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**Summary:**

# **Electric Vehicles - environmental, economic and practical aspects As seen by current and potential users**

TOI Report 1329/2014

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Oslo 2014, 141 pages English language

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*Electric propulsion is much more energy-efficient than internal combustion engine based propulsion (ICEs), and electric vehicles (EVs) emit neither local pollutants nor greenhouse gases. Norwegian authorities have introduced a number of incentives for EV diffusion, in order to support a transition to environmentally friendly transport. A survey among 1 721 EV owners shows that they experience few disadvantages and that the number of EV-only households is growing. EVs are mostly used for daily travel, especially to work, and the number of km driven annually by EVs is similar to that of the average car. The majority does not change their travel pattern when buying EVs and most EVs replace an ICE car. When an EV is acquired as an additional vehicle, some respondents increase their driving. Many EV owners are active people with high incomes living in large households in or around cities, and thus similar to other multicar owners. They value the economy of electric motoring, the environmental benefits, and most importantly; that EVs meet their transport needs. Almost all EV owners plan to continue buying EVs. Media and social networks seem to be the most important channels for the spread of knowledge of EVs. A parallel survey of 2 241 owners of ICE cars finds a growing interest in electric motoring, with one third of the respondents considering buying an EV. With the continuation of current incentives the market share of EVs will probably continue to increase.*

## **Surveys among EV users and average car users**

The study is a part of COMPETT, an ERA-NET Electromobility+ project aiming at contributing to an increased use of EVs. To gain more knowledge about current and potential users, two internet surveys were conducted in February 2014:

1. One survey answered by 1 721 members of the Norwegian Electric Vehicle Association (NEVA). All buyers of EVs are offered a one-year complimentary membership in NEVA, and 40% of the EV owners in Norway are members. The respondents received a newsletter distributed to 9 051 members. The respondents represent 8% of EV owners in Norway.
2. One survey where 2 241 member of the Norwegian Automobile Association (NAF) responded to a letter of invitation sent to 10 000 randomly chosen NAF members representing average car owners. This survey contains 672 potential EV buyers, 929 average car owners that do not consider buying an EV next time, while the rest has not yet decided.

Both surveys covered the Oslo-Kongsberg region, the most EV-dense region in Norway, with 40% of all EVs in Norway as compared to 20% of the country's population. The NEVA member survey also covered the rest of the country. The respondents are persons 18 years and older belonging to car-owning households. These characteristics were also the basis for a special sample extracted from the

National Travel Survey (NTS 2009), which serves as a reference point for the average person in car owning households in the population.

## Norwegian framework conditions favouring EV use

In February 2014, at the time the survey was conducted, EVs made up slightly less than 1% of the total fleet of passenger vehicles in Norway. The market share for EVs for new cars sold in 2013 was 5%. However, in 2014 (January-May), this share increased to 13%.

Norway has access to clean, CO<sub>2</sub> free and cheap electric power. EV engines are also more efficient than conventional engines, especially in urban settings. Norwegian speed limits are EV-friendly, with a maximum speed of 100-110 km/h on motorways and of 80 km/h on main roads. EV range is thus longer in Norway than in countries with higher speed limits, as energy consumption increases rapidly at higher speeds.

To profit from these advantages, the Norwegian Parliament and national and local authorities have developed incentives aimed at removing barriers for electromobility, like high purchase price and shorter range than Internal Combustion Vehicles (ICE). Exemptions from Value added tax (VAT), registration tax as well as a reduced annual vehicle licence fee have made EVs cheaper than similar ICE cars. Attractive local incentives are access to bus lanes, exemption from toll road charges (Norway has toll roads spread throughout the country), and cheaper ferry rides on the coastal main roads. To reduce possible range problems, Norway gives national, and in some places local, support to establishing charging infrastructure. 4 500 charging points were publicly available at the time of the survey.

## EV owners are similar to other multicar owners

The typical EV owner is male, 35-54 years old and working full-time. Compared to members of the car association (NAF) and the general population (studied in the National Travel Survey NTS), they are more likely to hold a five year university degree, and live in large, high-income, multicar households with children that are below 18 years old, located in and around big cities.

The share of multi-vehicle households amongst EV owners is 74%, and is larger than the nationwide average multivehicle ownership rate of 50% (among households with vehicles in NTS 2009). Comparing EV owners with other multicar owners who bought their last car less than two years ago, large socio-demographic similarities between the two groups are found. Figure S.1 illustrates this comparing household economy.

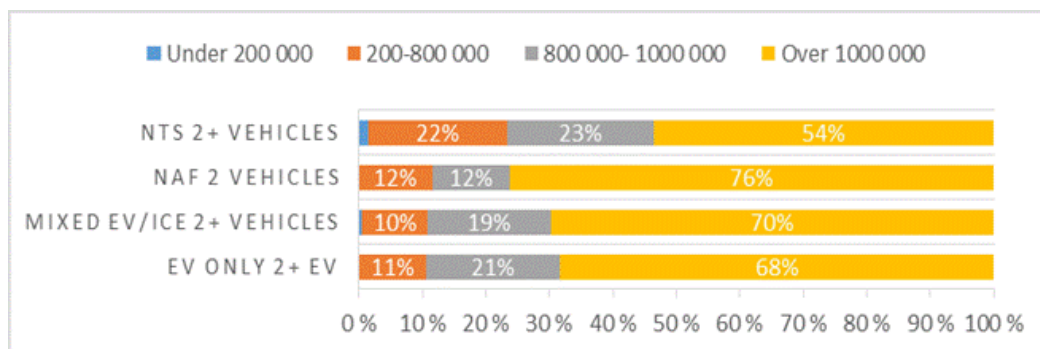


Figure S.1 Household income pr year (NOK) for persons belonging to multicar households owning a) ICEs only (National Travel Survey n = 801 and NAF n = 145), b) a combination of ICE and EV (n = 192) or c) only EVs (n = 19) in Oslo-Kongsberg region who bought their last car less than two years ago. Percent

## One third of EV owners belong to EV-only households

The study finds a higher percentage of EV-only households in the EV-fleet than earlier studies, see figure S2. This probably reflects the improved range, performance, larger size and reduced price of newer EVs.

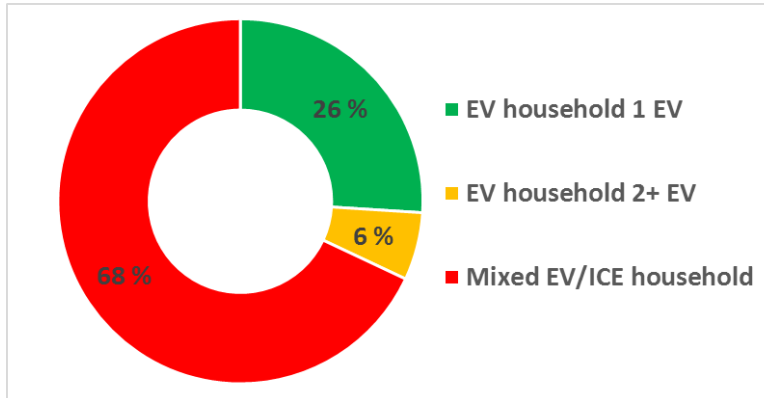


Figure S2 Share of EV-only and mixed EV/ICE households among EV owners in Norway ( $n=1\ 721$ ) in 2014. Percent

The share of respondents belonging to EV-only households was much larger in Oslo with 41%, than in the neighbouring municipalities, Bærum with 21% and Asker with 18%. This is probably related both to shorter distances and to the larger share of single-person households in Oslo. The EV-only households have equal shares of Nissan Leafs as households with EV and ICE(s), but higher shares of Tesla Model S.

The highest share of experienced EV owners are found among EV-only households owning more than one EV. Among the single vehicle EV-only households, 15% did not own a vehicle before, i.e. they bypassed owning an ICE vehicle. The majority (82%) of EV owners in the sample bought their cars less than two years ago, and most of them are first-time EV buyers. In the Oslo-Kongsberg region they bought new vehicles (81%) to a larger extent than NAF members (44%).

## Information from several channels

EV-owners rate their technical competence when it comes to cars higher than members in the Norwegian car organisation (NAF) in general, also when compared to those members who bought their car less than two years ago and those who will consider an EV the next time they buy a car. 84% of the EV owners had already decided to buy an EV when visiting the dealer. The EV-incentives and the comprehensive media coverage (mentioned as an information source by 77%) seem to be the most important drivers in the acquisition process. The market pull also appears to be generated and influenced by friends and family. 28% had received their information about EVs from friends and family and 6% from organizations. 13% received the information from the dealer.

## Motives related to economy, environment and needs

The most important factors influencing EV owners' purchase were lower operating costs, EVs being environmentally friendly, free toll roads, lower annual circulation tax, competitive price and that the car was "the best vehicle for my needs", see figure S3. For average car owners here represented by NAF members, the most important factors when buying vehicles were safety, competitive price and "best vehicle for my needs", followed by operating costs, see figure S4.

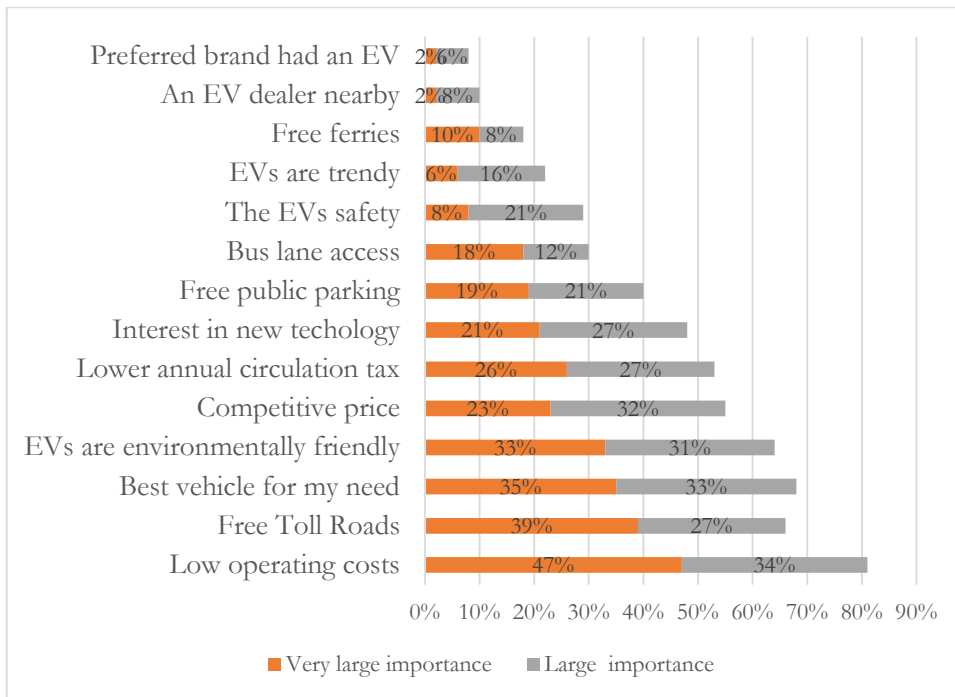


Figure S3 Important factors when buying an EV among EV owners in Norway (n = 1 721). Percent

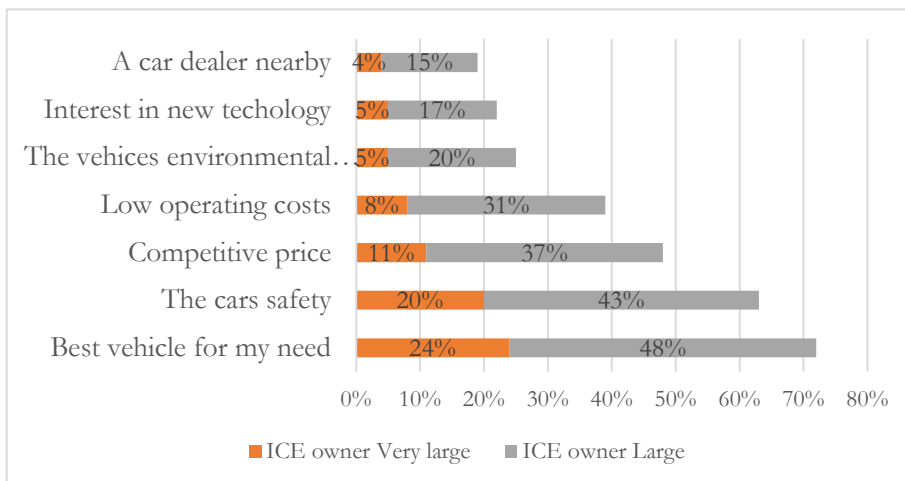


Figure S4 Important factors when buying a car among members of the Norwegian Automobile Association (NAF) in Oslo Kongsberg region (n = 2 241). Percent

## The use pattern is related to daily transport needs

EVs in Norway drive 14 000-15 000 km/year on average, as assessed on the basis of a combination of responses to questions about insured driving distance and odometer readings. The annual average mileage of new ICE vehicles in Norway is 15 160 km the first year, 14 800 km the second and 13 400 km the third year. It can thus be concluded that the annual driving length for EVs with the latest technology is about the same as for new gasoline vehicles.

81% of EVs are driven daily, another 16% 3-5 days per week, i.e. they are used for everyday transport activities. They are used for trips to and from and at work, for shopping, for visits, for escorting children and for leisure activities, but less for vacation. The average number of trips undertaken the last weekday before the survey is about the same as the Norwegian average, but the total distance travelled is longer.

The average distance to work for EV owners is 26 km, considerably longer than the Norwegian average of 15 km. First-time owners have longer distances to work, and those who have owned EVs for more than five years have the shortest distances, which probably reflects the technical development of EVs.

## The majority has not changed their travel pattern

69% of respondents report that the EV replaced other vehicles, for 28% it was an additional car in the household and for 3% it was their first vehicle. The smallest EVs became to a larger extent an additional vehicle, while the Tesla Model S replaced an existing vehicle in 86% of households. 94% of the replaced vehicles were ICEs. 62% of the respondents did not change the household's total insured driving distance when buying the EV, 18% increased it, 6% decreased it, and the rest had owned the car less than a year or did not know. The majority of respondents reported that they had not changed their travel pattern. From an environmental point of view we find both positive and negative changes, see figure S5.

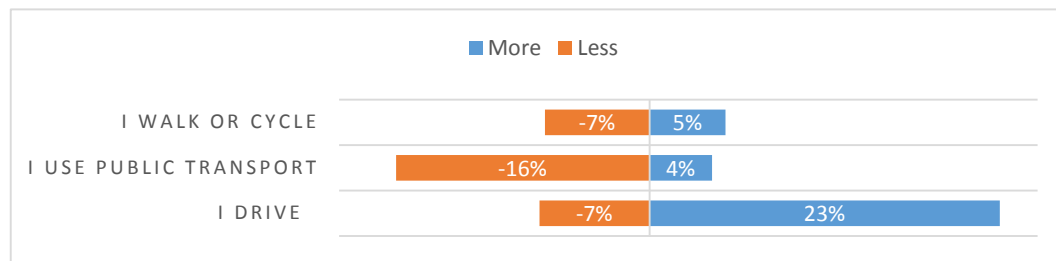


Figure S5 Changes in the travel pattern among EV owners in Norway 2014 (n = 1 722). Percent

Single vehicle EV households underwent the largest changes to their transport patterns. This is also true for the work trip, where one in five drive more after buying an EV. It is not possible to know whether similar modal shifts would have occurred anyway, i.e. that they had bought an ICE if EVs was not available. It is however likely that part of the changes can be attributed to the availability of the EV incentives.

## Most EV owners have satisfactory access to charging

EV owners are comfortable using on average 85% of the vehicle's range, and one in five are even comfortable using over 90%. This is a much higher rate than found in earlier studies, and indicates that the range meters probably function well and that EV owners in Norway have good access to public and private charging. Few (12%) have experienced running out of power when driving. Most EV owners had no problem choosing a charging solution, but around 10% (27% for Tesla) had experienced some problems selecting charge cable or home charging unit.

65% charge their vehicle daily at home in a garage, carport or outdoor, most in garages. Another 20% charge at home 3-5 days per week and another 15% 1-2 times per week. Public normal charging is used at least monthly by about half of the EV owners, and 7-14% use it weekly. This charging is usually free. Work place charging is more widely used than public charging.

The average annual number of fast charges per vehicle is about 14. 27% use fast chargers more than once per month, 6% are weekly users. EV-only owners use fast charging more than owners in multicar households. Half of the respondents do not pay for fast charging. There appears to be no difference between summer and winter,

even if the range is halved on cold winter days (except for Tesla), and one would expect owners to compensate by using fast charging more. However, fast charging speed is reduced to about half in winter, due to battery limitations, making it more cumbersome, and queues at fast charge stations potentially longer.

## **Opinions of EVs owners, EV buyers and others differ**

The EV owners' opinions about the advantages and disadvantages of EVs differ widely from those of members on the Norwegian Automobile Association (NAF) in general. More than half of NAF members and only about 20% of EV owners rate vehicle range, access to charging stations and charging time as big disadvantages. Four out of five EV owners, but only two out of five NAF members rate operating costs as a big advantage. However, the potential EV buyers among NAF members are very similar to EV owners and rate the performance of EVs higher than other NAF members.

Challenges with EVs are mostly related to the range being shorter and the winter performance worse than expected. When the EV's range is too short for the day's driving, EV-owners employ a strategy of planning the trip better, driving more efficiently and turning off heaters and AC. When this is not sufficient, they visit a fast charging station. When longer trips need to be undertaken, multicar households use another vehicle or public transport. Single EV households borrow vehicles from family or friends, rent a vehicle, use public transport or may even give up doing the journey. The EV owners plan for about 25-30% shorter range in winter than in summer. It should be noted that the winter 2013/14 was unusually warm in Norway.

The EV owners are not a homogenous group, however, and safety is rated very highly by Tesla and Nissan Leaf owners while owners of other brands rate it lower. Tesla and Nissan owners are happy with the vehicles' comfort and acceleration, the Tesla Model S is in a league of its own with 94% rating this as an advantage. The heating system is a component that divide EV owners. Tesla owners are very satisfied, and Mitsubishi/Peugeot/Citroen owners rather dissatisfied. For other factors the results do not differ much between vehicle makes and models.

## **Large regional differences**

There are large regional differences in the advantages the users report from the various incentives. Bus lane is more valued in the Oslo-region, where time savings are large (up to 30 minutes), whereas reduced ferry rates are more valued in the coastal regions in the west and mid parts of Norway. The share of EV owners using both free toll road and access to bus lane more than twice a week when driving to work is only 33%. In addition 26% uses toll roads only and 6% bus lanes only. It appears that EV owners live and work in areas where they to a larger extent can use these facilities than members of the Norwegian Automobile Association (NAF) who do not own EVs. Many NAF members being older and not working, can not take advantage of the bus lane and free toll road incentives.

The average annual value of free parking per EV is estimated to be 3 350 NOK. NAF members spend slightly less on parking than EV owners report that they save. The estimated value of all incentives per average EV in Norway are shown in figure S6. The total value for the fleet of 25 000 EVs in April 2014 was 400 million NOK.



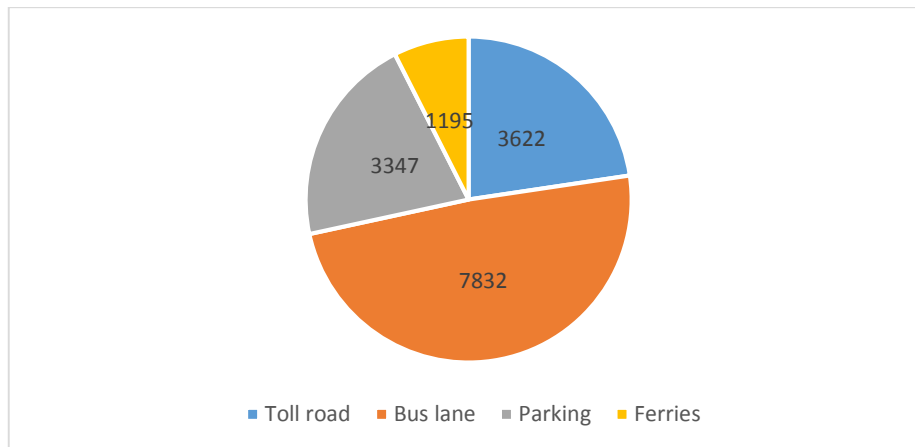


Figure S6 Average calculated value of local incentives per EV. EV owners in Norway 2014. NOK pr year

## EV customers in the future

Almost all EV owners (87%) will continue to buy EVs in the future. Less than 1% will not and 12% are undecided. The motivations to buy again are related to economy and incentives, environment, and the joys of EV motoring (comfort, low noise), and that it fits the user needs. Some also state that it is the technology itself, believing it to be the future of motoring, that is important.

The study confirms findings from innovation studies, which show that three factors are important for the spread of environmental technologies:

- The technology's characteristics and possibilities for future improvement of the technology relative to user needs - and knowledge of the technology
- Communication technologies, where both media and social networks have played major roles
- Societal support in the form of various incentives, as environmental technologies often entail additional costs for users

Both EV owners and potential buyers are more interested in technology and have more knowledge about EVs' properties than car owners who presently do not imagine buying an electric car. Increased knowledge of EV technology is thus a potential measure to increase the market share.

When it comes to communication, the surveys show that satisfied EV owners are of great importance for the further spread of EVs. A third of EV owners have friends who have bought an EV and a further third have friends who consider purchasing an EV. The importance of social networks can also be observed among the members of the Norwegian Automobil Association (NAF) who own ordinary cars. 30% of them would consider an EV the next time they buy a car. Among NAF members who have friends with EVs, the rate is higher (44%).

Norway has tried out a number of incentives to facilitate the purchase and use of EVs. With continued use of these incentives, the EV market will probably continue to grow. At the same time, it is also important to consider adjustments, based on economic as well as environmental arguments. The objective should be to avoid adverse effects and to diversify in the development towards a more environmentally-friendly transport encompassing several kinds of EVs (eg e-bikes, rechargeable hybrids, electric buses and electric vans) or other types of zero-emission vehicles (hydrogen cars).

The various groups in the study have been positioned in a market diffusion model, see figure S7. With successive groups of consumers adopting EVs (shown in blue), the market share (shown in red) will increase. The Norwegian Parliament has set a target of max 85 g CO<sub>2</sub>/km as an average for new cars which most likely requires 20-30% market share for EVs (all kind of EVs included) to be achieved. This target seems possible to reach. With the continuation of current incentives the market share of EVs will probably continue to increase, supporting the fulfillment of the target.

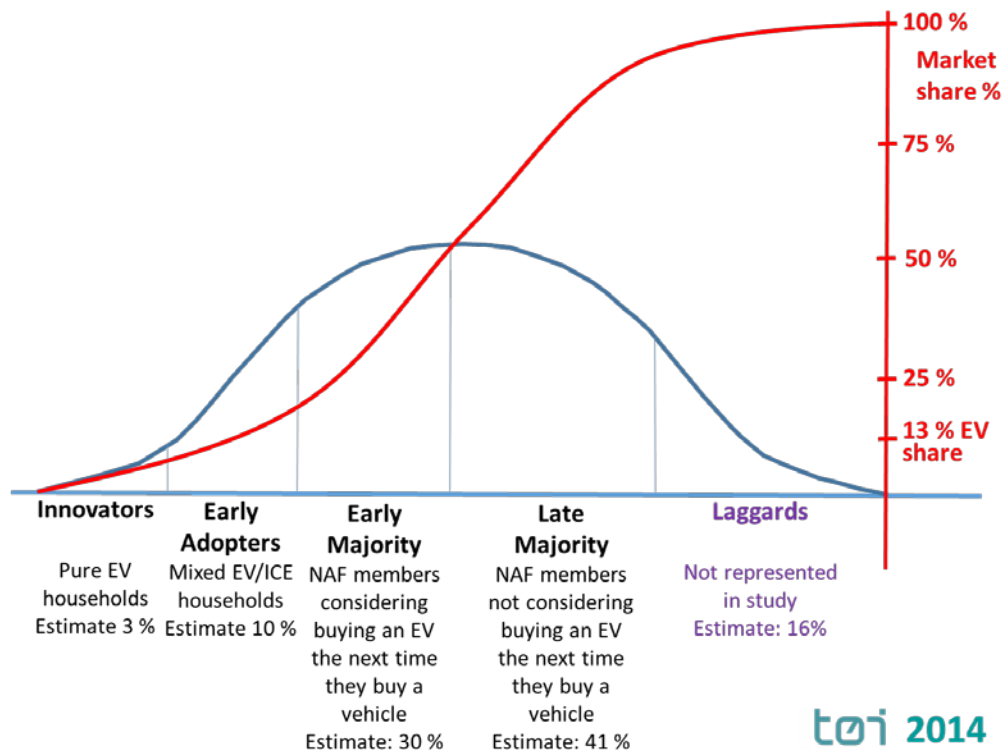


Figure S7 Owner groups on the road to market domination adapted to this study from Rogers (1962, 1995) diffusion model. NAF = Norwegian Automobile Association

A strategy for adjustments might be needed for both economic and environmental reasons, avoiding rebound effects. Future EV proliferation in Norway will be investigated in the COMPETT project using stakeholder interviews to find out what strategic paths authorities at different levels as well as industrial and other important actors are working along and by modelling different scenarios.