure 3.4 for the VW E-Golf compared with a similar ICE version of the vehicle with an ASG automatic gear box, and the PHEV version (GTE).

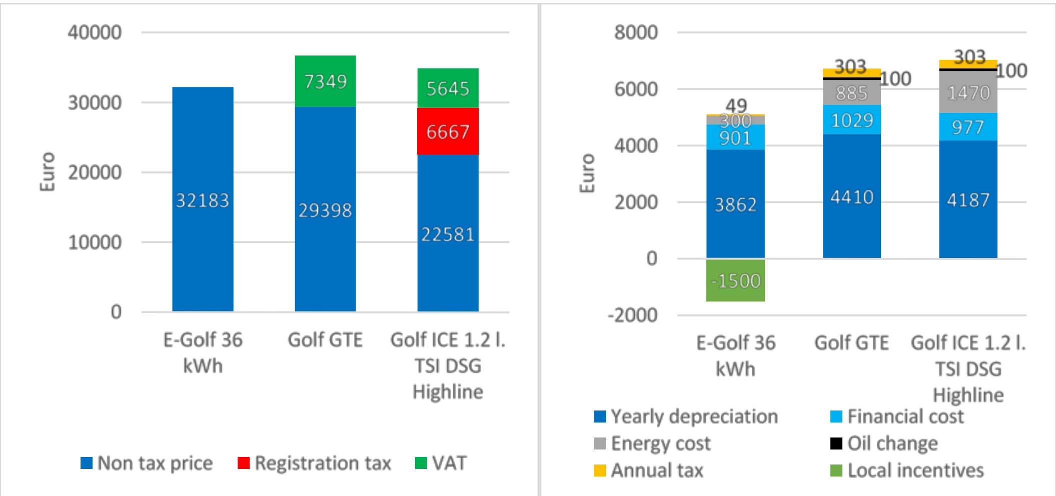


Figure 3.4: Price and elements of annual cost of ownership of BEVs in the compact vehicle segment compared with an ICEV and a PHEV in 2016. Annual cost includes depreciation (40% residual value after five years for all vehicle types), finance of loan, energy, oil change and annual tax. Insurance, tire wear and service and other maintenance cost assumed to be the same for all vehicles[5]. Euros.

[5] Service and maintenance cost are not transparent to buyers of vehicles. Some BEVs have had high service cost in Norway, although the expectation is that it will be lower due to fewer moving parts.

The BEV variant is the cheapest. The same situation is found in most vehicle classes, with the exemption of the smallest vehicles where one still can find a cheaper gasoline vehicle. The reason is that the registration tax for small gasoline vehicles is very low. BEVs are even more competitive (and also competitive in small vehicles) when the differences in variable cost of ownership is factored in, i.e. depreciation, financial cost, annual tax, oil change and energy costs, as seen in figure 3.4. The depreciation has proven to be comparable to other vehicle types for BEVs launched after 2013, but it was higher than average for pre 2014 models, mainly due to the introduction of new technology and falling new vehicle prices (Figenbaum and Kolbenstvedt 2015 and 2016, Dine Penger 2016). The residual value is held up by the fact that the local incentives follows the vehicle, not the owner. The service costs are also expected to be lower for BEVs but are not fully transparent to vehicle buyers, and difficult to take into account in the buying decision. Other costs, such as tire wear, should be more or less equal. Insurance cost may be lower for BEVs, but should become more equal over time.

On top of the reduced cost of ownership, BEV owners also have local incentives having an average user value of 1500 Euros per year (Figenbaum and Kolbenstvedt 2016), as explained in section 3.5. In a comparison of cost of ownership these 1500 Euros should be deducted from the BEV cost, providing BEVs with a 3500 Euro annual cost advantage over ICEVs, explaining the booming BEV market. But one should remember that BEV owners also have disadvantages when it comes to range, infrastructure and charge times.

3.5 Value of and usage of local incentives

The average user stated in a 2016 survey that the local incentives had a value of 1500 Euros/year/vehicle (recalculated from Figenbaum and Kolbenstvedt 2016). Toll roads accounted for about 50%, time savings in the bus lane for about 30%, free parking for about 16% and ferry rates for about 4%. The variation among individual users is large as seen in figure 3.5. About 10% of users have no benefits of these incentives, 10% gets benefits in excess of 4000 Euro/year. The median value is about 1100 Euros.

The geographical variation in the value of local incentives is also large as seen in figures 3.6-3.8. The highest values are found in large provinces having large cities and high BEV shares, such as Oslo, Akershus, Sør-Trøndelag and Hordaland (see figure 3.1 and table 3.1 for basic information about the provinces). Owners in Buskerud province also have a high total value of local incentives, although the share of BEVs in the fleet is below average as seen in figure 4.7 (chapter 4). The reason seems to be users that have a very high time saving of driving in bus lanes, as indicated in figure 3.8.

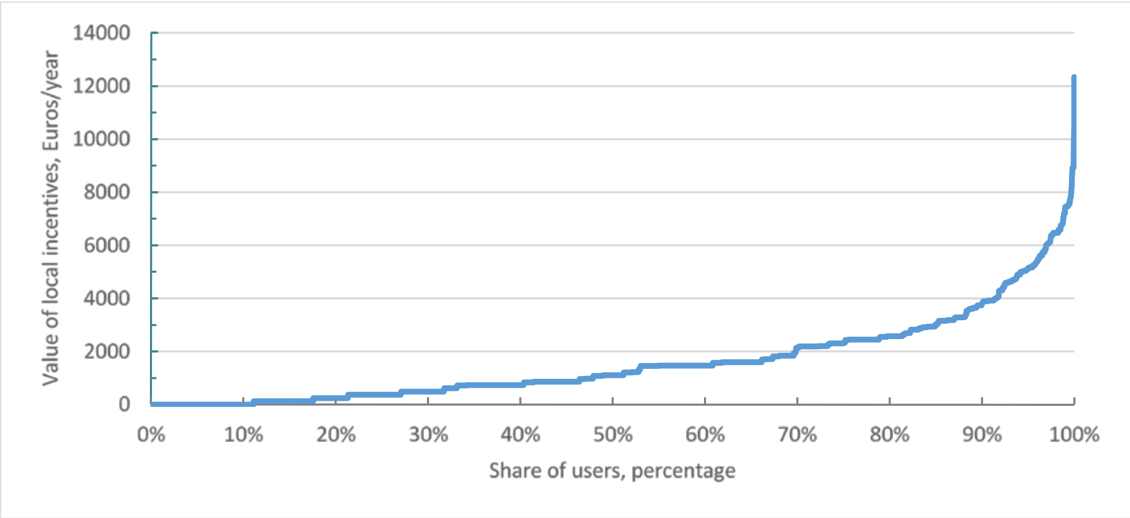


Figure 3.5: User estimate of total value of local incentives. N=3111. Source: Adapted from Figenbaum and Kolbenstvedt (2016).

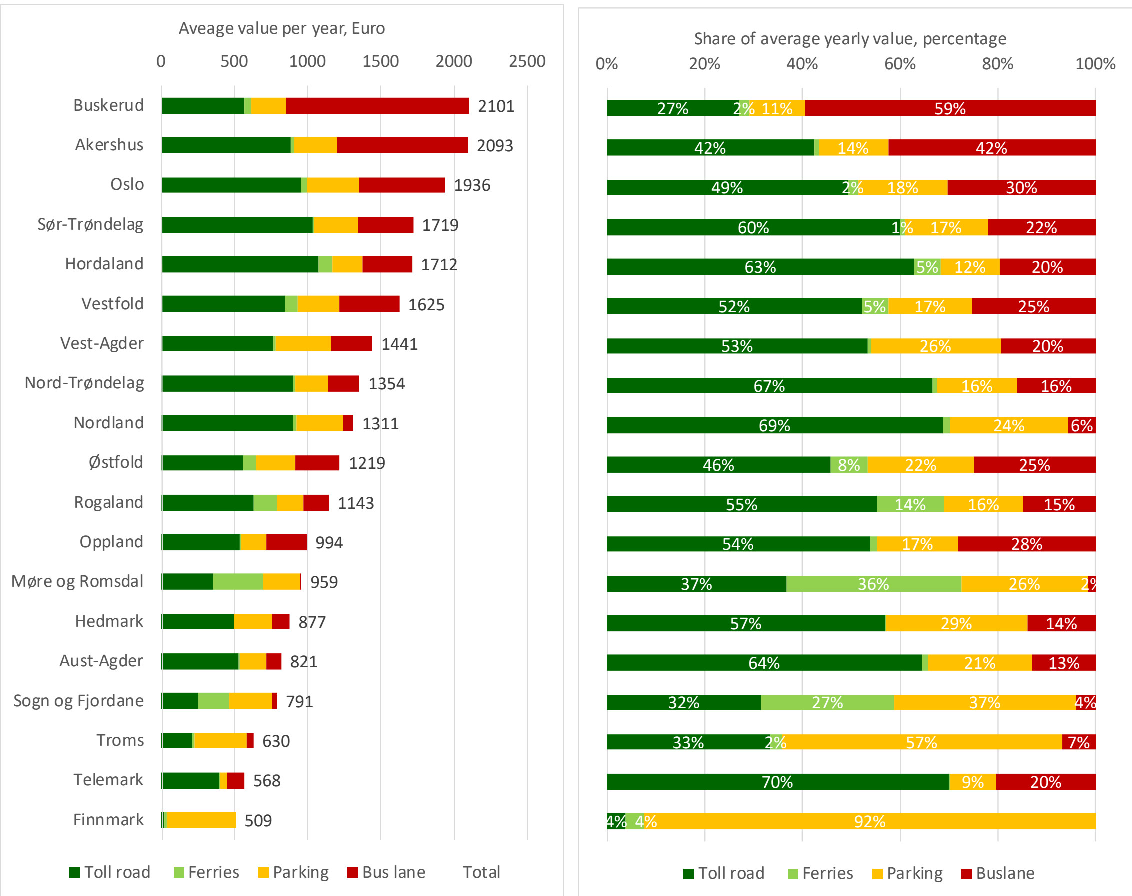


Figure 3.6: Geographical distribution of value of local incentives. Average per year in Euro and the share of this value for toll roads, ferries, free parking and admission to bus lanes. Norway 2016. Adapted from Figenbaum and Kolbenstedt 2016. Number of respondents: Akershus 601, Oslo 434, Buskerud 173, Sør-Trøndelag 201, Hordaland 459, Vestfold 165, Vest-Agder 104, Nord-Trøndelag 49, Nordland 78, Østfold 155, Rogaland 274, Oppland 46, Aust-Agder 74, Hedmark 64, Møre og Romsdal 96, Finnmark 6, Sogn og Fjordane 22, Troms 33 and Telemark 68.

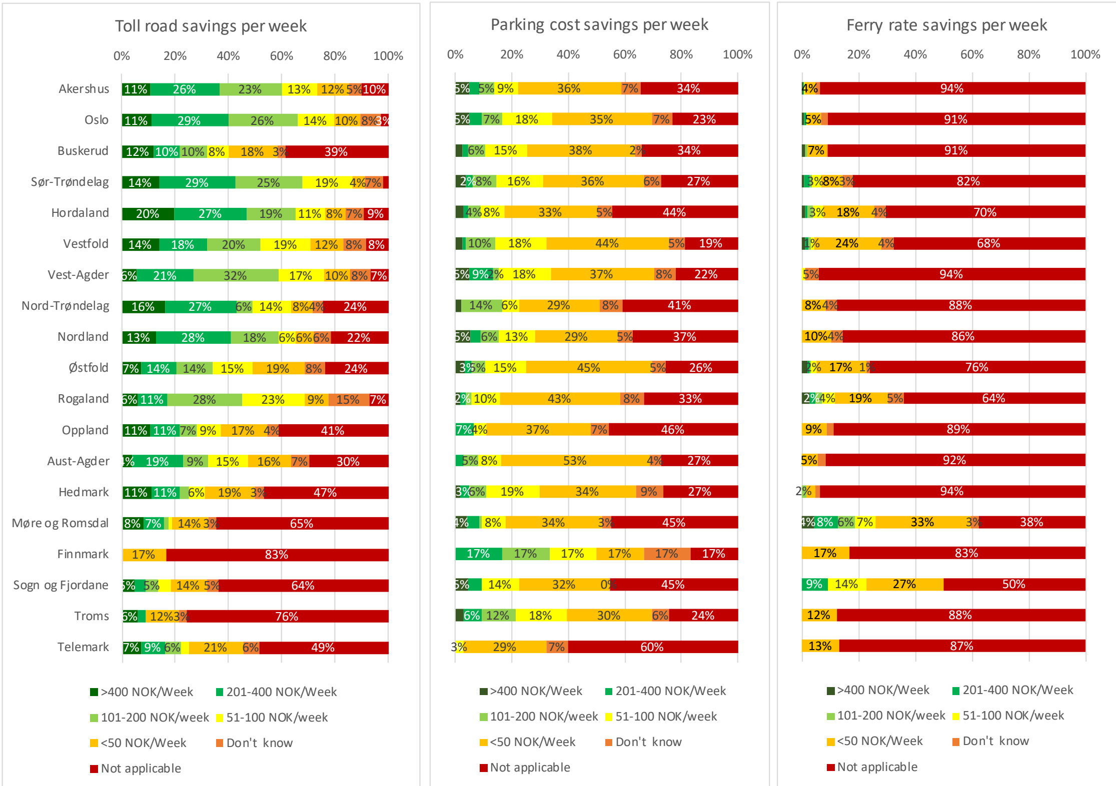


Figure 3.7: User's estimated savings/value of local incentives. Adapted from Figenbaum and Kolbenstedt 2016. Number of respondents: Akershus 601, Oslo 434, Buskerud 173, Sør-Trøndelag 201, Hordaland 459, Vestfold 165, Vest-Agder 104, Nord-Trøndelag 49, Nordland 78, Østfold 155, Rogaland 274, Oppland 46, Aust-Agder 74, Hedmark 64, Møre og Romsdal 96, Finnmark 6, Sogn og Fjordane 22, Troms 33 and Telemark 68.

The bus lane access is also important in Akershus, less pronounced as an average value, but in Asker the value is very high. In most provinces free use of toll roads is the most important incentive, being an advantage for a much larger share of users than the bus lane access. As expected the savings on ferries is mainly important on the west coast of Norway where most of the ferries are. i.e. Rogaland, Sogn og Fjordane and Møre og Romsdal. In the most northern provinces, free parking is the main incentive.

Figure 3.8 shows the share of drivers that use their vehicle to commute to work that can use bus lanes or pass toll roads when commuting. The spread of estimated time saving in the bus lane is also shown. Toll roads is the most important incentive for commuting trips. Bus lane time saving is high only in a few provinces, and especially in some municipalities.

Figure 3.8: Geographical distribution of toll road usage, and availability of bus lanes on trips to work (by the main user), and time savings of using bus lanes on these trips. Adapted from Figenbaum and Kolbenstedt 2016. Number of respondents: Akershus 601, Oslo 434, Buskerud 173, Sør-Trøndelag 201, Hordaland 459, Vestfold 165, Vest-Agder 104, Nord-Trøndelag 49, Nordland 78, Østfold 155, Rogaland 274, Oppland 46, Aust-Agder 74, Hedmark 64, Møre og Romsdal 96, Finnmark 6, Sogn og Fjordane 22, Troms 33 and Telemark 68.

Data on percentages of BEVs passing toll gates can provide further insights, into booth the travel pattern of BEV owners and the effectiveness of the toll road incentive. Figure 3.9 shows the overall BEV shares in 2016 for all national toll road projects. The average BEV share in all toll road was 5.6% in 2016. Hordaland has a particularly high pressure of toll roads, with two thirds of the value of local incentives from savings on toll roads (figure 3.6). The share of BEVs in the Hordaland fleet is the highest in Norway, as seen in figure 4.7 (chapter 4). The greater Oslo and Trondheim areas also have a very high toll road pressure (shaded areas in figure 3.9). Free parking and reduced ferry rates are important in provinces where toll roads are not, as seen for Møre og Romsdal, Sogn og Fjordane and Finnmark (few respondents). Main roads (blue color in figure 3.9) that are far from cities have low BEV shares (rural parts of Akershus and Oppland provinces), indicating that few BEVs go on long distance trips. Main roads that have local traffic between smaller cities have larger shares, such as in the Vestfold province. The largest BEV shares are found for the most expensive underwater tunnels where local users do not have alternatives, such as Finnøy, Halsnøy and Averøy. Finnøy is a separate municipality on an island that is connected to the mainland with a very expensive underwater toll road tunnel that commuters use to get to Stavanger. The BEV share in the fleet of Finnøy is the highest in Norway at 18.6%, but the toll road share was above 30% in 2017.

Some of the city packages (green) influence market shares in surrounding municipalities due to commuting. The share of BEVs is largest in the largest cities (Bergen, Oslo). Other areas with high BEV shares are found where tolls have been collected long (Askøy), or where they are particularly expensive (Bømlo). In the larger cities other incentives such as free parking and time savings in bus lanes also play a role. Most city package areas have higher shares of vehicles passing through the toll gates than it the fleets, as BEVs are used more in everyday traffic and for commuting to cities from surroundings, than other vehicles, and the first users are likely to be the ones that can get the largest incentives.

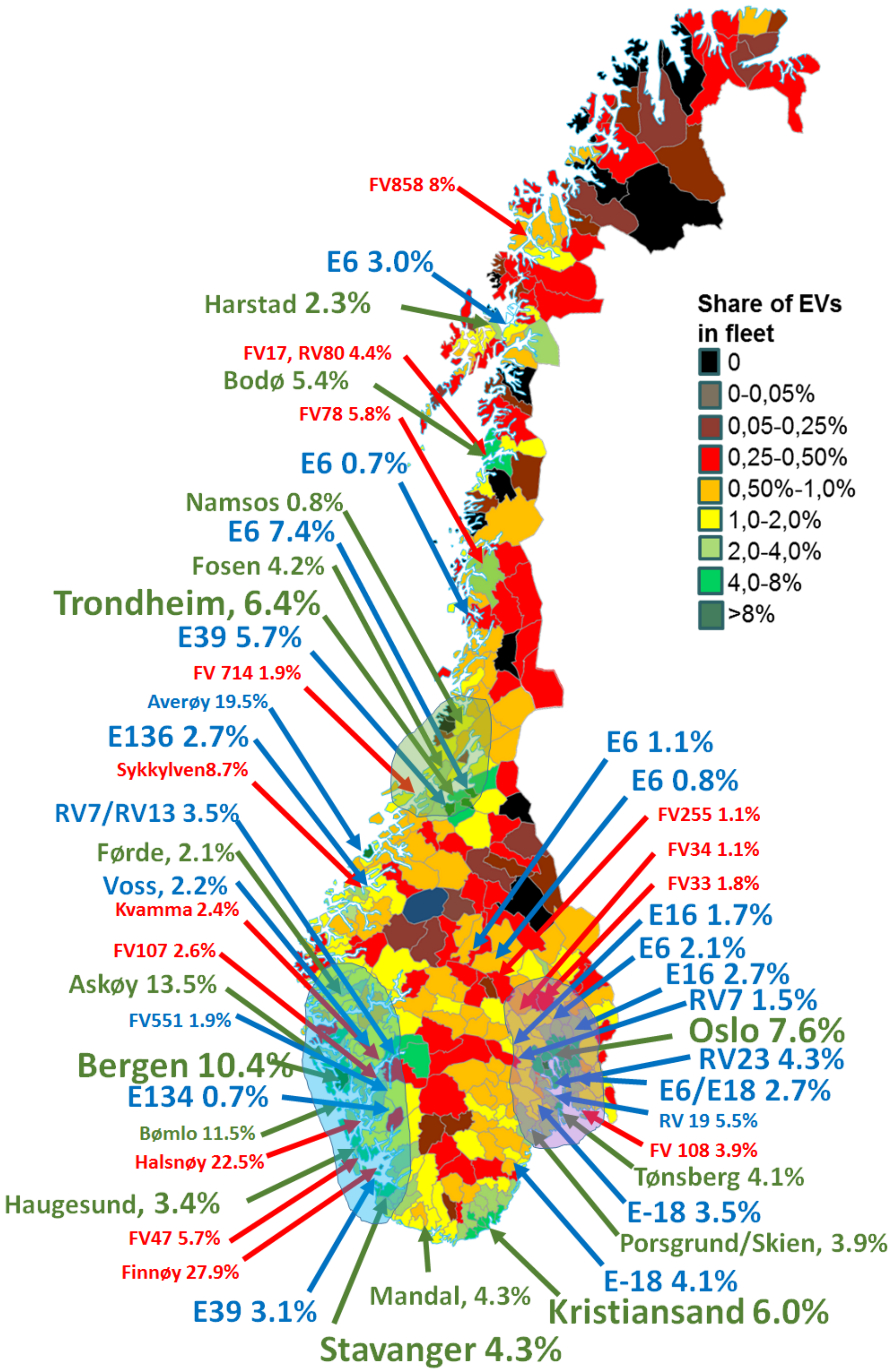


Figure 3.9: BEV shares in all toll road projects in 2016. City toll rings and larger area packages (green), main roads, i.e. E-roads, regional roads (blue) and smaller projects mainly influencing local traffic (red).

Local incentives are no longer anchored in national laws stating that BEV owners shall have certain rights, but transformed into a legal framework that allow local governments to introduce incentives. The result is a more chaotic situation with incentives differing between municipalities and within them, as seen in table 3.3. Free parking has no effect in small municipalities as everyone can park for free there.

Table 3.3: An overview of parking charges on public parking spaces by province and municipality (or city). Green: Free parking everywhere, Red: None of the municipalities has decided to keep free parking. Yellow: Some with, some without payment. Source: EV Association 2018a.

Province	Free parking	Partial payment	Same payment as for ICEVs
Oslo	Oslo city		
Oppland	Lillehammer, Gjøvik,		
Vest-Agder	Kristiansand, Mandal, Flekkefjord		
Akershus	Bærum, Asker		Frogn, Skedsmo, Ski
Buskerud	Ringerike, Skien, Drammen		Kongsberg
Vestfold	Horten, Larvik, Sandefjord		Tønsberg, Holmestrand
Østfold	Moss	Fredrikstad, Halden, Sarpsborg	
Hedmark	Hamar, Ringsaker, Elverum		Kongsvinger, Røros
Aust-Agder	Grimstad, Lillesand	Arendal	Tvedestrand, Risør
Rogaland	Sandnes,	Stavanger, Haugesund	Egersund, Time (Bryne)
Hordaland	Bergen		Voss
Nordland	Fauske, Mo i Rana	Bodø	Narvik
Telemark	Skien	Porsgrunn	Kragerø
Finnmark	Alta	Hammerfest	
Troms			Harstad, Tromsø
Møre og Romsdal		Kristiansund	Molde, Ålesund
Nord Trøndelag			Levanger, Namsos
Sør Trøndelag			Trondheim
Sogn og Fjordane	Florø	Sogndal	

The responsibility for some of the main road ferries were transferred from the Norwegian Public Roads Administration to the provinces when the road ownership reform was carried out in 2010. This change opened up for charging full ferry prices on some of these ferry services, as the reduced rate for BEVs only applies to the nationally controlled ferries.

3.6 Implications for future research

So far the purchase incentives remain in place and the effect of changing these cannot be studied in the field. Market models must thus be utilized to study the effects of potential revisions to these incentives. Regional analysis will be more important in the assessment of the future potential of Electromobility in Norway than it was previously, now that local authorities can revise or remove local incentives. It will be possible to study how these changes impact BEV sales.

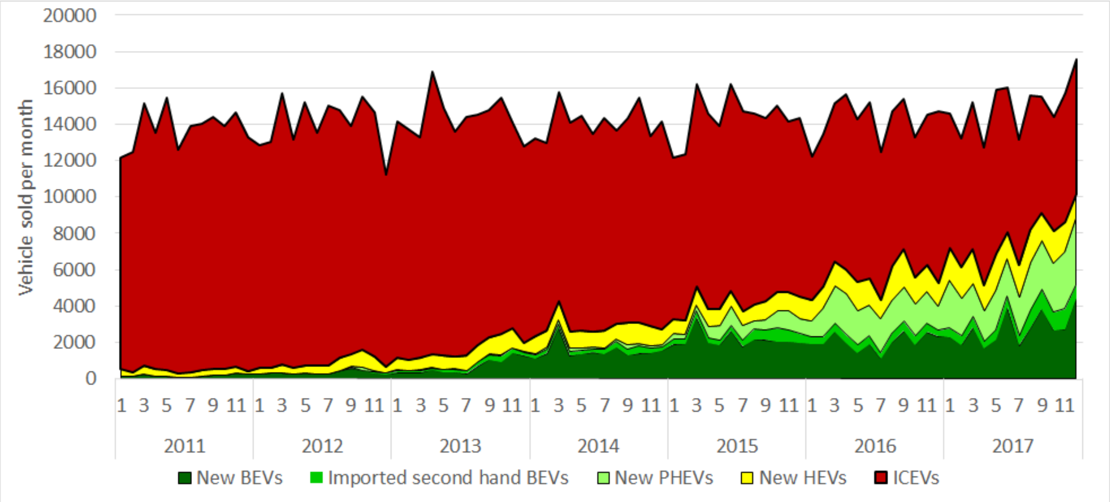
In some cities the cost of toll roads has increased substantially leading to a potential boost in the BEV sales the coming years. These cities should thus be studied specifically to investigate the effects. Oslo is one of these cities. Toll road data and user surveys reveal that BEVs are rarely used on long distance trips. When more long range models enter the market one would expect that situation to change. Toll road data therefore provide an indication of the normalization of BEVs as a general purpose vehicle and should be exploited. When range improves and charge times goes down, the barriers to BEV adoption will be reduced. The analysis in this chapter demonstrate that BEVs are economically competitive even without local incentives. At the same time the uncertainty about BEV technology and life of batteries is going down when more people use BEVs. The result should be a market expansion also among drivers that do not benefit from local incentives. Therefore, research should be directed at studying the future effectiveness of and need for local incentives in expanding the BEV market to new user groups.

4 Vehicle sales and fleet statistics

This chapter goes through the present passenger vehicle market situation in Norway and presents national statistics on BEV sales, ownership and fleet shares.

4.1 BEV sales passed 20% of total market in 2017

The total sales of passenger vehicles in Norway has been fairly constant since 2011, when summing up all first time registrations, i.e. new and second hand imports. The market share of electrified vehicles has gone from a few percent in 2011 to 50% in the period 01/2017-09/2017, of which BEVs makes up 20%, PHEVs 17% and HEVs 13%. The monthly BEV market share from 2014-2017 seems to be rather stable, as seen in figure 4.1. In periods buyers have waited for new and longer range BEVs, explaining some of the fluctuations.



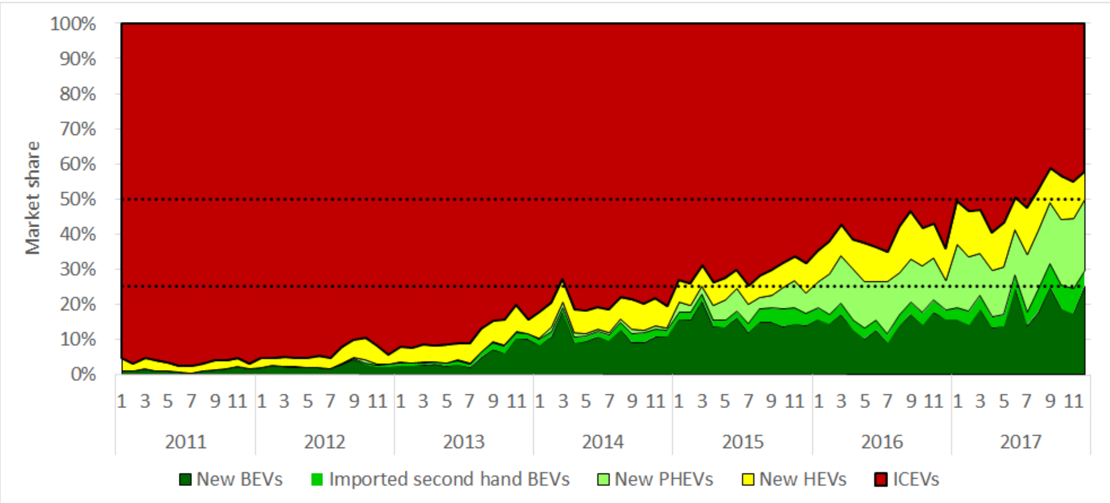


Figure 4.1: Total sales (including first registrations of second hand imported vehicles) and market shares of BEVs, PHEVs, HEVs and ICEVs (includes non BEV second hand vehicles). Source: OFVAS 2017.

The increased market shares of BEVs, PHEVs and HEVs rapidly reduce the average "official" CO_2-emission of new vehicles as seen in figure 4.2. A 2020 government target of reducing average new vehicle emissions to less than 85 g CO_2/km was met already in 2017.

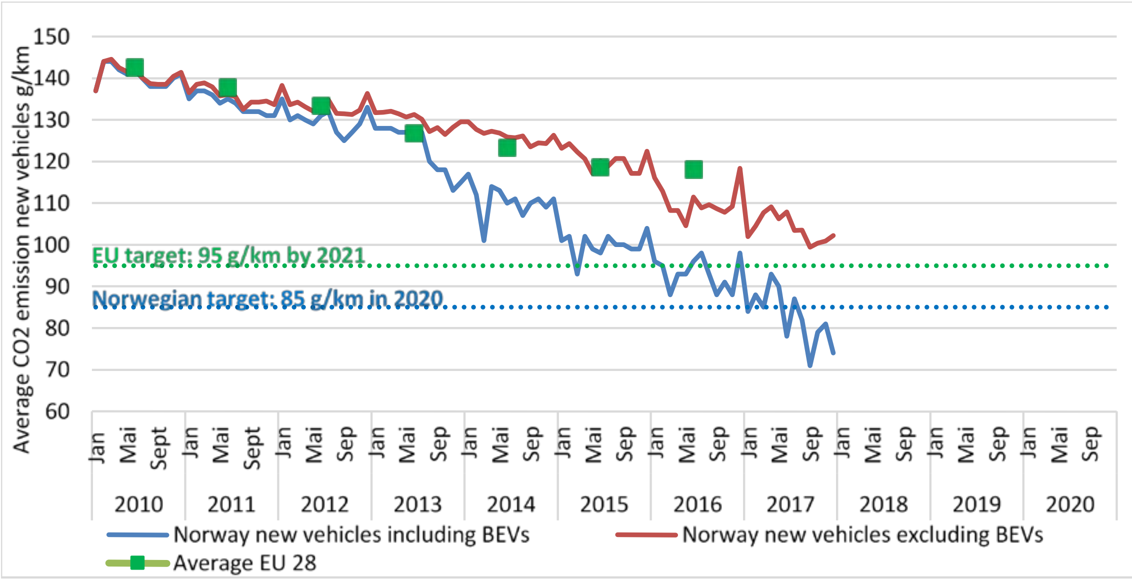


Figure 4.2: The progress towards the average Norwegian CO2-emission target of 85 g/km for new vehicles in 2020. Period: 01/2010-09/2017. Data source Norway: OFVAS 2017. The EU target of 95g/km by 2021 is also shown.

2018 should however be a period in which market shares reach new heights. New models are coming on the market with longer range and the waiting lists are long. The current trend points towards a potential for electrification (BEVs and PHEVs) of all vehicles from around 2022, as seen in figure 4.3, even earlier if HEVs are taken into consideration. When just evaluating the potential to only sell BEVs, the challenge becomes larger. A big expansion in the offering of vehicles combined with large incentives will be required to be able to reach high sales volumes (Fearnley et al 2015). As the market expands, more skeptical buyers and users with demanding usage patterns will need to be convinced.

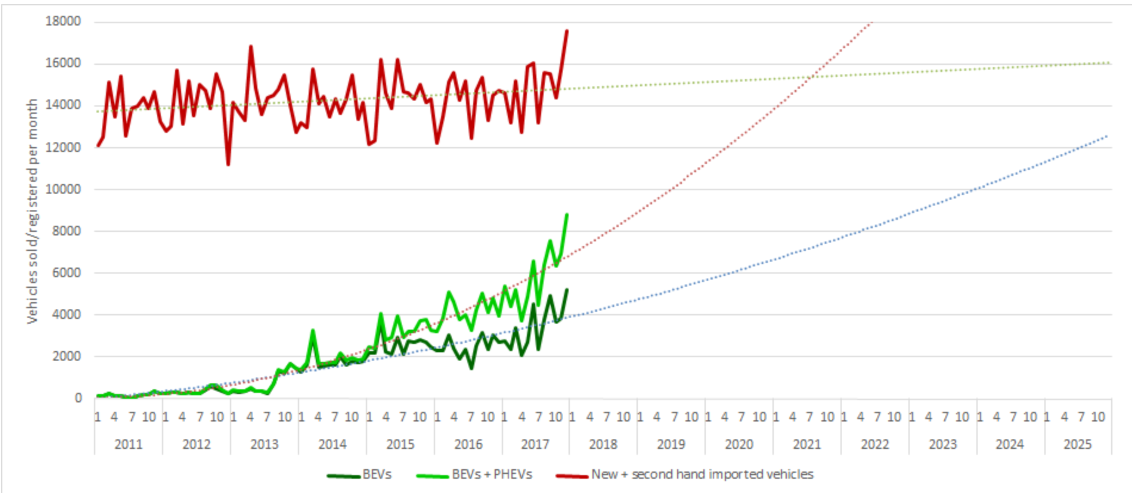


Figure 4.3: Progress towards the 2025 target of replacing all sales of vehicles (includes new and first time registration of second hand imported vehicles) with BEVs or BEVs + PHEVs.

Future PHEVs will get longer range in the pure EV mode, likely in the 70-100 km band (Mercedes 2017a). The average user will be able to operate these vehicles on electricity from the grid 70%-90% of the km driven (Figenbaum and Weber 2017, Plötz et al 2017). A pragmatic policy could let these longer range PHEVs count towards the 2025 target, or the target could be revised to allow for a share of these vehicles in the national fleet.

Regional sales have developed rapidly. All provinces, apart from Finnmark and Oppland and Hedmark, had higher BEV market shares than any other country in Europe in 2016 (Eafo 2017) apart from Iceland.

The two most northern provinces had market shares below 10% in the first four months of 2017. The largest increase in market shares between the first quarter in 2014 and the first tertiary of 2017, have been in Norway's rural provinces. There is thus a tendency of levelling out the market shares between provinces over time. The six provinces with highest market shares each has one of the six largest cities of Norway.

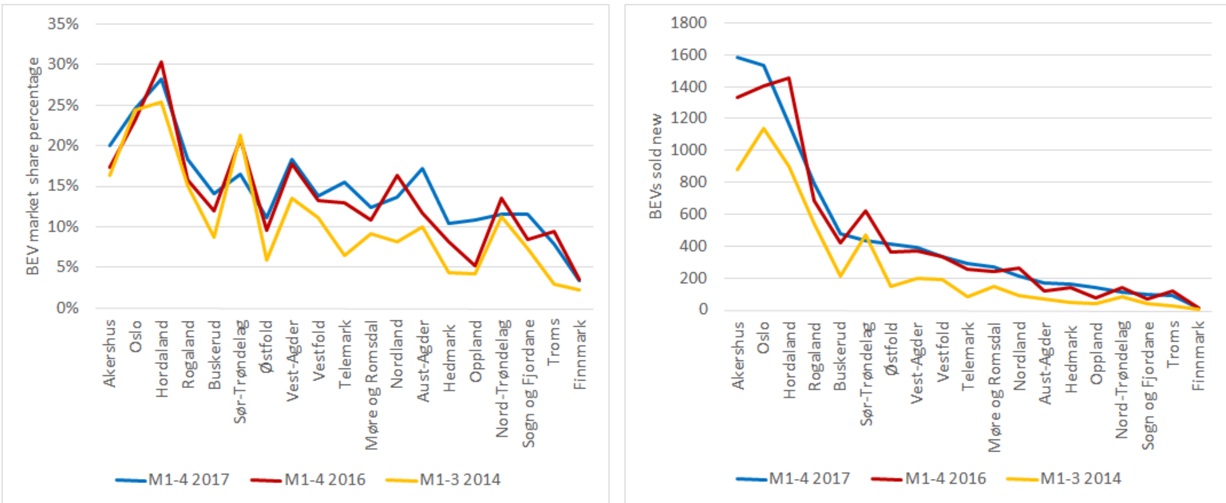


Figure 4.4: Regional distribution of new vehicle sales, 2017, 2016 (Month 1-4) and 2014 month 1-3.

4.2 Vehicle market dynamics

The vehicle market is split in segments. Mini and small vehicles are not particularly popular in Norway compared to some European countries. Norwegians tend to buy compact and larger vehicles. The mid-sized segment has however decreased the last years and the compact sized SUV segment increased. Four-wheel drive is a popular vehicle feature in Norway, with a take rate of around 40%, a result of the combination of tough winter conditions, mountainous topography and fashion.

Vehicle brands plays a role in the household vehicle selection process. Figure 4.5 shows the development of market shares for the top 20 brands by market shares in the 2017, divided into those that have BEVs and/or PHEVs for sale and those that do not.

The first observation is the dominant and rather stable market positions of Volkswagen and Toyota. Toyota does not have BEVs for sale obviously affecting the total market share of BEVs, whereas Volkswagen has two BEV models selling well, contributing to the increased BEV market from 2015-2016. Ford has a BEV model for sale, but has suffered a steady decline in market share since 2010, partly because the BEV model has not been attracting many buyers. Nissan and Renault market shares have risen since 2010 after the introduction of BEV models. The last years Nissan market shares declined somewhat as their prime BEV model, the Leaf, reached its end of life. Skoda, Audi and Suzuki have stable market shares although they do not offer BEVs. Mercedes and BMW has reached new heights in market shares, partly due to the introduction of BEV and PHEV models. Tesla's market share has increased from 0% in 2010 to over 5% in 2017. Peugeot and Citroën have lost market shares in spite of offering a BEV (the rebadged Mitsubishi I-Miev). Other brands market shares have gone up and down in a more arbitrary fashion.

Kia has lost some new vehicle sales due to a high share of the Kia Soul BEV being registered one day in Germany before being exported to Norway as a "second hand vehicle". Hyundai has suffered under a lack of availability of the Ioniq BEV.

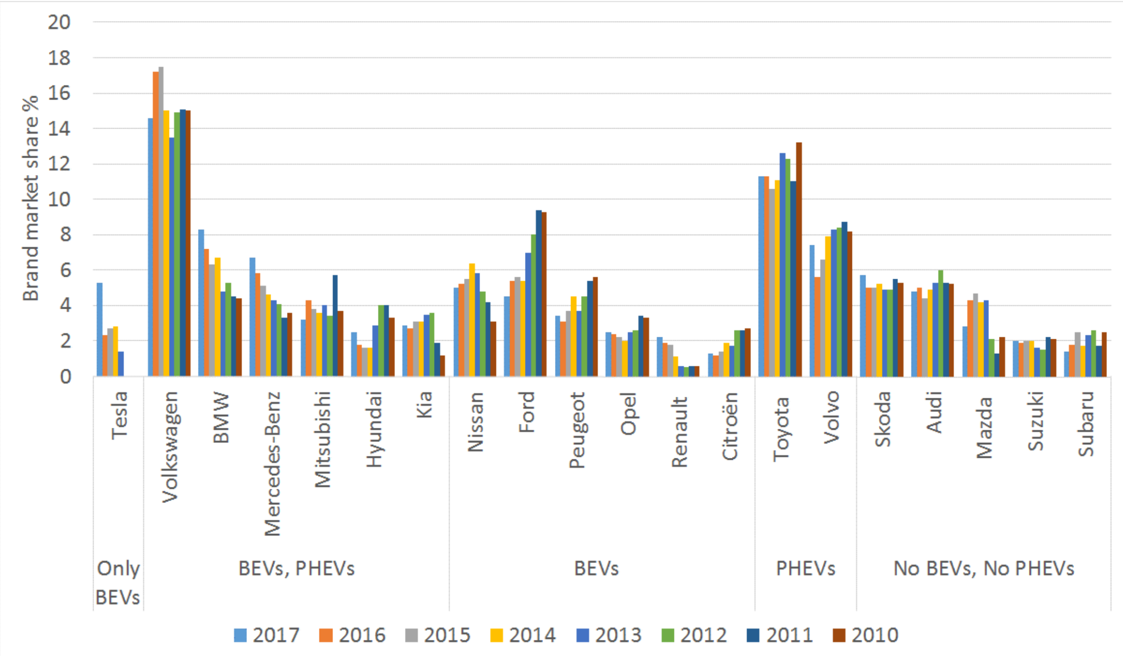


Figure 4.5: Market share development by brand and BEV/PHEV availability (in 2017) 2010 - 2017.

4.3 Limited supply and delays in delivery of some vehicles

Some of the vehicles are available in limited supply such as the Opel Ampera-e, with over 4000 Norwegians on the waiting list, and expected deliveries 12-18 months after order is placed. Opel has stopped taking orders for the vehicle as they do not know when they can deliver new orders. Opel was sold from GM, which produces the Ampera-E for Opel, to PSA (Peugeot Citroën) in 2016. Opel and PSA will offer other BEVs on the market by 2019. Tesla has a large order reserve on the Model 3 with deliveries commencing in 2018, but have not disclosed how many Norwegians are on the list. The latest information indicates a delay in deliveries of this vehicle (InsideEVs 2017). Shortages in supply also applies to other models, for instance the Hyundai Ioniq, and in 2018 also for the VW E-Golf. In general, there is also a time lag between model introduction and volume deliveries that range from months to over a year.

When a new model with longer range is announced then sales of older models may stagnate, and sales may be hampered until volume deliveries is commencing. The vehicle importers and dealers normally counters this by offering large discounts on the outgoing model. Volkswagen and Nissan has thus kept up sales of their BEVs fairly well in the interim period between announcement of the new model and the start of deliveries.

The second hand market has been strong in Norway, and is actually also keeping up the second hand prices in Sweden (Karlström 2017). The reason seems to be an increased faith in the technology, seen by less skepticism of risk of low second hand prices (Figenbaum and Kolbenstvedt 2016) among BEV owners and ICEV owners. This situation also helps the new vehicle market as the trade-in values of vehicles will be larger. Dealers in the Oslo area report strong demand for second hand BEVs following the increased price and the introduction of a rush hour component in the Oslo toll road from October 1st 2017 (Broom 2017).

4.4 The National BEV fleet passes 139 000, PHEVs 67 000

At the end of 2016 Norway had 97 532 BEVs in the passenger vehicle fleet, as seen in figure 4.6. The fleet increased to roughly 139 474 BEVs by the end of December 2017, which is 5.1% of the total fleet. About 1 500 four-wheel electric motorcycles are also in the fleet. 67 577 PHEVs were in the fleet at the end of 2017. The share of PHEVs in the fleet has passed 7.6% out of the total fleet of 2.71 million passenger vehicles. Given the pace of sales, a 10% share of the fleet could be reached by January 2019.

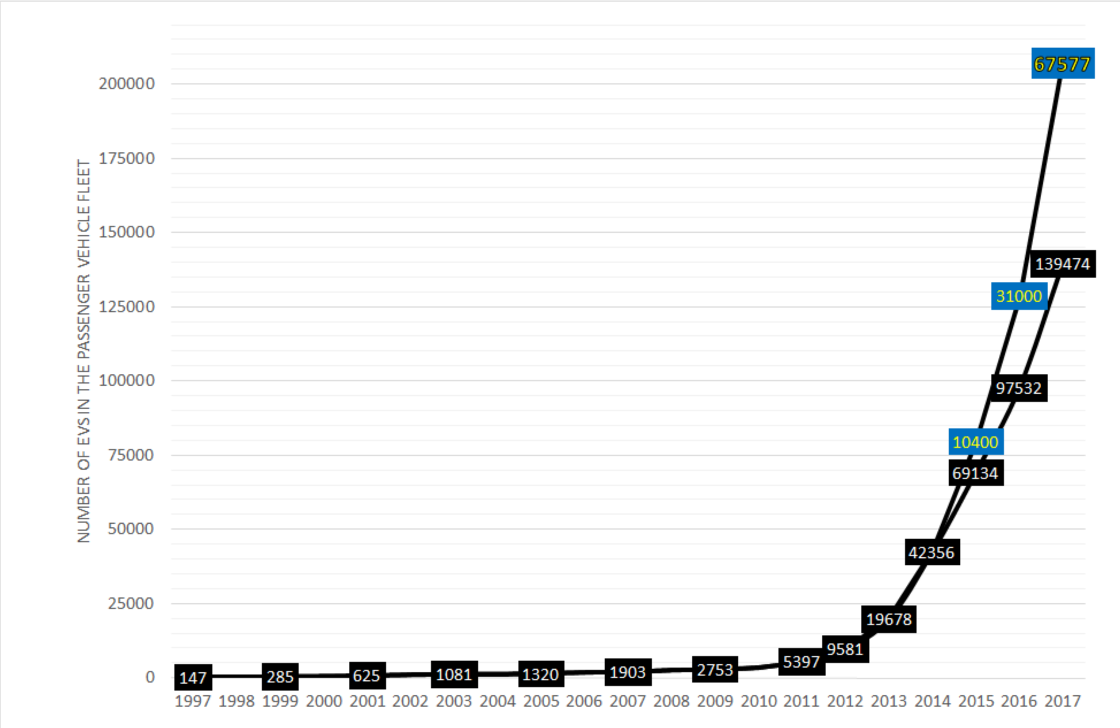


Figure 4.6: Passenger B2EV(black) and PHEV fleet (blue) from 1997-2017. Source OFVAS (2017).

The BEVs in the fleet are spread across the 19 provinces. The highest shares of the fleet are found in provinces containing Norway's largest cities, i.e. Oslo, Hordaland (Bergen), Akershus (surrounding Oslo) and Sør-Trøndelag (Trondheim), as seen in figure 4.7. The share in the fleet is actually higher in Finnmark than in most European countries.

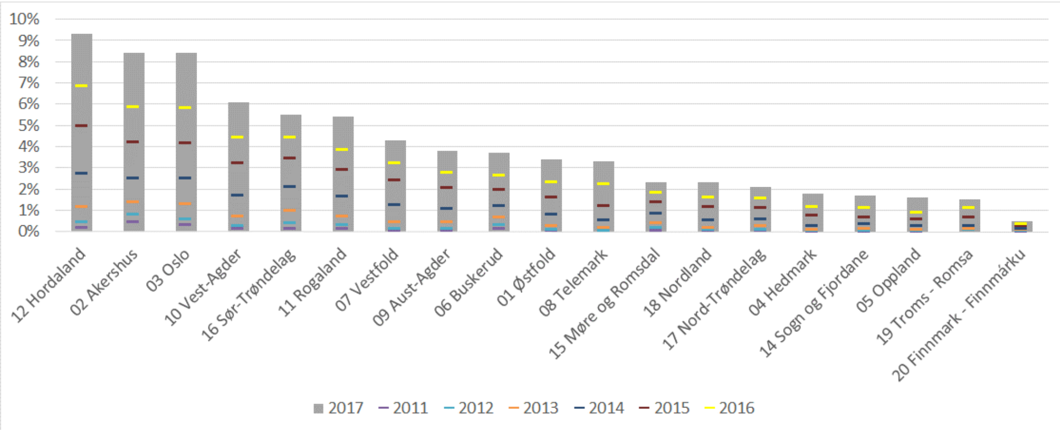


Figure 4.7 BEV share of fleet by provinces 2008-2017. Source: SSB.

These vehicles are used in everyday traffic and are newer than the average vehicle in the fleet, leading to the BEV share in the daily traffic flow being larger than the fleet share, especially in the rush hour, as seen by toll road data in chapter 3. The BEV impact in cities is thus larger than their fleet shares. The split between BEV models in the fleet at the end of 2017 is shown in figure 4.8, separately for privately owned and company vehicles.

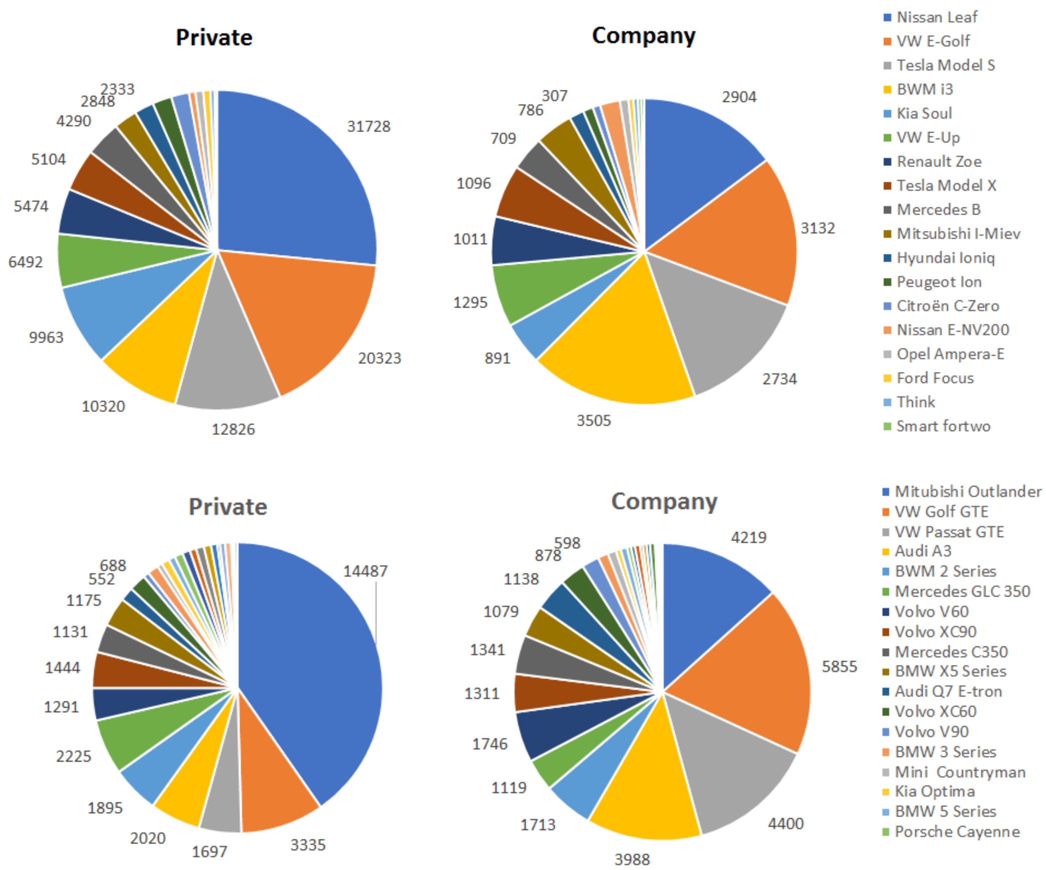
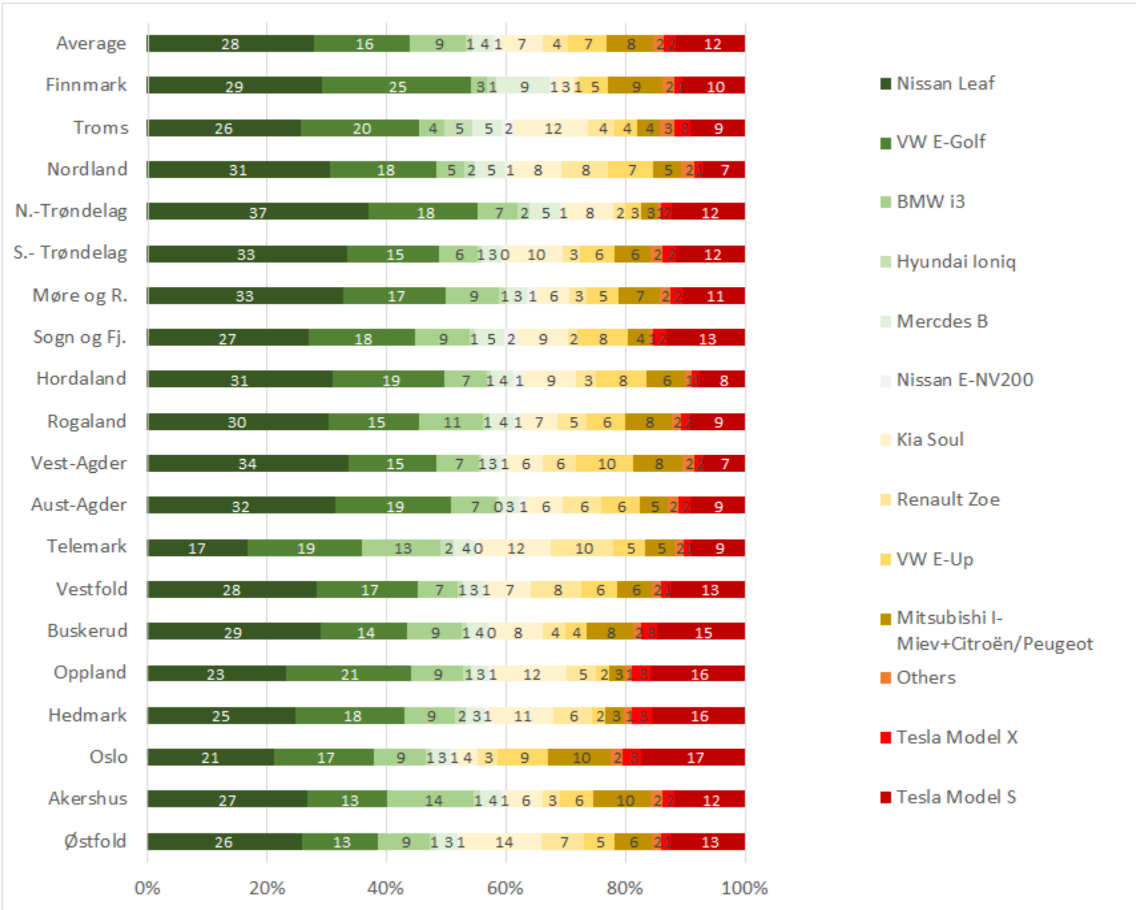


Figure 4.8: BEV (top) and PHEV (bottom) fleet by vehicle models, number in fleet and share of fleet 31.12.2017. Source: NPRA vehicle registry.

Three models constituted over half the BEV fleet, Nissan Leaf (25%), Volkswagen E-Golf (17%) and Tesla Model S (11%) and the variation across provinces is small as seen in figure 4.9. The PHEV fleet is dominated by the Mitsubishi Outlander (28%), the VW Golf GTE (14%), Audi A3 E-tron (9%) and VW Passat GTE (9%).

The large increase in BEVs, that mainly have been replacing ICEVs (Figenbaum et al 2014, Figenbaum and Kolbenstvedt 2016), have led to a tipping point of fossil fueled based vehicle ownership by households in 2014, as seen in figure 4.10. From 2014 the ICEV curve dipped downwards although the total vehicle ownership still increases, with BEVs making up the balance. The total number of ICEVs still increases as the number of households are increasing. Whereas the total number of vehicles increased 4.2% from 2014-2016, ICEVs only increased 1.9%. The geographical differences are however large as shown in figure 4.11.

BEV diffusion started around cities before spreading out radially to larger geographical zones as seen in figure 4.12 (updated from Figenbaum 2017).



Østfold	Akershus	Oslo	Hedmark	Oppland	Buskerud	Vestfold	Telemark	Aust-Agder	Vest-Agder	Rogaland	Hordaland	Sogn og Fj.	Møre og R.	S.-Trøndelag	N.-Trøndelag	Nordland	Troms	Finnmark
3880	21230	18211	1523	1140	4641	4462	2308	1854	4218	9654	17351	708	2760	7053	1296	2248	1039	144

Figure 4.9: BEV fleet brand/model composition by province. April 2017. Green colors: Compact sized vehicles. Red colors: Large vehicles. The rest are small or mini vehicles. Source: Autosys 2017.

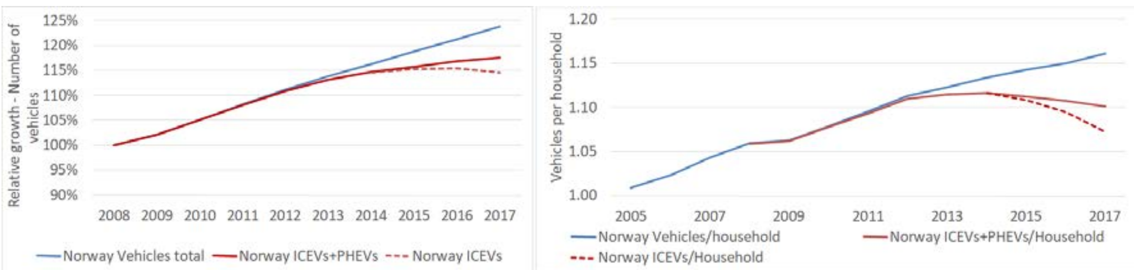


Figure 4.10: Left: Total number of passenger vehicles including BEVs (blue), ICEVS+PHEVs only (red) and ICEVs only (red stippled), per household 2005-2017. Right: Relative growth in total number of vehicles (blue), ICEVs + PHEVs (red) and ICEVs (red stippled) 2008-2017. Source: Statistics Norway 2017.

Figure 4.11: Relative number of passenger vehicles per household (2008=100%) and ICEV vehicles per household by province 2008-2017. Light green line: only ICEVs (incl. hybrids/plug-in hybrids), red line: total with BEVs. A change in the definition of households moved students to the municipality of their University from 2014, leading to a dip in the curves for provinces with large Universities, such as Sør-Trøndelag. The 2010 decrease in ownership in Hordaland and increase in Oslo is due to repositioning of leasing vehicles. Source: Statistics Norway 2017 and Autosys 2017.

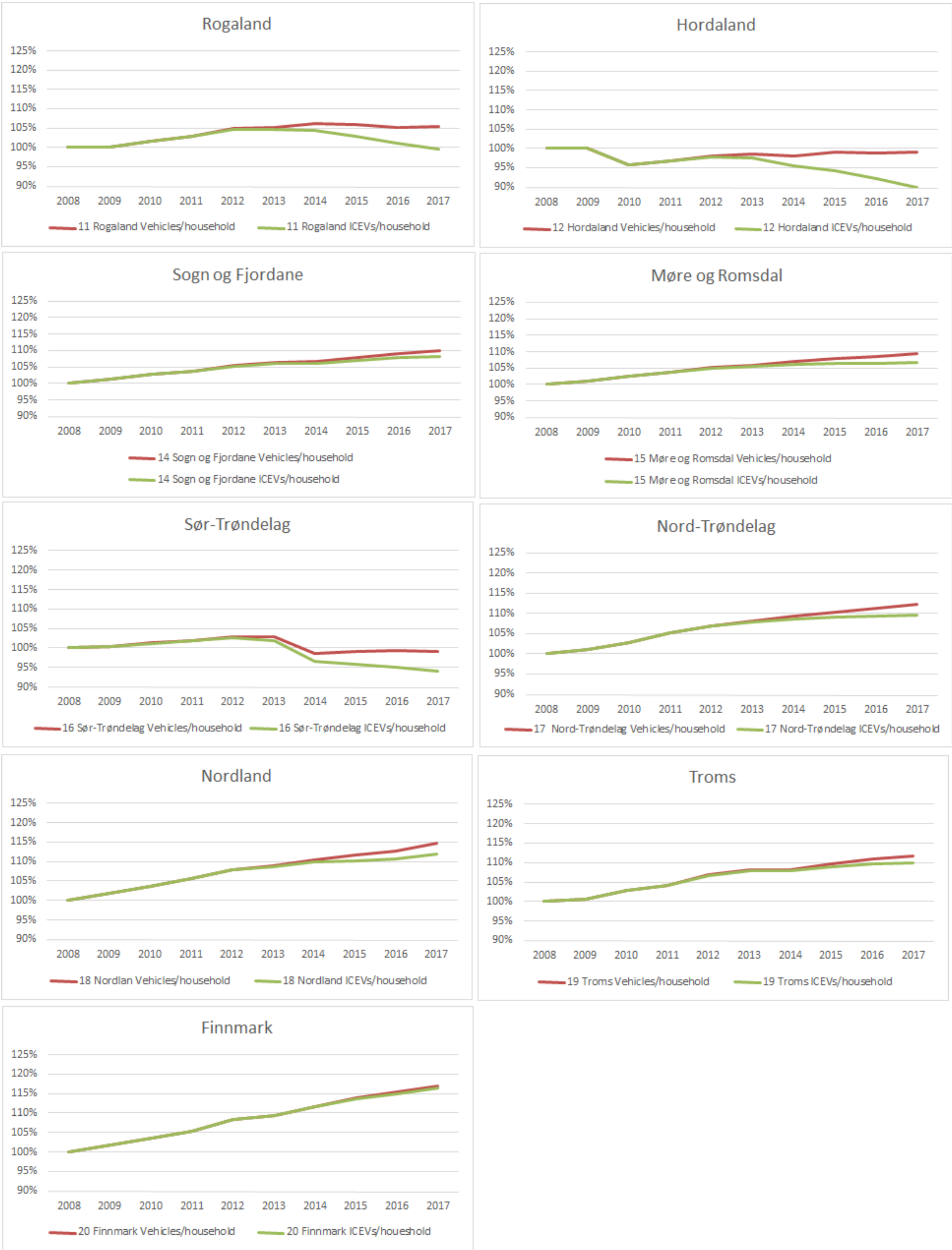


Figure 4.11 continued: Relative number of passenger vehicles per household (2008=100%) and ICEV vehicles per household by province 2008-2017. Light green line: only ICEVs (incl. hybrids/plug-in hybrids), red line: total with BEVs. A change in the definition of households moved students to the municipality of their University from 2014, leading to a dip in the curves for provinces with large Universities, such as Sør-Trøndelag. The 2010 decrease in ownership in Hordaland and increase in Oslo is due to repositioning of leasing vehicles. Source: Statistics Norway 2017 and Autosys 2017.

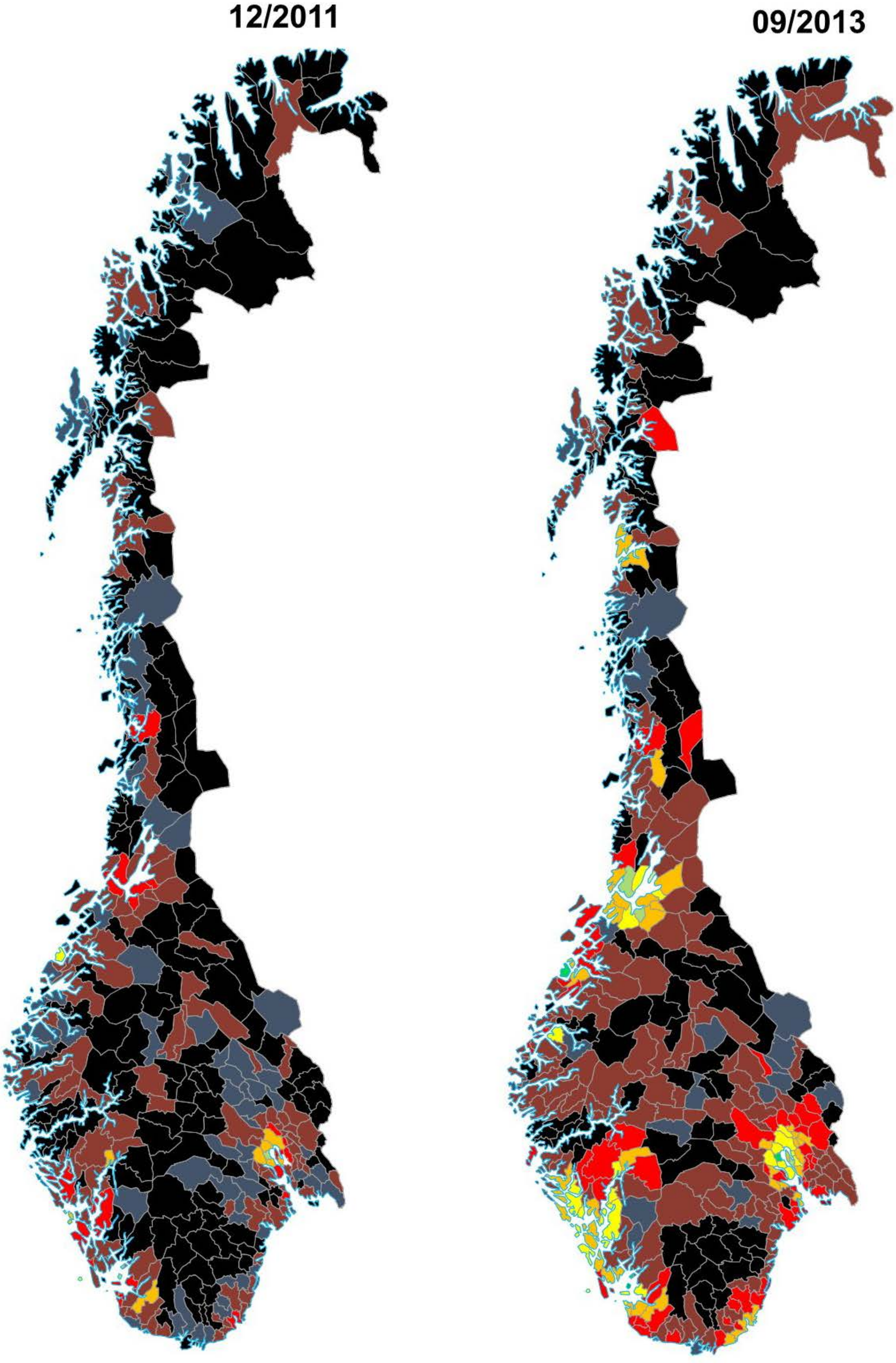


Figure 4.12: Map of geographical BEV diffusion, each colored area is a Municipality.

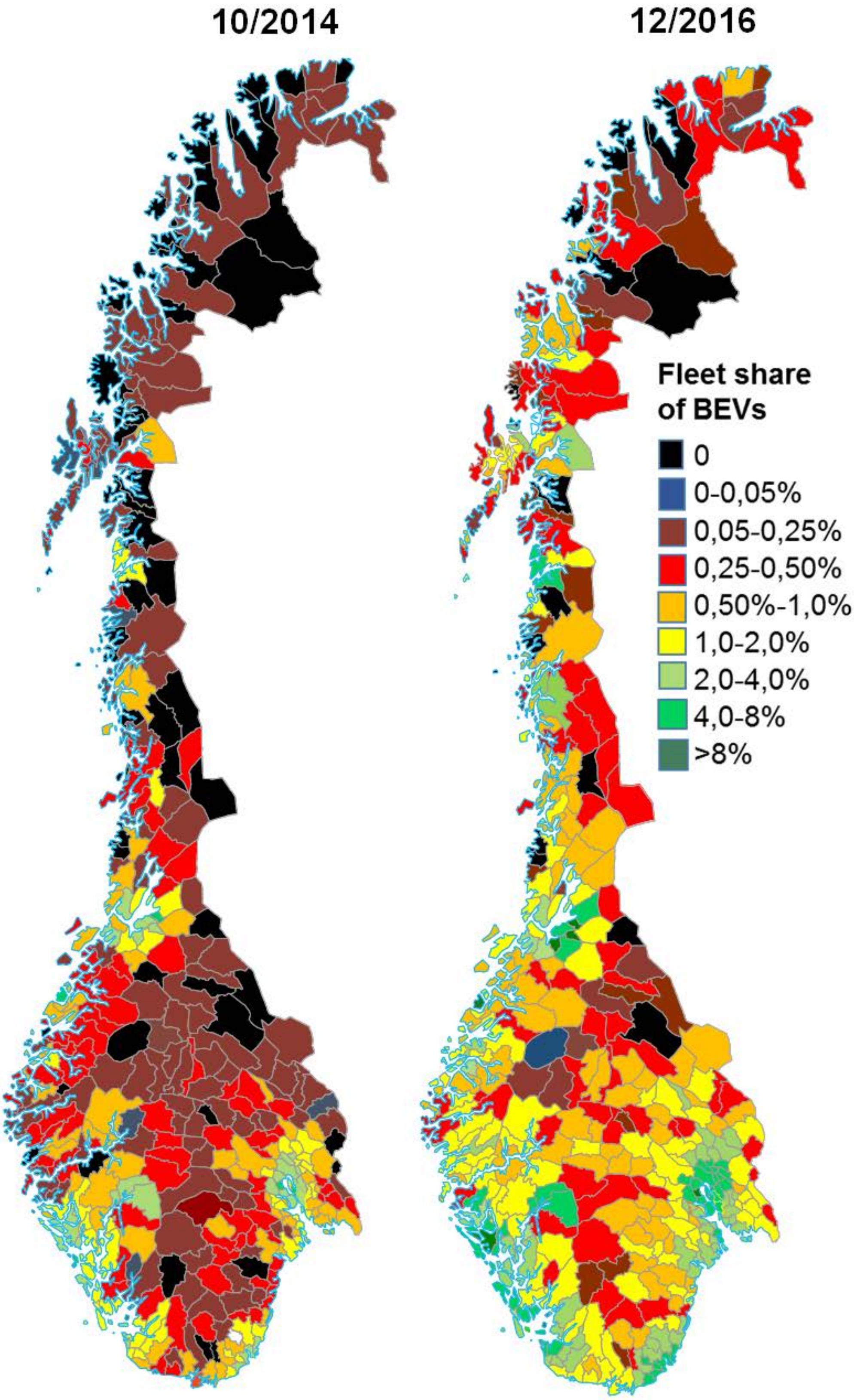


Figure 4.12 continued: Map of geographical BEV diffusion, each colored area is a Municipality.

5 Characteristics of owners, travel needs and BEV usage patterns

The user behavior and driving patterns of early adopters of BEVs in Norway, mainly multi-vehicle households, have been described in detail in Figenbaum et al (2014) and Figenbaum and Kolbenstvedt (2016). The focus in this report is on the prerequisites for mass-market adoption of BEVs by all user groups. The fundamental question is then how the characteristics and performance of present and future BEV offerings match the populations needs for vehicle based travel, and to which degree these needs can or will change. This chapter provides an overview of the existing knowledge of how single vehicle and multi-vehicle households in general use their vehicles, and to what degree that use is similar or differs from households that already have adopted BEVs.

5.1 Household vehicle ownership

53% of the Norwegian households owned one vehicle and 29% two or more vehicles in 2012 according to SSB (2017b). There were 2.35 million households in Norway in 2016 (SSB 2017c). About 82% of the households thus owns a "primary" vehicle, i.e. 1.93 million vehicles. Of those, 53% are in single vehicle households, i.e. 1.25 million vehicles, whereas multi vehicle households own 0.68 million primary vehicles. 2.66 million passenger vehicles were registered at the end of 2016 (SSB 2017d), so about 0.74 million vehicles are thus "secondary" vehicles in households (households may own more than two vehicles). A small share of these vehicles are fleet vehicles operated by enterprises. The national travel survey has slightly different statistics, with more of the households having more than one vehicle at their disposal, i.e. 45% of the households have access to one vehicle, 35% to two vehicles, and 8% to three or more vehicles (Hjorthol et al 2014b). The travel survey however not only count vehicles that are owned by the household, but also other vehicle access, such as vehicles borrowed from friends/neighbors/family, company vehicles and car sharing schemes, explaining some of the differences in the numbers.

Secondary vehicles in households are mainly used locally. They are used for commuting and for errands, and for evening/weekend activities, such as escorting children to activities. The primary vehicle in multi-vehicle households is dimensioned to be able to fulfill the maximum transportation needs of the households. The most demanding driving patterns are long distance driving on vacation trips and hauling of trailers and caravans.

5.2 The socio-demographics of BEV ownership

Figenbaum and Kolbenstvedt (2016) found that BEV owners are younger, better educated and more often live in households with children, and more often having more than one vehicle at hand, than ICEV owners, as seen in table 5.1. They also tend to have a higher employment rate and longer distances to work. They had a predominantly vehicle based transportation pattern also before the BEV was bought.

Figenbaum and Kolbenstvedt (2016) found that BEV owners more often bought the vehicles as an additional vehicle in the household (22%) than ICEV owners (12%), which partly seems to be due to socio-demographical differences. Both groups listed arguments such as changes to work or family situation or location as a reason for buying an extra vehicle, as well as insufficient public transport. BEV owners also stated a wish to use the other household vehicle less, which could be grounded in a wish to either reduce user costs or the environmental impact of the household's transportation. When separately comparing single- and multi-vehicle owners of 2011 and newer year-models, the household incomes differences are much smaller than when comparing the total ownership groups as done in table 5.1 (Figenbaum and Kolbenstvedt 2016).

Table 5.1: Socio-demographical data on vehicle owner groups. n_{BEV}=3111, n_{PHEV}=2065, n_{ICEV}=3080. Source: Figenbaum and Kolbenstvedt 2016.

		BEV	PHEV	ICEV
Employed or self-employed		91%	77%	67%
Retired/Benefit recipient/Student		9%	23%	33%
Primary, secondary, high school (1-13th grade)		22%	25%	33%
Higher education up to 4 years		38%	38%	37%
Higher education in excess of 4 years		40%	37%	29%
Gender, male share of respondents		80%	83%	78%
Average age		47 y	55 y	56 y
Average number of persons in household		3,2	2,6	2,5
Share of households with children		56%	32%	27%
Multivehicle households		79%	54%	52%
Average distance to work		24 km	17 km	17 km
Prior transportation to work: Vehicle based-driver/passenger		87%	85%	74%
Gross household income:	0 - 600 000 NOK	12%	15%	30%
	600 001 - 1 000 000 NOK	37%	41%	44%
	>1 000 000 NOK	51%	44%	26%

5.3 Total yearly travel is equal for BEVs and ICEVs

The average vehicle in the passenger vehicle fleet travelled 12480 km in 2016 (SSB 2017a). Vehicles newer than 11 years are driven more than the average and older vehicles less as seen in figure 5.1. A vehicle which is 1-2 years old is driven almost 40% more per year than the national average. The variation between provinces is small (within 6-8%).

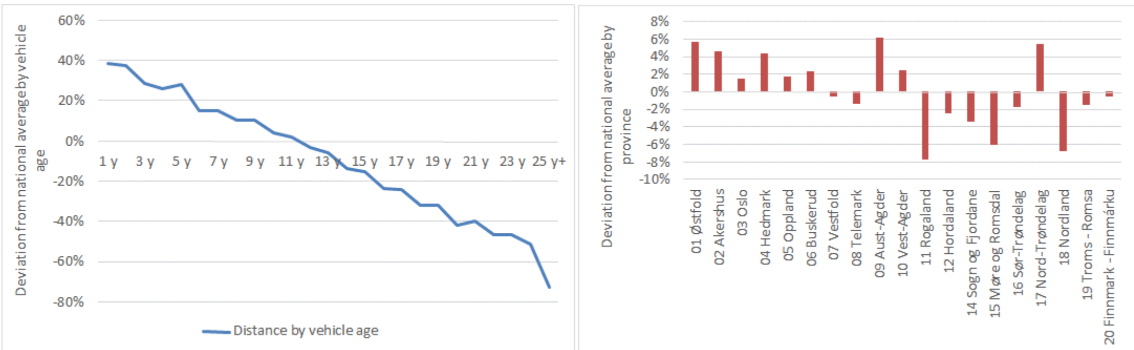


Figure 5.1: Difference from average yearly vehicles distance by vehicle age and province. Source: SSB 2017a.

Both the BEV/ICEV owner survey in 2014 (Figenbaum et al 2014) and the BEV/ICEV/PHEV owner survey in 2016 (Figenbaum and Kolbenstvedt 2016) revealed that BEVs are driven more per year than the average ICEV, although the spread between users was very large, ranging from up to 70 000 km/year to users driving only 5 000 km per year (Figenbaum and Kolbenstvedt 2016). When comparing workers having children, owning 2011 and never vehicles, the annual distance was 15 700 km for both groups.

5.4 Local trip types and vehicle usage

The average Norwegian does 3.26 trips on an average day, with an average length of 14.7 km which, sums up to 47.2 km of travel per day, according to the national travel survey (Hjorthol et al 2014b). Half of these trips are done as a driver and 8% as a passenger.

BEVs are used more frequently than ICEV and PHEVs on trips to and from work, as seen in figure 5.2, and the distance is longer (Figenbaum and Kolbenstvedt 2016). The same applies to local visits, shopping and leisure and when escorting children (Ibid).

Figure 5.2: Trip frequency distribution BEVs, PHEVs and ICEVs. N_{BEV}=3111, N_{PHEV}=2065, N_{ICEV}=3080. Source: Figenbaum and Kolbenstvedt 2016.

As the vehicles are used more locally and less on vacation (next section), and most BEVs (79 %) belong to multi-vehicle households also owning an ICEV, a shift in the household vehicle usage occur, so that BEVs are used more locally than ICEVs, offsetting ICEV trips.

The daily difference in driving pattern of regular BEVs and the long range Tesla Model S is surprisingly small, as seen in figure 5.3. This result suggests that the driving range of all current BEVs is sufficient for daily traffic. Longer range add the capability to use the BEV on long distance trips. BEV owning households have a vehicle based transportation pattern, which they had also before buying the BEV (Figenbaum and Kolbenstvedt 2016).

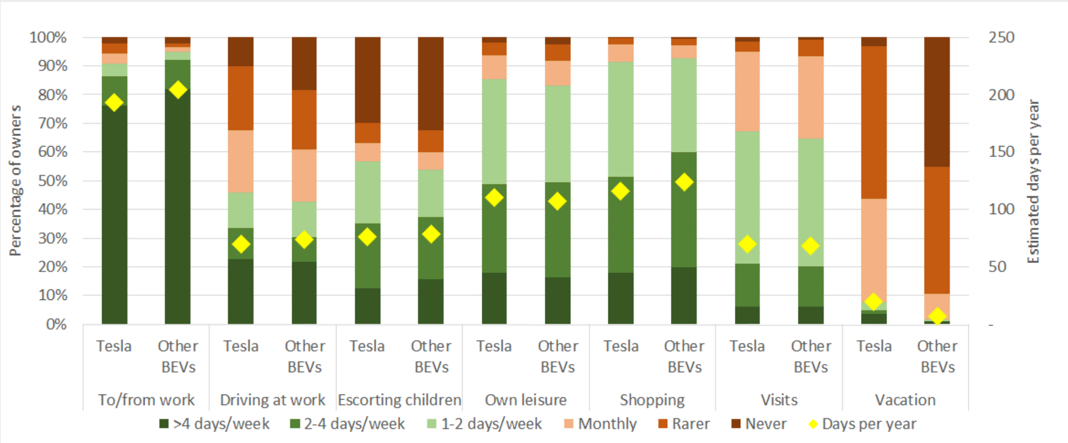
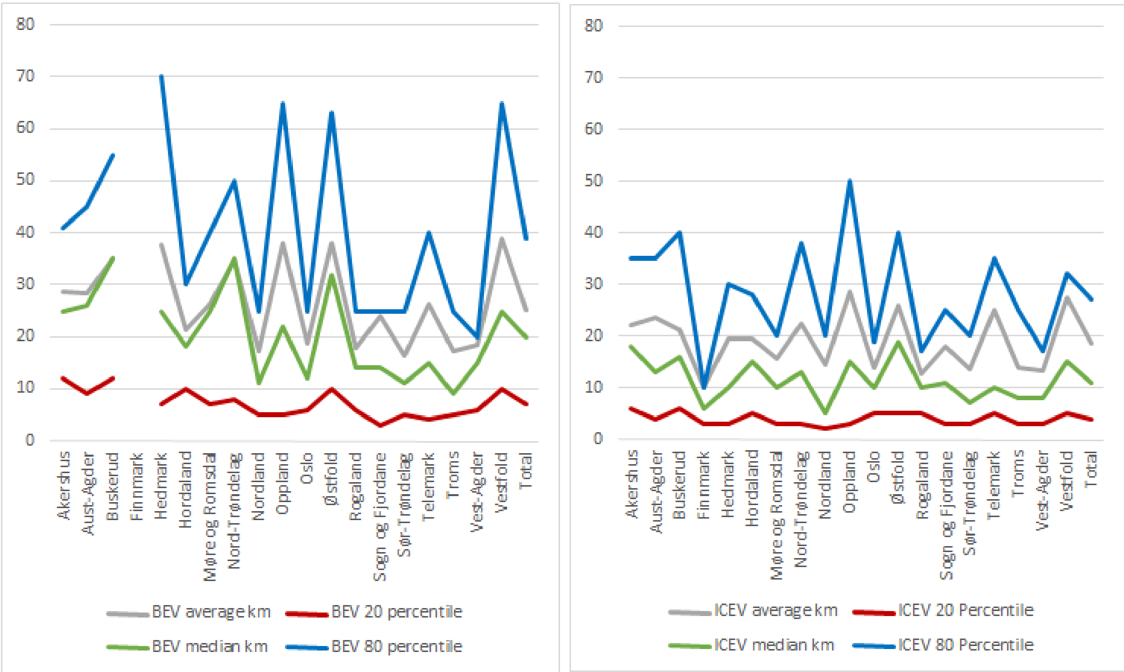


Figure 5.3. Driving pattern of Tesla Model S compared with other BEVs for owners that are working. N_{Tesla}=563, $N_{OtherBEV}$= 2249. Source: Elaborated from Figenbaum and Kolbenstvedt 2016 survey.

The driving pattern of BEVs and ICEVs bought from 2011 to 2016, owned by single and multi-vehicle households, were owners are working and have children, is compared in figure 5.4.

Figure 5.4: Single- (top) and multi-vehicle (bottom) households (BEV+ICEV and ICEV+ICEV) estimated driving pattern of BEVs and ICEVs. Estimate of number of days that each trip type is done per year. 2011 and newer vehicles, owners that work and have children. N_{BEVS}=304, N_{ICEVS}=96, N_{BEVM}=1246, N_{ICEVM}=198. Source: Elaborated from Figenbaum and Kolbenstvedt 2016 survey.

BEVs are used more locally than ICEVs in these comparable user groups but the differences are smaller than in figure 5.3. The difference in vacation trips is very small, whereas work related driving and leisure trips are more frequent among single BEV households. Those owning a BEV and an ICEV do shopping and leisure trips more often, and vacation trips less often, than those with only ICEVs. Other trip types are fairly equal, although BEV owners have much longer distance to work than ICEV owners, as seen in figure 5.5.



	Akershus	Aust-Agder	Buskerud	Finnmark	Hedmark	Hordaland	Møre og Ron	Nord-Trønde	Nordland	Oppland	Oslo	Østfold	Rogaland	Sogn og Fjor	Sør-Trøndel	Telemark	Troms	Vest-Agder	Vestfold	Total
BEV n	535	61	155	4	53	402	83	43	68	42	382	131	237	18	176	55	30	89	155	2726
ICEV n	269	34	94	28	75	161	106	53	88	76	191	73	131	38	107	48	58	53	61	1751

Figure 5.5 Distances to work (km) for BEV owners (left) and ICEV owners (right) by province. Number of respondents per province. Source: Elaborated from Figenbaum and Kolbenstvedt 2016 survey.

5.5 Long distance trip types and vehicle usage

Long distance driving in general involve moving all or some of the household members and their luggage and sports equipment from the home location to a hut, a vacation destination, to friends or family, or to work related activities. The trip may involve stops on the way for eating, other breaks or just for refilling energy to the vehicle. There is potentially a need to mount bicycles or skis on a roof rack or on a tow hook on some of these trips, which will increase drag forces, and reduce a BEVs range significantly. Some vehicle users have even more demanding trip types, such as pulling trailers or caravans. Most BEVs cannot tow trailers. The need for towing trailers could be reduced if people adapt their habits and start using home waste collection and delivery services rather than transporting waste and goods with a trailer themselves.

The average distance of vehicle based trips over the average day for the average driver is shown in figure 5.6. On 83% of days the travelled distance is below 80 km with the average vehicles (Hjorthol et al 2014a). The distances below 80 km are all within the range of all BEVs during the summer, and in most cases also in the winter. The interesting behavior to analyze therefore lies in travels above 80 km per day, which the average citizen does about once per month (0.99 trips), with an average travel distance of 213 km according to

Hjorthol et al (2014b). 39% of the trips above 80 km are for leisure/holiday purposes, 21% for private errands, 21% for visits to friends/relatives, while 14% are work related. Fridays and Sundays are the most frequent days of long distance travels, with twice as many trips as other days (ibid). The variation between regions is small, but residents in Bergen, Trondheim and Stavanger tend to have the longest trips (ibid).

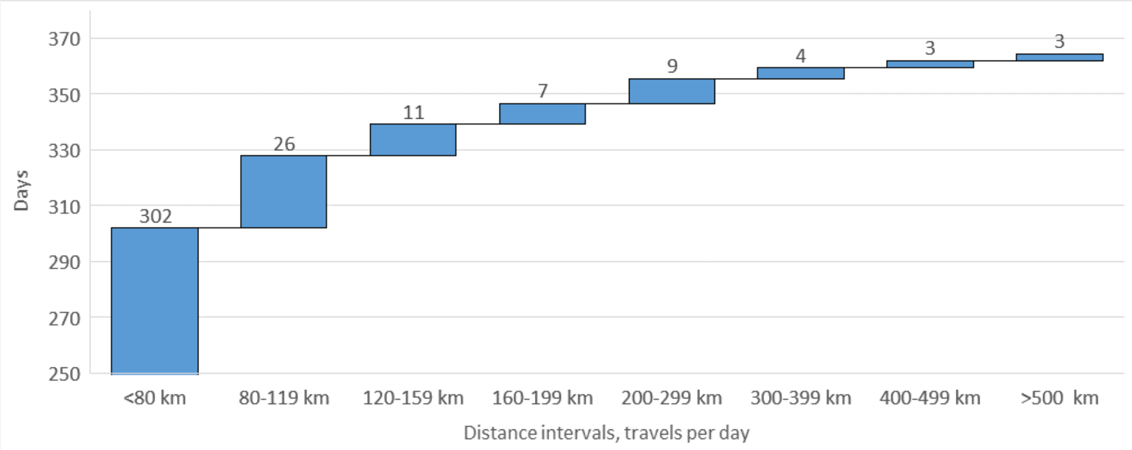


Figure 5.6: Average number of days of driving per day within km intervals, and winter and summer range of different generations of BEVs. Based on data from Hjorthol et al 2014a and authors assessment.

The average driver drives more than 300 km on a day 2% of the days of the year (Hjortol et al 2014a). If these days were randomly spread out across the year, then about 52 000 vehicles of the total fleet of 2.6 million vehicles would be on trips exceeding 300 km on any day of the year. Only 0.5% would drive longer than 500 km, or about 13 000 vehicles. The split is about the same in both seasons, but the challenge of meeting these needs with BEVs will be larger in the winter. In reality, a large share of these days will be centered around national holidays and vacation periods, leading to more vehicles on long distance trips on peak travel days. These days needs to be accomplishable with reasonable effort, to make all drivers switch to BEVs. The traffic flow on holidays in national travel corridors is thus of particular interest. BEVs have however so far been used much less frequent for vacation than ICEVs, especially in households owning ICEVs that could be used instead, as seen in figure 5.7.

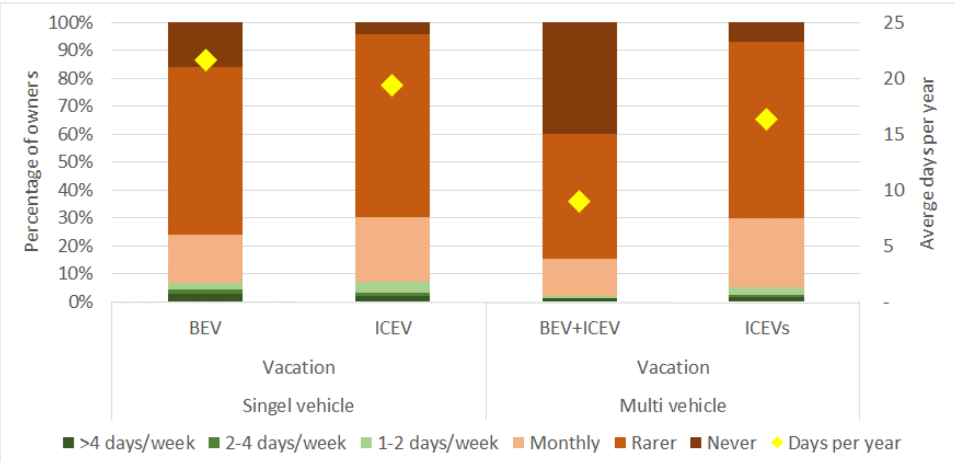


Figure 5.7: Frequency of using vehicle types for vacation trips for single and multi-vehicle households with children, owners that work, and 2011 and newer vehicles. N_{BEVS}=304, N_{ICEVS}=96, N_{BEVM}=1246, M_{ICEVM}=198. Source: Elaborated from Figenbaum and Kolbenstvedt 2016 survey. BEV owning multi-vehicle households: Frequency of use is for the BEV.

Many households do recurring long distance trips annually. Figure 5.9 shows the share of vehicles doing such trips by distance intervals for single BEV and multi-BEV/ICEV owning household (adapted from Figenbaum and Kolbenstvedt 2016). Trips above 300 km can be done by Tesla and Generation 3 vehicles (table 2.2), as seen by Tesla owners survey results (Ibid) and figure 5.8. Tesla owners use the Tesla Supercharger network on long distance trips (figure 5.10). 150-300 km trips can be done by Gen 2 vehicles, and trips below 150 km by Gen 1+ vehicles. Fast charging make these trips accessible with shorter range vehicles. The required range will be longer if there are no chargers at the destination.

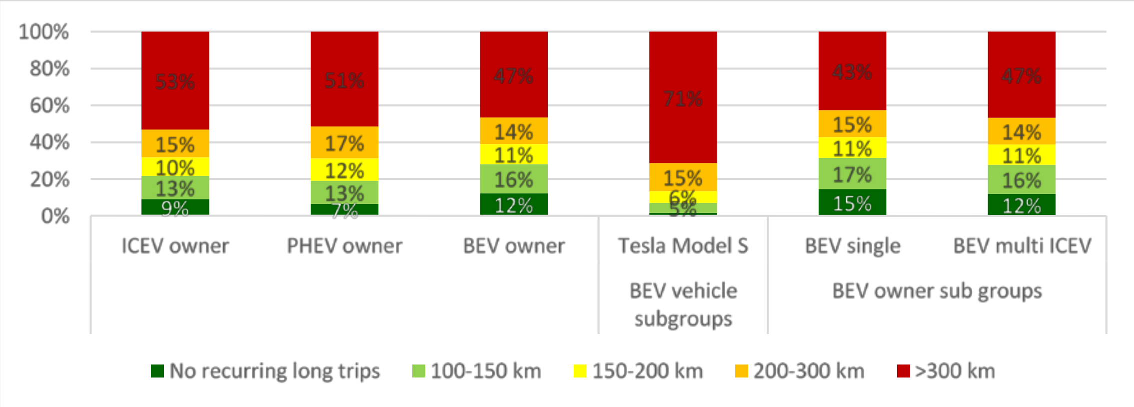


Figure 5.8: Frequency of recurring long distance trips by distance interval. Dark and light Green: Achievable with Gen 1 and Gen 1+ generation of BEVs. Orange and Yellow: Gen 2 BEVs with range of 200-300 km could be suitable. Red: Requires Gen 3 long range BEVs. Trips must be supported by a fast charging network and by charging capability at the destination. $N_{BEV} = 2775$, $N_{PHEV} = 1800$, $N_{ICEV} = 2623$. *Source: Figenbaum and Kolbenstvedt 2016.*

Figure 5.9: Tesla Supercharger Nebbenes. A Saturday night in September 2017.

Figure 5.10 shows separately the frequency of traveling on the three main types of recurring long distance trips for single- and multi-vehicle households. The three trip types are: (1) Travels to huts/vacation homes, (2) travels to relatives or friends and (3) other trips (including work related trips). The main differences between the user groups are that multi-vehicle ICEV owners have longer distances to vacation homes/huts, and that BEV owners also owning an ICEV use their BEV for less than half of these trip types. Single BEV owners will to some degree borrow/rent/swap vehicles to accomplish these trips, and a small share uses public transport, but the majority use their BEV. ICEV owners always use their ICEV for these trips.

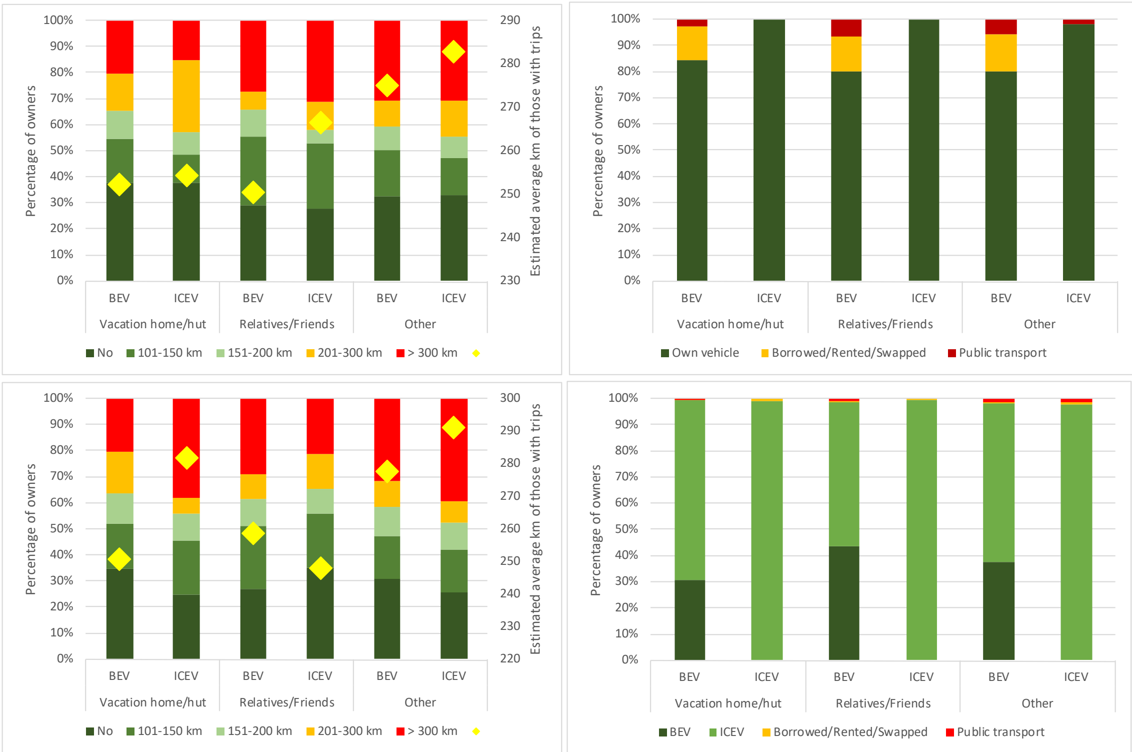


Figure 5.10: Recurring long distance trips, distance distribution, average distance, means of transport used. Single-vehicle households (Top) and multi-vehicle households (Bottom). N_{BEVS}*=304,* N_{ICEVS}*=96,* N_{BEVM}*=1246,* N_{ICEVM}*=198. Source: Elaborated from Figenbaum and Kolbenstvedt 2016 survey.*

The distances are longer in some of the rural provinces, as seen in figure 5.11.

Figure 5.11: Regional differences (Provinces) in recurring long distance trips for ICEV owners. Left: Single-vehicle households. Right: Multi-vehicle households. N_{ICEVS}*=1438,* N_{ICEVM}*=1584. Source: Elaborated from Figenbaum and Kolbenstvedt 2016 survey.*

An interesting observation is that single vehicle households in general does fewer long distance trips, and when they do, a higher share are intermediate distances (100-300 km), than what multi-vehicle households do. Multi-vehicle households thus have the lowest barrier against BEV adoption as a "secondary" vehicle, but the highest for adopting BEVs as a "primary" vehicle. Exceptions are Oppland and Møre og Romsdal. In Oslo the groups have about the same travel behavior. Vestfold and Finnmark have higher shares of multi-vehicle owners not doing long distance recurring trips. No information is available from the 2016 survey on the frequency or distances driven on non-recurring long distance trips.

5.6 Variation in traffic flow on main roads over the year

The variation in traffic flow of light duty vehicles and BEVs on main roads between cities and destinations over a year can be analyzed using toll road data. Figure 5.12 shows the total traffic flow and the flow of BEVs through the toll road in Hallingdal (Hallingporten) per week and per weekday in 2016. This road is a two-lane national main road between Eastern and Western Norway. It is also leads to various mountain resorts in the inland of Southern Norway. The variation in the total traffic is huge. The yearly peak times of travel is clearly the winter school holiday in week 8 (traffic starts Friday evening week 7), Easter in week 12, the Fall school vacation in week 40 and the main summer vacation period in July. The traffic is in general highest on Fridays (in direction out of Oslo) and Sundays (opposite direction) on this road. BEVs driving pattern is similar, indicating that some are used for weekend and vacation trips.

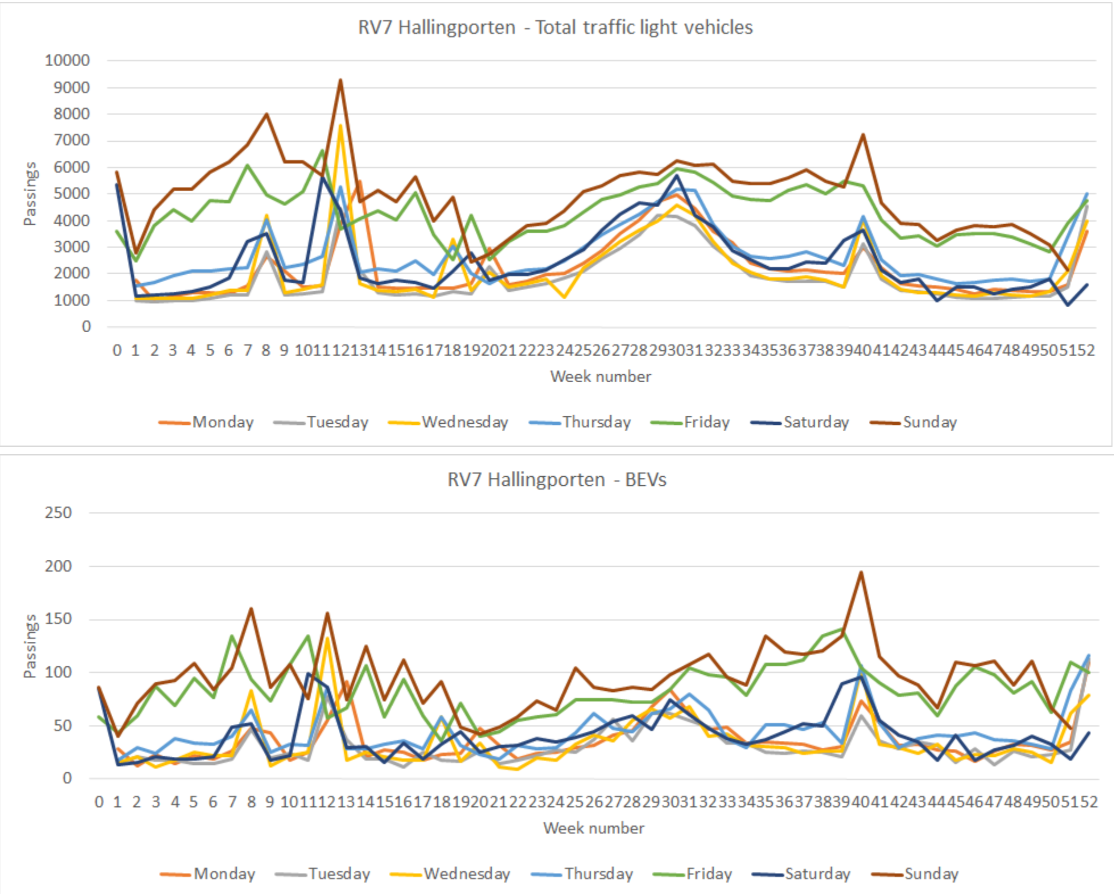
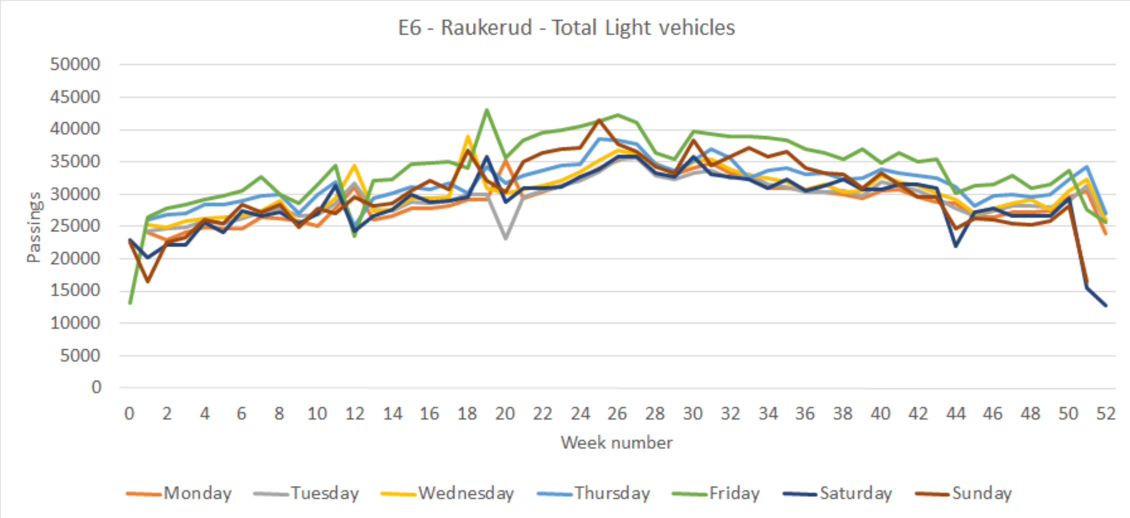


Figure 5.12: Traffic flow per week and weekday through the toll gates of Hallingporten on main road R7. Source: Vegfinans.

The traffic situation through the toll gates on the E6 main road south east of Oslo (near Moss city) is quite different, as seen in figure 5.13. This road is four-lane motorway The traffic varies less over the year and between days than in Hallingporten. National holidays are almost indistinguishable. Looking at travel in a week without holidays, reveals that the traffic is a mix of commuters with peak travel at 07-08 in the morning and 16-17 in the afternoon, and long distance drivers. The latter leads to a higher peak at 16-17 hours. The peak traffic is in the end of June and in the end of July (start and stop of the "main" summer vacation). Most of the BEVs on this road appears to be used for commuting. Travel is most frequent on week days and low in vacation weeks (week 8, 12, 28-30, 40).



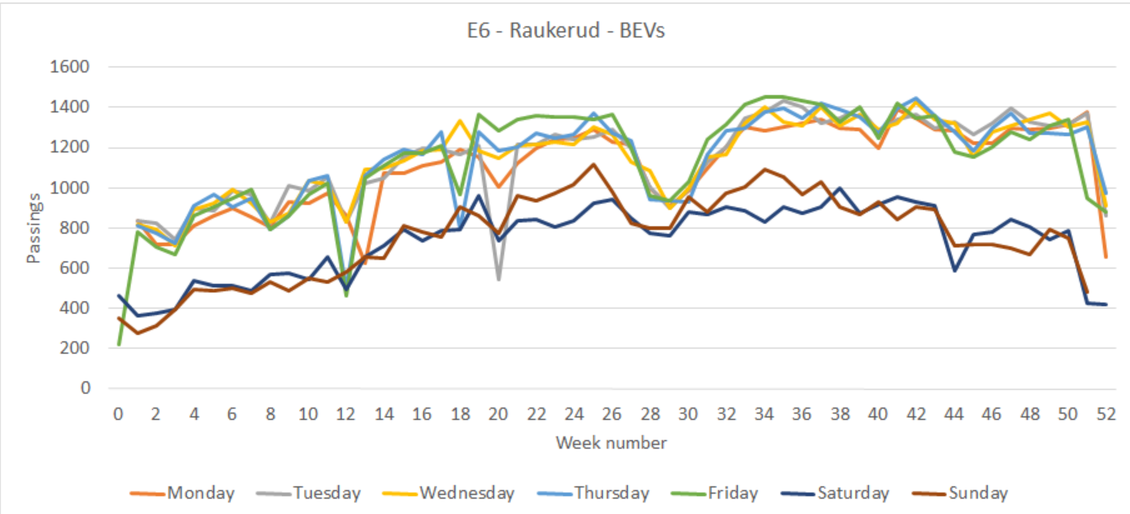


Figure 5.13: Traffic flow per week and weekday through the toll gates at Raukerud (just north of Moss) on motorway E6 south of Oslo. Source: Vegfinans.

Large differences in traffic over the week and year in travel corridors, and the variation in BEV energy consumption between seasons, will be challenging. How should the system be dimensioned and what will be acceptable queue times? These are key questions. The high number of vehicles on the road in the peak travel times during the year will lead to slower traffic which again lead to a lower energy consumption of BEVs, and thus less need for fast charging. Congested traffic may have the opposite effect in the winter season. New BEV generations with longer range may reduce the challenges if those that frequently drive long distances during peak travel time owns longer range BEVs.

It is not uncommon for Norwegians to use vehicles for vacation trips in Europe and the lack of common payment systems for fast charging makes such travels challenging with BEVs. Norwegians driving abroad also risk encountering a less developed charging infrastructure as the markets develops slower elsewhere.

5.7 Charging habits

More than 94% of BEV owners charge their vehicle at home (Figenbaum and Kolbenstvedt 2016) as seen in figure 5.14. The 6% that never charge at home could be charging at work or be frequent users of public chargers.

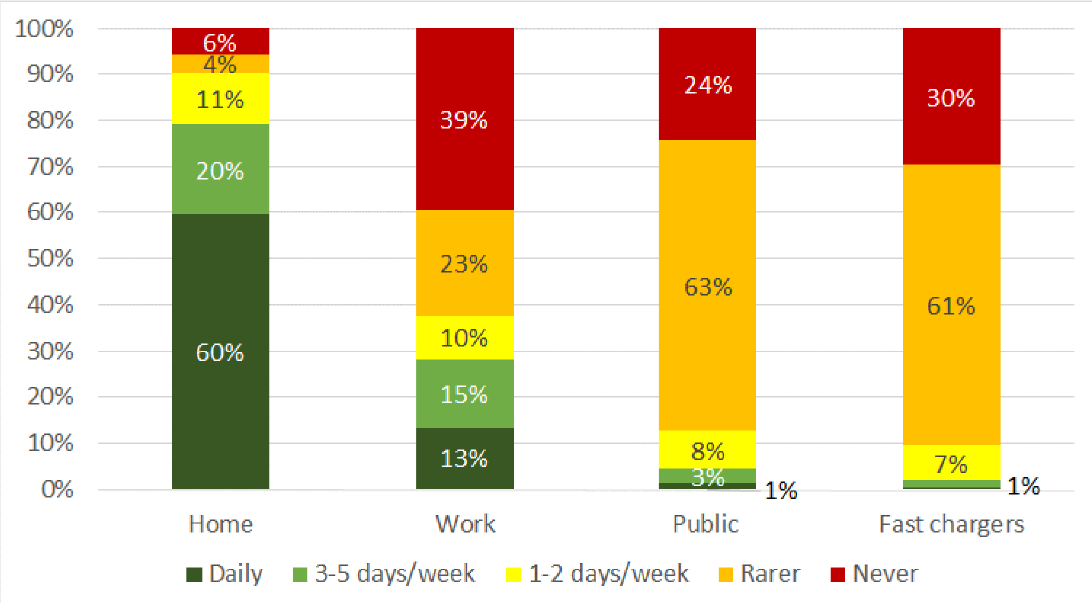


Figure 5.14: Frequency of charging BEVs in different locations.

The typical user plugs into a domestic Schuco plug when coming home from work, leading to a peak in BEV charging starting around 16.00 and lasting until midnight (Figenbaum and Kolbenstvedt 2016). 24% of BEV owners in 2016 had installed a Level 2 Type 2 connector wall box at home (Ibid). Public slow chargers are mostly used on an irregular basis. Long distance trips are rare occurrences as seen in figure 5.7, but fast chargers will be needed to support such travels. Some intermediate trips, or problems on the go, may also lead to a need for public charging infrastructure or fast charging. Most of the energy consumed over the year will however be charged at home.

People without home charging ability may need on-street parking with charging facilities, which will work best for those that user their vehicles seldom. Longer range will reduce the need for home charging availability and potentially unlock more potential users with on-street parking in cities. These on-street chargers may also serve more vehicles when range increases as vehicles will not need daily charging. The availability of chargers at destinations will reduce the need for fast chargers in the travel corridors.

The average Tesla owner use Tesla's free superchargers 26 times/year, whereas other BEV owners use fast chargers on the average 13-16 times/year. Fast charging is mainly used for planned irregular trips, and, but less often, to solve unforeseen challenges during a trip (Figenbaum and Kolbenstvedt 2016). The latter occurs more often in the winter season.

Almost a third of BEV owners have experienced problems with the charging infrastructure at home and other places (Figenbaum and Kolbenstvedt 2016). Infrastructure issues, are responsible for about half of aborted or avoided trips (Ibid).

5.8 Traffic accidents

Prior to 2010 most BEV models on the market where small low speed vehicles with little safety equipment. The exception was the Think passenger vehicle being equipped with airbags and ABS. Since then many BEVs have become regular sized vehicles with similar levels of safety equipment as ICEVs, as seen in recent crash tests by EuroNcap (EuroNcap.com), but Høye (2018a) found that BEVs as a group has less safety equipment and less crash safety than other new vehicles. BEVs are much newer than the average vehicle in the fleet and is thus equipped with more active and passive safety equipment than the average ICEV in the fleet. New vehicles are in general much less involved in accidents than older ones, due to more active safety equipment in the vehicle, and being used much less by high risk groups (Høye 2018b). BEV owners differ from other vehicle owners in age, the number of children they have, and other sociodemographic characteristics (Figenbaum and Kolbenstvedt 2016). They could thus be a subset of new vehicle owners with even lower risk than new vehicle owners in general. They also have been used more locally and regionally and less on long distance trips (Figenbaum and Kolbenstvedt 2016). BEV owners tend to drive energy efficiently to extend range when doing long distance trips (Figenbaum and Kolbenstvedt 2016), thus reducing their risk of accidents, but with potential rebound effects leading to the opposite for other drivers (Alam and McNabola 2014). BEVs are heavier than ICEVs, which could lead to higher risks for other vehicles in accidents. Roll-over accidents are likely to occur less often due to the heavy battery and low center of gravity. BEVs are used more locally and in cities with lower speed roads, and much less on the high speed main roads where the most serious accidents occur than ICEVs.

Two accidents involving BEVs have resulted in fatalities in Norway since the modern BEV was introduced on the market in 2009. The first resulted in the death of a motorcyclist after a frontal crash with a BEV. The other involved a large BEV that had a frontal crash with a smaller ICEV, leading to the death of the ICEV driver (TU 2017). About 150 accidents have resulted in persons being injured (Ibid.), but that number is very uncertain. At the end of 2017 there will be 135000 BEVs on the road, up from 3300 at the end of 2010 and BEV have been driven about 4700 million km since 2010 as seen in table 5.2.

Table 5.2: Average number of vehicles on road per year 2010-2017, and estimated million km driven by fleet

	2010	2011	2012	2013	2014	2015	2016	2017	2010-17
BEVs on road middle of year	3057	4379	7489	14629.5	31017	55745	83333	116266	
BEV traffic volume (million km)	34	57	112	219	465	836	1250	1744	4718

The risk of death for BEV drivers and passengers cannot be calculated, as no one has died in a BEV in an accident yet. The risk of being involved in an accident resulting in injuries with a BEV thus seems to be about 1 per 30 million km of driving (0.03 per million km of driving), which is substantially lower than the general risk of accidents with injuries for the average vehicle in the total vehicle fleet (Høye et al 2018). The number of accidents involving BEVs is however very uncertain and likely underestimated. The reasons for the difference in risk could be due to differences in user groups, driving behavior, vehicle age, and where the vehicles are used. More research is required in this area to estimate risk differences between users of BEVs and ICEVs. The low noise of BEVs can introduce new risks, as seen by a higher share of BEV owners than ICEV owners saying (Figenbaum and Kolbenstvedt 2016) they have experienced dangerous situations because pedestrians or cyclists did not hear the vehicle coming.

5.9 Implications for future research

There are small differences in daily trip frequencies between long range Tesla vehicles and short range BEVs, leading to the conclusion that all BEVs on the market can cover the vast majority of daily travels. If BEVs are to take over the entire new vehicle market, they will however have to be used also on long distance trips, such as holiday trips, and for extreme transport needs such as towing trailers. Further research in the ELAN project will therefore be directed towards long distance driving, and the variable needs of Norwegian vehicle owners over the year. These needs and habits will be compared with the new possibilities provided by longer range BEVs, many of which can be used over 300 km on a winter day.

The use of fast chargers will in principle make long distance travel possible for all BEV owners, but could be rather unpractical for owners of short range BEVs. A central question is which combination of battery range and availability and speed of fast charging, that will be optimum for different drivers.

The travel on peak demand days will be very demanding for the charging infrastructure, especially on roads with large differences between everyday traffic and holiday and weekend traffic. Research should uncover the spread of drivers distances between the destination and the starting point on these days. Research should also be done on the total acceptable waiting time and charging time on these trips on peak travel days. The use of fast charging has been fairly limited. More research will be needed to understand how often and where BEVs with longer range will be charged.

The changes to traffic safety risk when BEVs replace ICEVs needs to be better understood. The data gathered up to now is valid for early adopters using their BEVs mainly locally or regionally. Preliminary information suggests that the risk of accidents could be lower for BEVs, due to differences in driving behavior and limited use of BEVs on high speed roads. Data from insurance companies on actual accidents with BEVs will be needed to find out more. As the market and technology for BEVs evolve, the driving pattern of BEV owners will approach that of ICEV owners, and they will be more equal also in socio-demographical characteristics.

The crash safety of ICEVs and BEVs will be similar for future vehicles, although the offering of BEVs in 2017 had a crash safety level slightly below that of ICEVs.

In the future the BEV owners risk of accidents, injuries and death should approach that of ICEV vehicle owners. BEV owners may however employ a more efficient and calm driving style to extend range, which could lead to a lower risk of accidents on long distance trips. The low noise of BEVs, and PHEVs and HEVS, when driving on electricity can poise risk for pedestrians. These factors should also be further investigated.

6 Charging infrastructure

The availability of charging infrastructure is a much more important parameter when using BEVs for long distances than when using them mainly locally. Charging infrastructure is a particularly important parameter in making single vehicle households adopt BEVs, and to enable BEVs owners to go on longer journeys.

The charging infrastructure can be split into home charging, public or workplace charging in a local/regional area, local and regional fast charging, fast charging to enable long distance trips and destination charging to allow a recharge at the end of the journey.

6.1 Home charging on own property

Norway is probably one of the countries in Europe with the least challenges with establishing a basic charging infrastructure for BEVs. 75% of all the households in Norway can park a vehicle directly on own land, and a further 12-13% park on own parking space less than 100 meters from their home (Hjorthol et al 2014b). The first group can with little effort establish a possibility for charging, either through existing power sockets in garages, carports or outdoors or by setting up a BEV specific socket or wallbox. Those that park less than 100 meters from the house are likely to have common parking spaces, i.e. people living in flats or car free neighborhoods. They may encounter substantial challenges with establishing charging capability, as seen in section 6.2. Those that park further away, and the 11% with no parking facility, may need to rely on charging at work or neighborhood public chargers.

Most BEV owners can and will therefore be able to charge at home on their own property, and as shown in section 5.7, 94% charge at home and about 80% do it at least three times per week. Most households in Norway rely on electricity for space heating and have sufficient power installed to handle a 2-3 kW BEV charger. Newer houses with a 63 A three phase connection to the grid can easily handle 7-11 kW. Most BEVs and wallbox charging stations can be programmed to charge at night in low cost and low demand periods, and to reduce the peak loads. All BEVs are supplied with a charging cable that can be connected to existing domestic Schuko sockets, and this type of connection is the dominant way of charging BEVs. Schuko plugs are however not rated for continuous operation at full power so a dedicated EV charging station should be installed at home. Most BEVs sold in 2017 were also equipped with a type 2 connector charging cable, specifically designed for EV charging. Roughly 24% of the buyers (Figenbaum and Kolbenstvedt 2016) had by 2016 installed a wall box with a type 2 connector. The EV associations survey in 2017 indicate that this share is rising (Elbilisten 2017). This home charging infrastructure will allow safe charging at 3.5, 7 or 11 kW power levels, thus supporting newer vehicles with more powerful on-board chargers. Wallbox installations in Norway cost 10 000-15 000 NOK (Figenbaum and Kolbenstvedt 2015), but the cost is expected to decline over time (IEA 2017).

The Norwegian company DEFA/Salto (DEFA 2018) has developed a new device that measures the power used by the house, and use that to control the power the BEV can be charged with by the wallbox. The advantage is that faster charging will be possible when the house installation uses less power. There is no public support available for installation of chargers in private houses. Previously VAT could be deducted on a standard wallbox installation when bought as "extra equipment" with the vehicle.

6.2 Home charging in apartment buildings

Home charging in apartment building, and other types of houses where parking is in shared facilities, has been a challenge. Most of these types of parking facilities were built in a time when BEV charging was not foreseen. Even apartments coming on the market in 2015-2017 were often planned before the BEV market in Norway took off. A dedicated electricity outlet at the parking space of the BEV owner might not be available. The parking facilities electrical system may not handle the added power demand. The result could be a fire risk unless the electrical system is upgraded. The parking facility may for instance need a larger overall power supply cable to be able to handle BEV charging. The cost can escalate as the utility company can charge the facility owner with the cost of improvements in the local grid. The result is a debate in these apartment buildings over who should pay for the charging equipment installation and the electricity charged. Zaptec, a Norwegian charging station equipment producer, has therefore made a system where charging stations communicating with a central control unit are connected to the same power line (Zaptec 2018). The control unit adjusts the charging power of each charger to keep the power line load within allowable limits. Each unit report the charged kWh to a central database, allowing the housing cooperative to charge users for the electricity.

There are several public support programs for charging infrastructure installation in such buildings. A survey of the general population found that chargers had been installed in 18% of housing cooperatives and condominiums in January 2018 (Elbilbarometer 2018).

6.3 Neighborhood on-street home-charging

Some places vehicle owners do not have access to private parking spaces. This situation is typical of denser city zones were people rely on on-street parking. Providing charging facilities for this group will be challenging. The costs will be very high due to the excavation of the road, wiring and a need for robust charge poles. Cost will be less for off-street installations such as in parking houses. The availability of chargers cannot be guaranteed as they can be used by any BEV owner. So far only a limited number of chargers have been installed, and very few BEV owners rely on on-street charging (Figenbaum and Kolbenstvedt 2016), partly due to the lack of it. and partly due to low vehicle ownership in general in city zones with on-street parking (Gripsrud and Vågane 2007).

Longer range BEVs may influence the need for on-street home-parking. These vehicles will need to be recharged less often, potentially only once per week if the vehicle for instance can charge at 7 kW. They will thus be more suitable for people without parking availability, which could increase the overall demand for vehicles. It is however not clear how these two factors combined will influence the overall demand for on-street parking and charging.

6.4 Work place charging

Workplace charging is utilized on a daily basis by 28% of the BEV owners and a further 10% on a weekly basis (Figenbaum and Kolbenstvedt 2016). There is no statistics on the availability of work place charging.

The need for workplace charging may move in two directions in the future. One possibility is that the need is constant, i.e. that the short range BEVs still need to charge, while the longer range BEVs will not need to charge at work. The other possibility is an increased need due to BEVs being taken into use by persons who do not have access to home charging, and thus want to charge at work.

6.5 Public charging – Slow and semi-fast

The first BEV charging infrastructure installed in the period up to 2010 used Schuko sockets, as no BEV specific charging sockets had been standardized at the time. Schuko plugs have also been installed in Norway prior to the BEV era in public and company parking lots, to enable the use of ICEV engine block heaters in cold regions of Norway. Many of these installation can potentially be used for or upgraded to BEV charging.

Public charging infrastructure now use the type 2 connector socket to facilitate safer and faster charging. All BEVs sold since 2010 from the major vehicle manufacturers can use a type 2 cable, and most vehicles are delivered with it. Aftermarket cables are also available (Hjemmelader 2017, Salto 2017).

The new parking regulation contains requirements for availability of charging infrastructure for BEVs (Lovdata 2017). The regulation specifies that it shall be charging infrastructure for rechargeable vehicles on a sufficient number of parking spaces, but the obligation is limited to 6% of the total number of parking spaces.

6.6 Public charging – Fast and ultra-fast

Fast charging has dual purposes. First of all, fast chargers reduce range anxiety and increase the utilization of vehicles. Fast chargers for these needs are typically installed in and around cities. Secondly, they enable long distance trips, when located along major roads. Fast chargers charge at 50 kW power and prove about 3-5 km range per minute of charge.

Transnova, a government entity tasked with supporting charging infrastructure and new transportation solutions, initiated a support program for fast chargers in 2011. The program was completely open to suggestions for position of fast chargers and the first chargers where free to use and positioned freely. In a later stage Transnova developed a fast charger deployment strategy (Pöyry 2012). To get support, the fast charger could not be free and payment was introduced on all fast chargers. The first chargers used only the Chademo plug. These have been replaced by multi standard chargers, offering 50 kW DC with the Chademo and CCS standards. A few also have a 43 kW AC option.

Enova took over Transnova on the 01.01.2015, and has up to 2018 carried out four tender rounds for the installation of fast chargers each 50 km along all major roads in Norway (figure 6.1). The tender for the Northernmost provinces and the Lofoten Islands, failed to attract bidders. The infrastructure providers did not believe that there is a viable business case there yet. Enova do not support fast chargers in cities. They are viable without support.

Some provinces have had similar support programs and fast chargers have been put in place to establish a local offer, by municipalities and utilities. Private funding of chargers has resulted in fast chargers at shops such as Kiwi (food store chain), McDonalds (fast food chain), Ikea (furniture), and at some fuel stations.

Figure 6.1: Enova's four tenders for fast charger infrastructure in major travel corridors between Norwegian cities. Source: Enova 2017.

The average BEV owner say they use fast chargers about 13-16 times per year on the average (Figenbaum and Kolbenstvedt 2016). The average session lasts about 20 minutes (Sprei 2017), and the price is about 2.5-3 NOK/minute (Fortum charge and drive 2017). The 2017 fast charger turnover in the Norwegian market should then be about 80 million NOK, or about 100 000 NOK per fast charger unit, assuming there were an average of about 100 000 non Tesla BEVs on the road in 2017 using 800 physical fast chargers (section 6.9). The average annual variable cost (apart from the investment cost) of the fast chargers would be about 85 000 NOK[6]. A fast charger used twice as much would generate incomes of 200 000 NOK and annual variable cost would be 118 000 NOK. The investment cost is at a minimum 400 000 NOK/fast-charger, in a typical dual fast-charger station. It is thus obvious that a public support program for the installation of fast chargers is still required in locations with low utilization rates.

6.7 Will ultra-fast charging be the future or a supplement?

Fast charging infrastructure is in for a massive change with the introduction of ultra-fast charging at 150 kW or 350 kW, providing a usable range of 9-15 km/min and 21-35 km/min respectively. These chargers could be designed so that the power can be split so that each unit can charge two or three vehicles simultaneously, at half or a third of the available power. The charger producer DBT introduced such a multi standard charger (Combo CCS, Chademo, AC power) to the market in 2016 (DBT 2016). The likely scenario is that they in low demand periods charge at the full power of 150 kW, whereas in high demand period the power will be reduced to 50-75 kW, which happens to be the strategy of Tesla. These chargers are likely to be installed for long distance driving between cities.

YX-Norway, a fuel station chain, will together with the Danish EON and CLEVER companies install ultra-fast chargers along main roads in Southern Norway, i.e. between Oslo and Stavanger, Kristiansand, Bergen and Trondheim (YX 2017). They will install these chargers on 20 fuel stations in the initial phase between 2018-2020. The charge power will be 150 kW with a potential upgrade to 350 kW later. Ionity will be establishing a network of ultra-fast 350 kW charging stations over the next years across Europe. The Circle K fuel station chain is the Norwegian partner and the construction work on the first stations will start in 2018. Fortum will also install ultra-fast chargers in Norway, with the first station operational in February 2018.

Willingness to pay for 150 kW charging should be higher than three times the price of a 50 kW charge, since it provides a much better service. Potentially a proprietary charging network of 150 kW or 350 kW chargers could be put in place only for vehicles capable of that charge level. That would provide the suppliers of these vehicles with a competitive advantage over other suppliers. It is however difficult to see how regular charge service operators would want to lose potential income from 50 kW capable vehicles in low demand times. If that is the case, then 50 kW charging would still be the backbone of the network of fast chargers on peak travel days. Such an approach will minimize cost and maximize potential income but will lead to charge time variability that may put-off some potential users.

[6] The average fast charger would be used 36 250 minutes/year (604 hours) and consume about 23 000 kWh/year. Other assumptions are: operational costs of 25 000 NOK/charger/year, average power tariff 714.78 NOK/kW, 112 099 NOK/year annual price for grid access, 0.24 NOK/kWh for grid transfer cost and 0.382 NOK/kWh energy cost (data from Langseth 2015)

6.8 The Tesla Supercharger network

The Tesla Supercharger network shown in figure 6.2 is only accessible for Tesla vehicles, but proves that it is possible to establish a network of fast chargers to enable long distance driving. These chargers charge at 120 kW if one vehicle is connected to the charger, and at 60 kW when two vehicles are connected to the same charger unit. All Tesla vehicles have had free access to the Supercharger network. Tesla users thus enjoy low energy costs on long distance trips. In Norway these stations are positioned along main roads between cities to enable long distance driving, back to back with chargers for other types of BEVs. The network also enables driving across borders inmost of Western, Northern and Southern Europe. Tesla vehicles can also charge at regular fast chargers using an adapter. Tesla owners fast charge 26 times per year (Figenbaum and Kolbenstvedt 2016), twice as often as other BEV owners do.

Figure 6.2: Tesla Supercharger network. Source: Tesla Motors 2017.

6.9 1000 fast chargers in Norway, 42 000 type 2 wallboxes

Table 6.1 provides an estimate of the number of publicly available and home charging point in Norway per main type. There are a few additional charging points with non-standard connectors and a number of workplace chargers that are non-public. These are not included in the statistics.

The numbers for different home charging infrastructures is an estimate. The estimate is based on the share of BEV/PHEV owners that said they could charge at home in the 2016 user survey, and the type of infrastructure they say they have installed (Figenbaum and Kolbenstvedt 2016, Elbilisten 2017). Owners that own more than one BEV or PHEV was assumed to have one shared charging station/socket for home charging. Based on this estimation method it is found that about 38 400 EVSE Type 2 wallboxes are currently installed for private charging, representing a consumer investment of about 400 million NOK. About 122 000 BEV and PHEV owners rely on the domestic Schuko household sockets. It seems feasible for a further to 1.2 million further households to facilitate home charging with limited effort. Of the remaining 0.4 million vehicle owning households, about half have parking facilities that can potentially be fitted with charging.

The installed fast chargers represent an investment of some 500-700 million NOK. The cost of the Tesla Supercharger network is not known.

Work place chargers have not been surveyed in Norway. Some of the BEV specific sockets are included in the official charging infrastructure database Nobil. Many workplace parking areas have wired up sockets for use of electric engine block heaters. The number of these are not known, nor their power rating. Many of these could be usable for charging.

Table 6.1. Charging infrastructure in Norway, installed public chargers, estimate of home charging infrastructure variants, potential among non-BEV and non-PHEV owners. Source: EV association 2017b and authors estimates. Most fast chargers are multi-standard, i.e. CCS + Chademo (some also AC 43 Kw).

Charging standard	Charge level	Charging stations	Charging points
CCS COMBO	50 kW fast chargers		729
Chademo	50 kW fast chargers		773
AC 43	43 kW fast chargers		48
Tesla	120 kW superchargers	36	272
	Total number of charger units		1001
Public/workplace	Type 2 22 kW		1119
	Type 2 11 kW		148
	Type 2 3.5-7.0 kW		1697
	Other AC		186
	Schuko		4316
	Unknown		
	Total number of charging units		7466
Total public charging infrastructure	**Total Fast/Supercharger + Public/workplace**	**2181**	**8467**
Home charing -Estimates	BEV owners Type 2 EVSE wallbox	36888	36888
	BEV owners Schuko	87450	87450
	BEV owners other plug	6625	6625
	PHEV owners Type 2 EVSE wallbox	5431	5431
	PHEV owners Schuko	54915	54915
	BEV/PHEV owners without home charging	10353	10353
	BEV + PHEV owners using EVSE Wallbox	42319	42319
	BEV + PHEV owners using Schuko sockets	142365	142365
Total installed charging infrastructure		**144546**	**150832**
Potential among non BEV/PHEV owners	Vehicle owner - Parks on own land	1190311	1190311
	Vehicle owner - Parks in shared facility	222191	222191
	Vehicle owner, no parking at home	174579	174579

6.10 Cost of time important in long distance driving

Long distance driving between cities in Norway would in general be 300-500 km long, as seen in table 6.2. 500 km travel distance will therefore be used in the calculations of the worst case charge times on long distance trips. The total time spent driving is high, as average travel speeds are in the order of 70-80 km/h when abiding to speed limits. Drivers will need some stops on long distance trips, for a leg stretch, toilet visits and to eat. Such stops can be utilized for fast charging with zero time-cost. An average of 5 minutes of breaks per hour of driving seems to be a reasonable assumption for such stops.

Table 6.2: Travel distances and speeds between cities in Norway, free floating traffic. 5 min breaks/hour driving. Source: NAF Ruteplanlegger.

From	To	Distance	Total time	Average speed	Pause time
Oslo	Bergen	463 km	6h 57min	67 km/h	30 min
Oslo	Trondheim	494 km	6h 28min	76 km/h	27 min
Oslo	Stavanger	474 km	7h 24min	64 km/h	37 min
Oslo	Kristiansand	322 km	3h 59min	81 km/h	15 min
Bergen	Trondheim	629 km	9h 39min	65 km/h	43 min
Bergen	Stavanger	210 km	5h (incl. ferry)	42 km/h	On ferry
Bergen	Kristiansand	468 km	7h 45min	61 km/h	34 min
Trondheim	Bodø	705 km	10h 7min	70 km/h	45 min
Bodø	Tromsø	550 km	8h 38min	64 km/h	38 min
Bodø	Harstad	313 km	5h 40min	55 km/h	23 min

In figure 6.3 the cost of charging during a 500 km trip has been calculated based on the technical data of BEV generations presented in table 2.2, and the cost of time and energy[7], and compared with the energy and time cost of a diesel vehicle. The time cost of driving is not shown as it is the same for all alternatives. The time cost was split in three; time spent for charging within regular pauses, time spent charging in excess of these regular pauses, and the cost of the time to get to the charger and time spent in charge queues. The cost of recharging the vehicle to 100% after the trip is also included. A hypothetical vehicle with a 40 kWh battery and 150-350 kW charge capability is included to evaluate the effectiveness of ultra-fast charging separately.

It is from figure 6.3 clear that short range BEVs will use much more time on long distance trips than owners of longer range BEVs or ICEVs. They will also be more vulnerable to queues as they will need to recharge the batteries many times during these trips. The cost of the extra time is not balanced out by reduced energy costs on that trip. For long range BEVs with faster charging, the reduced energy cost provides an economic advantage to owners, compared to the cost of operating an ICEV, without having to spend more time charging during long distance trips than they would for normal pauses. The reason is that the time used for regular pauses is longer than the required charge time. The question then will be if it is possible to build out so many fast charge stations that queues are avoidable, or kept below the five-minutes assumed in the calculation. The calculation gives about the same results for 150 kW and 350 kW charging. 150 kW charging is therefore the real game changer under Norwegian conditions. Moving to 350 kW does not add much benefit to users. Keeping queues down is more important. 350 kW charging will however allow faster turnaround on chargers (assuming that the number of kW charged is the same), which will

[7]Cost of time is 173 NOK/person in a vehicle, vehicle occupancy is 2.6 persons on average on long trips. Fast charging cost 3 NOK/min for 50 kW charging, increasing proportional to charge power. A queue time of 5 minutes is assumed for fast charging. 5 minutes pause time per hour of driving can be used for charging. Average speed 70-80 km/h on long distance trips. BEV consumption 150 Wh/km in the summer, +50% in the winter. Fast chargers average power is 80% of rated power in the summer and 70% in the winter. Winter season: 5 months per year. No time cost is assumed for the time spent driving. 2 minutes is assumed to get from the road to the charging/fueling facility. For diesel vehicles, cost of fuel and time cost (pauses on long distance trips) is shown as a sum. One fuel filling of 2 minutes. Diesel cost 14 NOK/liter, and the vehicle is assumed to use 5.5 liter diesel/100 km in the summer and 6.5 liter/100 km in the winter.

be beneficial when the space to install the chargers is scarce or expensive. Ultra-fast charging also makes sense for high speed driving over longer distances. Driving on motorways will either lead to longer drive times for BEVs than diesel vehicles, as users may strive to keep energy consumption low, or longer charge times and more frequent charging than calculated in figure 6.3, due to higher energy consumption at high speeds. The motorway network is however limited in Norway.

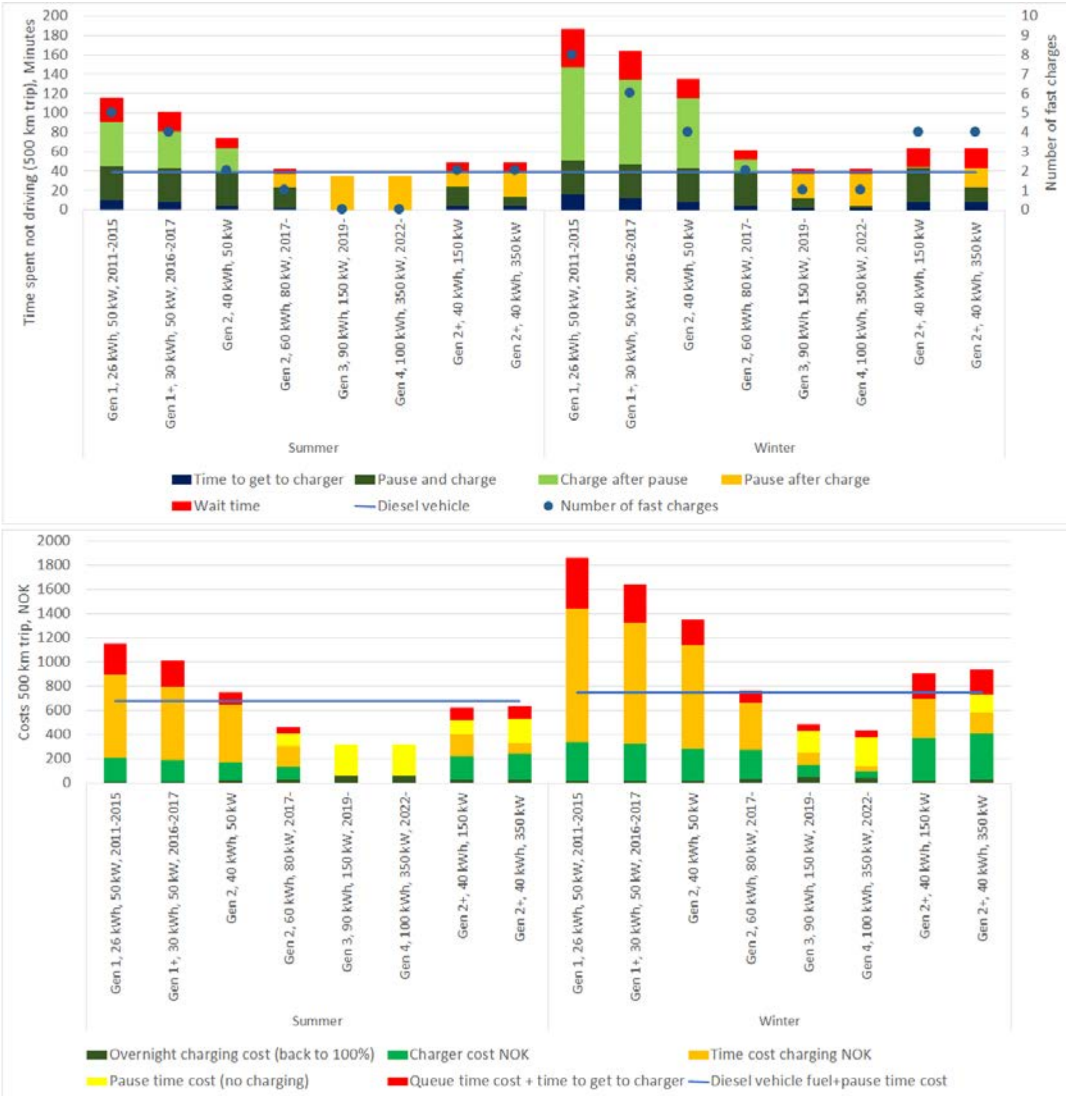


Figure 6.3: Time spent for charging, pauses and queues when fast charging BEVs of different generations on a 500 km trip, and number of fast charges. Diesel vehicle cost includes time spent for one tank filling. Gen 2+ 150/350 kW is a hypothetical BEV with a 40 kWh battery fast charging at 150 kW and 350 kW respectively[7].

All BEV users apart from those owning the shortest range gen 1 BEVs, would save money over a year, as seen in figure 6.4, assuming an average users long distance driving pattern. The underlying driving pattern was taken from the 2009 national travel survey (Hjorthol et al 2014a)[8]. The energy cost savings in daily traffic will by far outweigh the added time cost

[8] Data from Hjorthol et al 2014a: 83% of days people drive less than 80 km. 7% of days 80-119 km. Distribution of days above 120 km taken from special analysis of the long distance trips (assuming these trips are overnight trips). 5% of days 120-199 km, 2.4% of days 201-300 km. 1.1% of days 300-399 km. 0.7% of days 400-499 km and 0.7% above 500 km. Days of driving below 80 km average 21 km to make the total km equal to 17800 km (same as Hjorthol et al 2014a) when the middle of the interval is used for the other intervals (+500 km set to 550 km).

on the rarer long distance trips for owners of longer range and/or faster charging BEVs. Even the owners of the shortest range BEVs will on the average break even, and save money when savings due to free toll roads are added. They will however have to spend almost 2.5 hours extra for a trip covering 500 km in the winter. This extra time could be prohibitive for user acceptability. There is also a high risk of even more added time due to the potential for longer queue times than assumed in the calculations. A high number of required charge stops increase the risk of experiencing queues further. The available range between recharges will also be low, so that a very dense net of fast chargers would be a pre-requisite to make such trips possible. Most of these vehicles are however used by multi-vehicle households (Figenbaum and Kolbenstvedt 2016, Figenbaum et al 2014) that can solve these long distance trips using the other vehicle in the household.

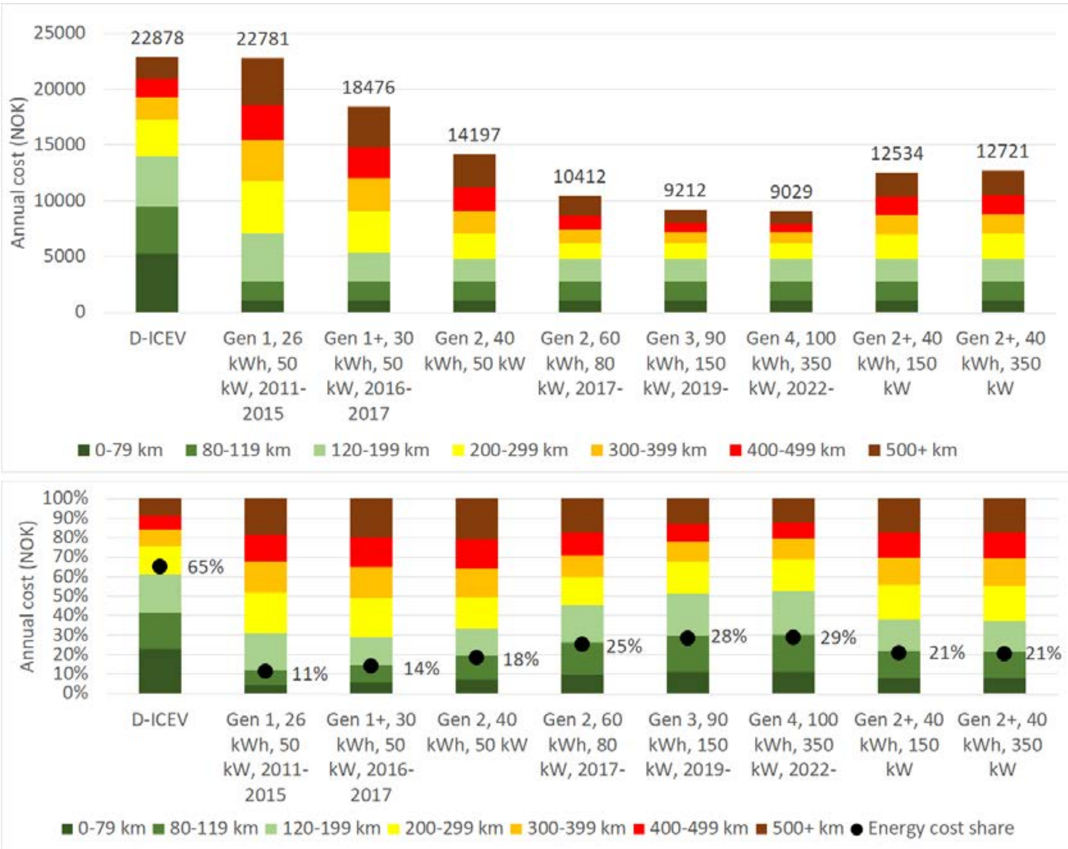


Figure 6.4: Annual time cost (non-driving related time, pauses, energy filling time, wait time at filling stations) and cost of energy of an average vehicle user in Norway (upper chart). The spread of cost over days of driving in distance intervals and the energy cost share of the total cost of energy and time (bottom chart). Gen 2+ 150/350 kW is a hypothetical 40 kWh battery BEV with fast charge capability of 150 and 350 kW respectively.

The energy cost savings over a year of vehicle use for a BEV compared to a diesel vehicle is actually large enough to cover the cost of occasionally hiring a vehicle for the longest trips. Owners of the shortest range BEVs need to rent vehicles on the average 6 days per year to cover days when driving needs are in excess of 400 km. They could spend 7 400 NOK on vehicles rentals on these 6 days without exceeding the cost of the diesel vehicle (brown+red bar in the chart), which would be feasible. Car rental will however involve additional effort and take more time. 20% of households that only have one vehicle do see renting a vehicle as an option to solve range challenges (Figenbaum and Kolbenstvedt 2016). Only 4% of multi-vehicle households owning also an ICEV see renting as an option to solve range issues. They rather swap their vehicles to match needs.

A second generation BEV having a nominal range of 300 km and a fast charge capability of only 50 kW will have higher cost (sum of time and energy) than the diesel vehicle on days of driving in excess of 300 km of driving. When battery size increase to 60 kWh and the charge power to 80 kW the distance increases to 500 km. The cost difference for users between vehicles charging at 150 kW and 350 kW is minimal in Norway. 350 kW charging might make more sense in countries with higher speeds on main roads and motorways.

Tesla is a separate case for fast charging. Tesla owners fast charge for free at Tesla Superchargers, and only have time costs when charging. The time cost can vary due the possibility that the 120 kW power of the Tesla Superchargers is split between two vehicles.

6.11 Implications for future research

Home charging is straight forward for the 75% of the Norwegian households that can park on own land. Further research will however be required to better understand the need and the potential for home charging for the rest, about half of which park within 100 meters from their house and the other half having no parking. The need for daily home charging could be drastically reduced when the driving range of a long range BEV can cover up to a week of local driving. Research should be done on whether this new development could reduce barriers to BEV adoption in cities.

BEVs save time, effort and money in everyday traffic due to the convenience of home charging, using low cost electricity. The downside is that long distance driving takes more time due to a need to frequently fast charge, especially in the winter with short range vehicles. A central research question is if users will accept this trade-off, and if there is a minimum driving range and fast charger infrastructure required before large percentages of consumers accept the proposition. Range anxiety could evolve into charge anxiety if the charging infrastructure lags behind the increase of BEVs.

Users will have an option to rent vehicles for long distance driving. Renting vehicles could solve the long distance driving issues. The cost could be less than the annual savings of driving a BEV instead of an ICEV (sum of money and time). The willingness to rent vehicles to solve long distance driving challenges, and the awareness of this as an option should be further investigated in future research project.

The cost of energy from a 50 kW fast chargers is about four times the cost of home charging. Adding the time cost of delays on journeys, it is obvious that consumers will limit fast charging to a level sufficient to get to the destination, and slow charge there at lower cost. That could mean that fast charging might not take much time for owners of long range vehicles, building down the charge time barrier. More research needs to be done on the demand for fast charging and the acceptable wait time on peak demand days. The fear of queues on peak days of travel is a potential new barrier that should be investigated.

Ultra-fast charging at 350 kW is a new development and no research has been done on the effects on travel patterns with BEVs. Usage of ultra-fast charging at 150 kW could resemble the pattern of use of Tesla owners, or be different as the vehicles will appeal to different customer types. The first vehicle capable of charging at 150 kW will be the Nissan Leaf with the 60 kWh battery option coming in 2019. A few vehicles can charge at intermediate levels (70-100 kW). The first 350 kW capable vehicles will not enter the market until 2019 or later. It is interesting that ultra-fast charge stations are installed in traditional fuel stations, indicating a potential adoption of Electromobility by ICEV fuel station actors. The motives for this move and their views on Electromobility is also of interest in the analysis of the potential to replace the ICEV regime with Electromobility.

7 Market outlook

The new generations of BEVs coming on the market the next 1-5 years will be more competitive when it comes to technical and practical capabilities. BEVs will get longer range, faster charging, and similar safety and convenience equipment as ICEVs. The compact powertrain requires less volume in the vehicle, thus freeing up volume that can be utilized for new unique features. These vehicles will with the help of incentives continue to drive the market forward as the BEV awareness and knowledge expands in the population.

7.1 Awareness, changing perception and readiness to buy

BEV owners and potential BEV buyer's expectations for the BEV technology and their buying intentions will change as the technology evolves and the BEV diffusion deepens. It is gradually becoming easier to be a BEV owner, due to longer range of BEVs, improving charging infrastructure, and the establishment of a functioning second hand market (Figenbaum and Kolbenstvedt 2015). The knowledge of BEVs among transportation system actors and in the general public is also increasing. BEVs already have a firm foothold as one of the vehicles in multi-vehicle households, primarily used in local transport (Figenbaum and Kolbenstvedt 2016). BEVs are increasingly taken into use in single vehicle households and to cover both the shorter daily and longer distance transportation in multi-vehicle households.

The EV association, Nordic Energy Research and Opinion AS carried out a survey of the general public perception of BEVs and purchase intentions in the Nordic countries in January 2018 (Elbilbarometer 2018). The survey has a representative sample of 1001 responders in Norway. They found that 89% of the Norwegian population knows someone that owns a BEV, 66% have been a passenger in one and 34% have driven one. Only 22% have never been inside a BEV. 3% of the sample said they would buy a new BEV the next year, which Opinion interpreted into a latent market of about 70 000 BEVs in 2018. The number might be optimistic. Equally many will buy an ICEV, and even more people a PHEV, which sums up to a total number of purchase intentions larger than the expected annual vehicle market. A more realistic number would be to split an estimate of the total market, by the stated buying intentions for different technologies, which would give a potential market for about 40 000 BEVs in 2018. The markets look totally different in the other Nordic countries with much smaller market shares due to smaller purchase incentives and less awareness of BEVs than in Norway. Another finding was that Norwegians do not worry about the second hand value of BEVs, which is a big concern in other countries. In Norway 38% actually believe that ICEV cars will be less attractive in the second hand market than BEVs, only 20% believe the opposite to be likely (Elbilbarometer 2018).

7.2 Range increasingly compatible with needs of users

Long distance driving is done fairly seldom by the average consumer as seen in chapter 5. These trips needs to be possible to do with little extra effort, if all drivers are to switch to BEVs. Figure 7.1, based on figure 5.6, illustrates that the first generation of BEVs meets average users driving needs on 340 days/year without using fast charging. Gen 2 BEVs cover another 16 days of driving needs. Tesla Model S/X and coming Gen 3 vehicles covers all but 4-5 days/year. On an average day the fast charging infrastructure for a fleet of only Gen 3 vehicles would need to support 1 fast charge for 13 000-52 000 Gen 3 vehicles. In a fleet of only Gen 2 vehicles, 1-2 fast charges would be required for 100 000-180 000 vehicles/day. Providing fast charge on long distance trips for a fleet solely consisting of Gen 1 vehicles is not realistic. It would simply require too many fast chargers.

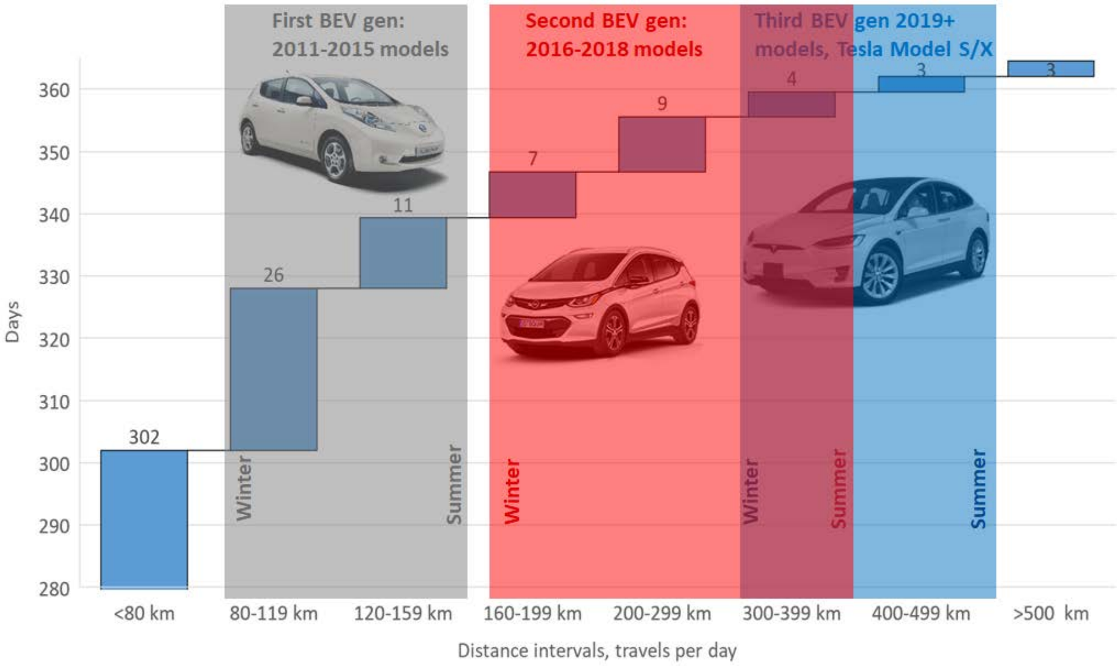


Figure 7.1: Number of days of the year with total driving within distance intervals, colored areas mark the spread of range of different BEVs in the winter and summer seasons. Based on data from Hjorthol et al 2014 and authors assessment.

A large share of these long distance trips could potentially be centered around national holidays and vacation periods, leading to higher shares of vehicles on long distance trips on these peak travel days. The traffic flow on holidays, and the distances travelled summer and winter, is thus of importance when analyzing the prospects of switching the entire vehicle fleet to BEVs. The share of vehicles with different range is also a parameter needed to be able to estimate the needs for fast chargers in fleets consisting of different vehicle generations.

Figenbaum and Kolbenstvedt (2016) asked BEV, ICEV and PHEV owners how long the winter range of BEVs should be to make more people interested in buying them. The result is shown in figure 7.2 together with the range of different generation BEVs.

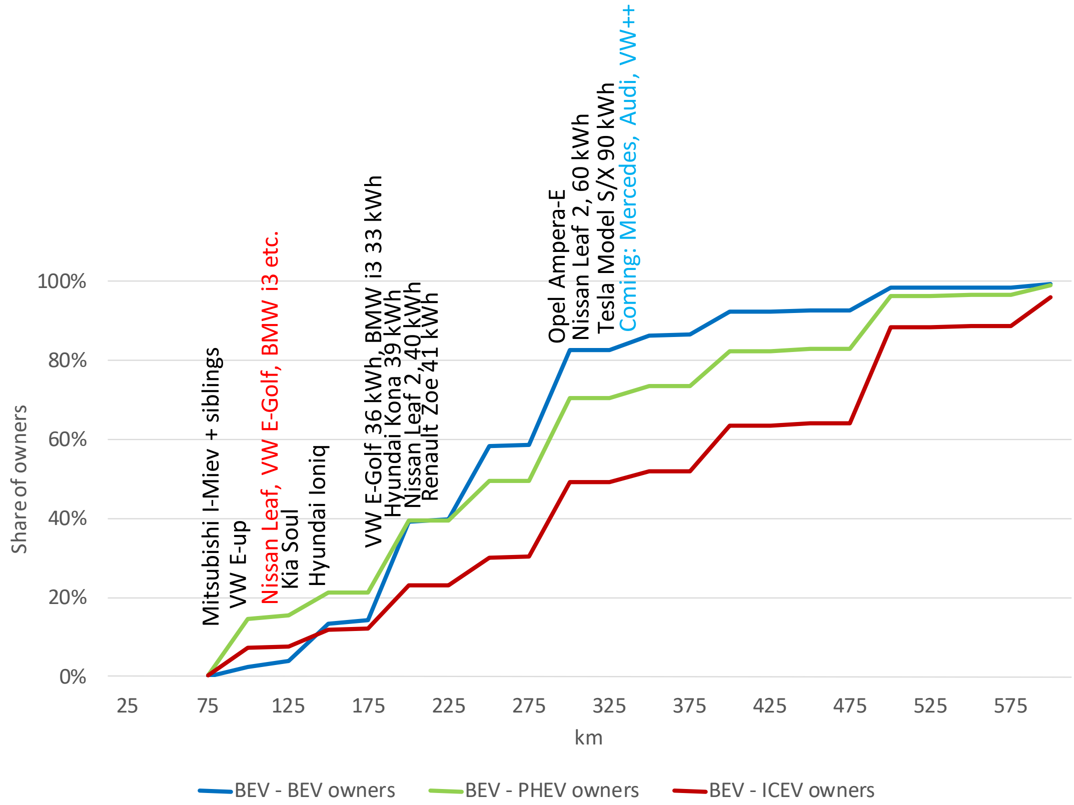


Figure 7.2: BEV, PHEV and ICEV owner's suggested winter driving range that they believe will make BEVs interesting for more people. N_{BEV}=2613, N_{PHEV}=1618, N_{ICEV}=2579: Adapted from Figenbaum and Kolbenstvedt 2016.

BEVs on the market up to 2016 (apart from Tesla Model S and X) had a range that less than 5% of ICEV and 15% of BEV owners said was good enough to attract more buyers. BEVs with larger batteries, such as the 2018 Nissan Leaf, 2017 VW E-Golf and the BMW i3, are seen as adequate by 40% of BEV owners, and about 20% of ICEV owners. BEVs with range up to 300 km in the winter (Tesla since 2013, Opel Ampera-E since 2017), is seen as sufficient by 50% of ICEV owners and over 80% of BEV owners. The acceptability among ICEV owners might increase and come nearer to the levels seen for BEV owners, once they get to know BEV capabilities better. Improve infrastructure may also lead to increased acceptance for vehicles with shorter range.

The differences between provinces in acceptability among BEV owners and ICEV owners is fairly small as seen in figure 7.3. The tendency is the same everywhere. ICEV owners want much more range than what BEV owners believe is sufficient. For BEV owners the winter range acceptable to over 50% in all provinces is 250 km, for ICEV owners 400 km. The acceptable BEV range does not seem to be lower in provinces with a high BEV share, but acceptability is lower in provinces with long driving distances and a rural population.

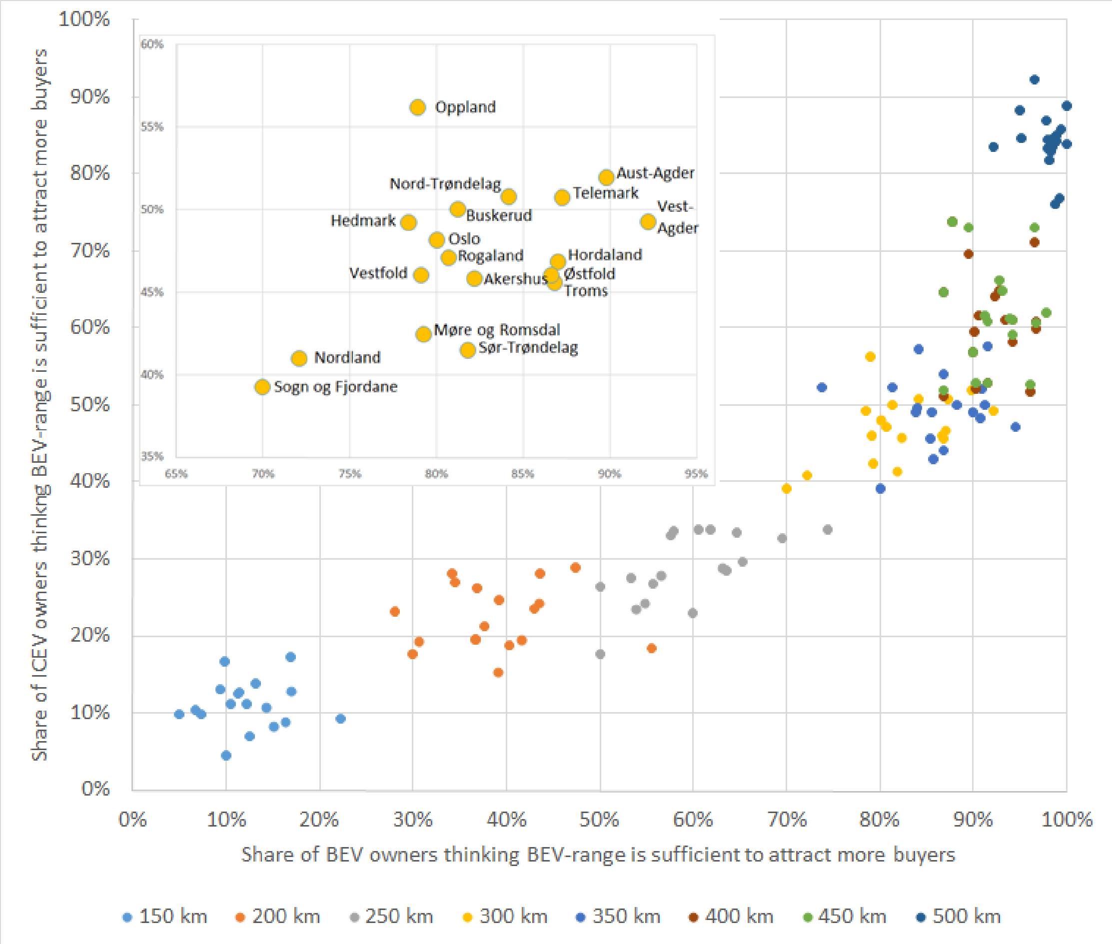


Figure 7.3: Difference in acceptance of winter range of 150-500 km of BEV owners and ICEV owners. Each dot is the average per province. The position of the named provinces shown for 300 km winter range. N_{BEV}*=2613,* N_{ICEV}*=2579. Adapted from Figenbaum and Kolbenstvedt 2016, dataset.*

7.3 Loyal if economy of use and incentives continues

The user survey in 2016 (Figenbaum and Kolbenstvedt 2016) showed that 88% of BEV owners will buy a BEV again (about the same as in the 2014 survey of Figenbaum et al 2014). Among ICEV owners 63% will buy and ICEV again. The main reason to buy a BEV again was economy of use, environmental concerns and the availability of the free toll road incentive (Ibid). The interest to buy again is likely influenced by the generous incentives, as local driving privileges and incentive should be seen as an integral part of the ownership experience. ICEV owner reasons not to buy an ICEV again were related to environmental concerns, or rather wanting a PHEV or a BEV. The main reason to buy an ICEV again was reliability. It is therefore advantageous that second hand value of BEVs is now seen as less of a problem in the 2016 survey than in the 2014 survey (Figenbaum and Kolbenstvedt 2016). In the 2014 survey, 30% of ICEV owners said they would consider buying a BEV next time they buy a vehicle, 28% didn't know (Figenbaum et al 2014). The question was not repeated in the 2016 survey.

The market will react to changes to incentives. Some incentives are already on the way out, such as free ferries no longer available on some services, and free parking being scaled down. The law on toll roads is being revised so that BEVs can start paying toll roads, but the Parliament limited the payment to maximum 50% of the rates for ICEVs in 2016

(Stortinget 2017). In the national budget for 2018 it was decided to reduce the imposed benefit taxation rate advantage for BEVs used as company cars from 50% of the rate of ICEVs to 60% of the rate of ICEVs. Another proposal in the national budget for 2018 was to introduce a small registration tax on the heaviest BEVs (above 2 tons.). This proposal was turned down in the Parliament. A number of larger BEVs coming on the market in 2018-2019 would potentially be hit by this tax, had it been introduced.

7.4 An avalanche of new models will expand the market

An avalanche of new and second generation BEVs, including longer range versions of existing BEVs, will come from most vehicle manufacturers 2018-2021, as seen in table 7.1. There will be new offerings in all vehicle segments. The list of models in table 7.1 is not exhaustive. These model announcements have been followed by announcements of large increases in R&D spending for BEV development, and investments in production facilities, from manufacturer such as Ford (2017), GM (2017), Renault (2017), VW (2017), BMW (2017b) and Mercedes (2017b). Volvo and Toyota has announced that all models will be electrified in the future, although not specifying the shares of BEVs in the model mix.

The biggest near term development in vehicle offerings will come in the medium, large and luxury segments. These segments had up to now either no offering, or only a couple models have been available. The competition will also be tougher in the compact segment, with many new models coming on the market.

Table 7.1: Vehicles coming on the Norwegian BEV market 2018-2021(status 12/2017). New and reworked longer range models. SUVs and MPVs placed according to size as small, compact, medium, large, luxury. Sources include manufacturers web sites, vehicle news services etc. The list is not exhaustive, but examples of vehicles coming.

Segment	2018	2019	2020	2021
Unknown segments		2 Nissan models	Audi, Ford-CUV, Skoda	Genesis, Kia, Hyundai, 5 new Renault models, Subaru-CUV
Mini		Mazda	Mitsubishi	
Small			Peugeot-208	Citroën DS SUV Peugeot-2008
Compact	Nissan-Leaf2, Kia-Niro, Kia-Stonic, Hyundai-Ioniq, Hyundai-Kona	Mini-Cooper-E, BMW-i3-2, Volvo XC4	Mercedes-EQA Ford, VW-ID-Hatch	
Medium	Tesla-Model3	Mercedes-EQC	BMW-4-GT, BMW X3, VW ID-CUV	VW ID-Sedan
Large	Jaguar-I-Pace, Audi-E-Tron-SUV	Volvo	Tesla-Y, Audi-E-Tron-Sportback BMW-i5/INext	Mercedes-EQE VW-ID-Buzz
Luxury	Aston-Martin-RapidE	Porsche-Mission-E		Mercedes- EQS
Sport		Tesla-Roadster		

Notes: Mercedes: 6 additional models expected up to 2025. Opel: Additional Models expected.. PSA: Peugeot, Citroën and Citroën DS, 2 more models planned for introduction 2022-2025. Toyota: 10 models by early 2020s, new division lead by CEO to develop BEVs. Skoda: 6 additional models by 2025. Porsche: Additional variants planned. BMW plans BEV versions of all model lines introduced after 2020, all model lines can have any powertrain.VW: Additional models planned for 2022-2025. Likely to replace E-Up mini vehicle with upgraded model. Chinese manufacturers could introduce additional BEVs in European market in this timeframe. More replacement vehicles and new models are likely also for the mini segment, but none has been disclosed.

The large increase in models and availability by market segment will lead to a much more competitive market, putting pressure on manufacturers to reduce prices. Many of these vehicles use battery cells from the same battery manufacturers, leading to rapid volume increases which should decrease battery cost even faster than what Nykvist and Nilsson (2015) found up to 2015.

Fearnley et al (2015) found that an increase in the availability of BEV models will drive the Norwegian market upwards rapidly, and is a more important than reducing prices. For Austria the result was the opposite, reflecting the different stages of BEV diffusion these countries are in, and the differences in purchase incentives.

7.5 Implications for further research

The large difference in perception of the need of range between BEV owners and ICEV owners could be due to differences in needs, experience or perception of the technologies capability to provide transportation services to the household. Further research should be directed at fining the real needs for range and infrastructure for different types of users.

Another research question is if there is a psychological effect of changing incentives beyond the economic or practical effects. For instance, it could raise an expectation of further weakening of incentives, that could make consumers more uncertain about the future value of BEVs in the second hand market.

When the local incentives are scaled back will the purchase incentives alone be a sufficient incentive? How deep is the loyalty to BEVs in future purchases, i.e. how much depends on the future of incentives, how much on the price of vehicles, and how much on the future technical development? Will current BEV owners remain faithful to the technology even if the incentives are reduced?

A further factor will be the increased availability of attractive models with longer range and faster charging in more vehicle segments from more brands over the coming years. A better understanding of what the mix of the fleet will be in terms of range, is also required to estimate the needs for fast chargers and other public charging infrastructure.

8 Business impacts and potentials

The development of the BEV market in Norway is supported by the efforts of a number of different enterprises in many business sectors. Some of these have merely revised their business strategies and focus, while new enterprises have emerged, and in some cases new business segments and sectors. A detailed analysis is beyond the scope of this report.

The following sections provide a starting point for further analysis.

8.1 Opportunities and threats for existing enterprises

BEVs where before 2010 sold through special BEV dealers. When the traditional automakers entered the BEV market, these early niche actors soon went out of business, unable to compete with the nationwide dealer networks of the traditional automakers. New BEVs are now exclusively sold through the vast nationwide dealer networks of the traditional auto-importers, while some independent dealers import second hand BEVs from other countries, as demand is high.

Selling a BEV instead of an ICEV will in general not affect the vehicle sales part of the dealerships much, although the new technology in these vehicles may take longer time to explain to buyers in the buying and hand over process (Assum et al 2014), potentially leading to lower margins. BEVs require less maintenance as there are fewer moving parts that can wear out (UBS 2017). These facts will affect the service and maintenance of vehicles, an important business for dealers. BEVs lead to less manpower needs in service workshops, if new activity or offerings is not found.

The Norwegian automotive parts industry is mainly involved in delivering plastic and metal parts and electromechanical assemblies to vehicle manufacturers. They have diverted into the EV business with for instance Kongsberg Automotive supplying chargers to Volvo through the subsidiary ePower. ePower was however in November 2017 sold to the German automotive supplier Preh (Kongsberg Automotive 2017).

Norway has a large materials and metallurgic industry that also has started to deliver materials to battery cell producers, for instance Elkem. The rapid international development of batteries can lead to further opportunities for these industries.

8.2 New industries, business models and infrastructure

The research on new materials for batteries or smarter charging can lead to the establishment of new spin-off companies from universities and existing enterprises.

Norway have had a couple of BEV producers producing the Think and Buddy vehicles. These are now out of business, but Paxter (2018), a new company, produce four-wheel street scooters that have been taken into use by the Norwegian post.

Zaptec produces chargers for BEVs and has delivered charging cables with a built in EVSE-controller combined with an ultra-compact transformer, to Renault in Norway (Zaptec 2015). Zaptec now produce flexible charging solutions for apartment building parking facilities (Zaptec 2018). Salto is a designer and supplier of smart home chargers and fast chargers. Salto was recently bought by DEFA, a traditional Norwegian automotive aftermarket supplier of electric engine block and cabin heater systems. Meshcraft is providing back-office solutions for charger operators. Nor-charge provides charge stations and back-office solutions.

Charging infrastructure providers is a new businesses segment that have emerged since 2010. They install and operate fast chargers in cities based on commercial criteria, and between cities along major highways. The latter as a response to public tenders and support schemes. The main national actors are Grønn kontakt and Fortum Charge and Drive. Ishavsveien, Lyse kraft and BKK are smaller actors in limited geographical zones. Some municipalities and provinces have also supported the installation of fast chargers, but these are normally operated by one of the major actors. The fast charging infrastructure construction and required support functions, provide entrepreneurs and electricians with new business opportunities. One example is Infra-Tek. The same is true for local electricians that has added business opportunities from installation of home chargers.

Fuel stations are increasingly installing fast chargers, mainly franchise takers initially, but with the advent of ultra-fast charging it is expected that the fuel chains will start installing fast chargers, as seen by the Ionity initiative (Ionity 2017) cooperating with Circle K in Norway (E24). Over time the BEV expansion will erode the market base of fuel stations in and around cities. BEV owners get most of the energy by charging at home, and fast charging may take place in new locations. The traditional fuel stations will be better positioned for the intercity traffic energy supply market due to optimum locations and existing exits and entries along the major motorways. The total number of fuel stations in Norway declined 7% between 2012 and 2016 (NP 2018), potentially a sign that the market for fuel declines. BEV charging infrastructure is increasingly used to attract customers to food stores and shopping centers. The food store chain Kiwi has installed fast chargers outside numerous shops, all IKEA furniture shops have fast chargers and there are fast chargers outside many McDonalds fast food restaurants. These fast chargers are typically operated by one of the national charge operators.

Public normal chargers are less of a business case for operators due to the high cost of the infrastructure and the very low amount and value of the energy that can be transferred to the vehicle per unit of time. These chargers mainly generate a business for the operators if they attract customers to other business generating activities such as shopping centers.

BEVs could go hand in hand with car sharing in cities. MoveAbout is an example of a company that offers businesses shared BEVs as an alternative to tradition vehicles and taxis. Bilkollektivet (2018), a car sharing system in Oslo, offers BEVs and FCEVs for rent to its members as part of their total offer of vehicles.

8.3 Implications for research

The business impacts seem to follow a three pronged path. Existing actors loose some opportunities, but if they can revise their product portfolio and take advantage of new opportunities, they might be able to keep their market position. New actors that can more easily take advantage of the new opportunities have entered the market, and has an opportunity in the booming BEV market in Norway. BEVs open up for completely new business concepts or the linking of BEVs to other newer concepts such as car sharing and in the future also autonomous driving. Research should aim at establishing new knowledge about business impacts of BEVs along these lines.

9 Discussion and conclusions

The BEV market in Norway is gaining momentum each year, to the extent that a BEV regime is about to emerge according to an analysis using the Multi-Level Perspective (MLP) research framework (Figenbaum 2017). A regime is in this sense defined as the motoring practices, companies, services and authorities involved in establishing BEVs as a part of the societal way of doing transportation. BEVs struggled for a long time to get a foothold in Norway. As seen in this report, BEVs is increasingly becoming a standard vehicle technology option for Norwegians and now approach a 40-50% market share, thus providing further evidence to the conclusions put forward in the MLP analysis.

A rapidly increasing number of companies are involved in developing this new regime further, such as fast charge operators, electricians and entrepreneurs installing charging infrastructure, vehicle importers and traditional ICEV actors. Several vehicle importers now rely on BEVs to increase and defend their market shares.

The charging infrastructure has expanded. More than 1 000 fast chargers were installed in Norway by October 2017. Enova support has led to the installation of fast chargers every 50 km on main roads, enabling long distance driving with BEVs (Enova 2017). 3 000 Type 2 public charging points and more than 42 000 Type 2 home charging points have been installed. The total infrastructure investment has passed 1 billion NOK.

The total vehicle market has however been fairly constant between 2010 and 2017. The trend in the number of vehicles per household has not changed after BEVs came on the market. It thus seems that BEVs replace ICEVs, leading to less fossil fueled vehicles on the road than would otherwise have been the case. The number of ICEVs per household has peaked and is going down in provinces were BEVs are popular, such as in Akershus, Vest-Agder, Rogaland, Hordaland and Sør-Trøndelag. The ICEV ownership flattens out in Oslo, Telemark, Buskerud, Østfold, Vestfold, Aust-Agder and Møre og Romsdal.

BEV ownership is particularly strong in areas around expensive toll roads in rural coastal areas. The majority of BEVs however traffic city roads, benefitting from the exemption of city toll roads, and the access to bus lanes and free parking. The share of BEVs in the traffic flow through toll road gates passed 12% in Bergen (Bergen Bompengeselskap 2017) and 10% in Oslo (Fjellinjen 2017) , in the first half of 2017. The air in the cities should thus be less polluted in the coming years, in conjunction with the decline in the diesel vehicle share of new vehicle sales. In all these city toll rings the BEV share of the traffic is higher than the BEV share of the fleet, indicating that these vehicles are put to use in everyday traffic.

The toll roads on the main roads and motorways between cities have much lower BEV shares. The reason is the low BEV share in the fleets in these areas, and that few BEV owners take their BEV on long distance trips. The main roads south west of Oslo have higher BEV shares, likely due to a combination of local traffic between cities along the coast, and fairly high BEV shares in these cities.

A new generation of BEVs is coming on the market. The number of makes and models is increasing. There will be offerings in all popular vehicle segments. These vehicles transport utility will be significantly improved through longer range and faster charging. The latter may very well be the most significant development if the charging infrastructure can be built out sufficiently. Fast charge times can approach the fill-up time of ICEVs, or be accomplished within normal stops on long distance trips, when the charge power increases from 50 kW to 150-350 kW. In theory fast charges takes a long time, longer than normal break time even with 150 kW chargers. Users are however likely to minimize charge time at fast chargers as they can charge at home at less than a third of the cost of fast charging. One can therefore expect that they will fast charge enough to get to the destination and rather fill-up the battery 100% there.

The average user will save money using home charging with cheap electricity at the cost of using more time on long distance trips. When the fast charge is increased above 80 kW and the battery capacity reaches 60 kWh, the cost of time on a 500 km trip will be reduced so much that a long range BEV will have a lower total trip cost than a diesel vehicle, measured as the cost of charging plus the cost of time. The BEV owner will however use about 20 minutes longer total time in the winter season. If the charge power is increased to 150 kW or higher, BEV owners will be using about the same time as an ICEV owner on these trips. The reason is that fast charging will be accomplished during breaks that users have on long distance trips anyhow, and the battery will be recharged to 100% at the destination.

It will be challenging to provide fast charging to everyone on peak travel times, such as winter holidays. The summer vacation time will be less problematic, with driving more spread out, BEV range at its maximum, and with the batteries capable of charging with the maximum fast charge power. The traffic flow and travel distances on holidays is of particular importance for the prospects of switching the entire vehicle fleet to electricity. Preliminary analysis shows large geographical and seasonal differences in the travel volumes on major roads, which could make it very challenging to put in place a fast charging infrastructure to handle these differences completely. The issue will be reduced if long distance drivers buy long range BEVs.

The needs of users, the potentials to change their habits, the new possibilities provided by longer range BEVs coming on the market in the coming years, improvements in the infrastructure, and national policies and incentives, will influence the BEV market. Up to 2018, most users have been multi-vehicle households, using their vehicles mainly for local travel. BEVs must make the step into the rest of the market, also replacing the vehicles used on long distance driving and for vacations. The market will move from enthusiastic early adopters, and early majority buyers, to the late majority and the more skeptical laggards. These groups will be more difficult to persuade to make the switch to BEVs. They will need to be convinced that BEVs solve their travel needs at acceptable cost and risk. Cost efficient solutions for charging vehicles parked roadside in cities must be found. Such a massive societal challenge will need to be supported by efficient policies and incentives also in the coming years.

BEVs is not the only new technology on the horizon. The competition and market appeal differences between BEVs, PHEVs and FCEVs will be influenced by their development paths, the selection of models, and the extent that the necessary infrastructure is built out. The demand will also be shaped by national policies and the incentives offered. There are segments of the consumer market where BEVs may not be the most attractive option, for instance those that tow heavy trailers.

Research results will quickly be outdated by the rapid changes in the technology and the build out of charging infrastructure. ELAN will therefore study the effects and effectiveness of these policies and incentives, and the expansion of the charging infrastructure, on the diffusion into the mass market of the next generation of BEVs.

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