Institute of Transport Economics
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Summary

Learning from Norwegian Battery Electric and Plug-in Hybrid Vehicle users – Results from a survey of vehicle owners

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Battery electric vehicles are more energy efficient, pollute less and emit fewer greenhouse gases than vehicles powered by fossil fuels. Plug in hybrid vehicles are in a mid-position, capable of prolonged driving in electric mode with electricity charged from the grid or the use of fossil fuel in an internal combustion engine. A survey of over 8000 vehicle owners show that plug-in hybrids drive electrically with power from the grid 55% of the time but battery electric vehicles are driven more in total and in everyday traffic. Buyers are different but motivated by economy of use and environment, whereas battery electric vehicle owners also are motivated by the free toll road incentive. Battery electric vehicle owners are younger, have more children, longer distance to work and own more vehicles than other vehicle owners. Normally diesel and gasoline vehicles are replaced but a larger share of battery electric vehicles become extra vehicles in households. These owners could belong to an age group and family type where such behaviour is more common or indicate a rebound effect. The vehicles are mainly charged at home, partly at work and rarely elsewhere. Fast charging is used for irregular trips where users plan to use fast chargers to accomplish the trip or to solve a problem on the go. Most battery electric vehicle owners manage everyday life well and are satisfied with the vehicle which in combination with attractive local incentives not available to other vehicle users, may explain why these two vehicle types do not seem to compete for the same customer.

Survey sample

This report presents the results of a nationwide survey of Battery Electric Vehicle (BEV), Plug in Hybrid Electric Vehicle (PHEV) and Internal Combustion Engine Vehicle (ICEV) owners in Norway conducted in March 2016. The 3 111 BEV respondents were recruited using e-mails sent to members of the Norwegian EV Association. The 2 065 private PHEV owners were recruited using postcards sent to their home address. The 3 080 ICEV owners were recruited using e-mails sent to a representative national sample of the members of the Norwegian Automobile Federation (NAF). The total response rate was about 19%, slightly higher for PHEV owners (26%) and lower for ICEV owners (15%). The BEV owner sample is mostly representative of the total BEV fleet, apart from an overrepresentation of Tesla Model S, and minor regional deviations. The PHEV sample is relatively representative of private owners.

Owner's socio-demographic characteristics, housing and vehicle ownership

Vehicle purchase taxes are very high in Norway. The registration tax consists of taxes on vehicle weight, engine power, CO_2-emissions and NO_X-emissions. The tax is progressive, and registration tax for heavier vehicles with large engines and high emissions can be over 15 000 Euros. Tax for a typical compact vehicle could be 6 000 Euros, for a small vehicle around 2 000 Euros. BEVs' are exempted from this tax and the compact sized PHEVs typically have no registration tax as the low CO_2-emission value of these vehicles gives a tax deduction that can be deducted from the tax on the other elements. In addition, BEVs are exempted from the 25% VAT imposed on other vehicles. Several local incentives are also available, such as access to bus lane and free passing of toll roads.

The sociodemographic data show that PHEVs and BEV owner's are very different groups. BEV owners live in larger households with more children and are on the average seven years younger than PHEV owners are. They more often belong to multivehicle households than PHEV owners and have longer distances to work.

PHEV owners have many similarities with ICEV vehicle owners in general, such as about average share of multi vehicle households, but lie in some ways between ICEV and BEV owners' characteristics.

For working owners of vehicles from 2011 and newer, the household income proves to be more or less the same, with the exception that single vehicle PHEV owners are better off than BEV and ICEV owners.

About two thirds of people in these three groups live in detached houses, the remaining split in two between other small houses and flats. BEV owners in general live in more urban locations than PHEV owners do, whereas ICEV owners are the group that is most spread out. These housing conditions mean that BEV owners and PHEV owners in general have good access to parking and charging facilities on their own property.

Most BEV owners (71%) also own an ICEV, 4% a PHEV and 4% more than one BEV. The remaining 21% only have the one BEV. 46% of PHEV owners and 48% of ICEV owners belong to single vehicle household. The most multipurpose BEV, Tesla Model S, is twice as common in single BEV households as in households also owning ICEVs, and four times as common in households owning several BEVs.

Why did they buy the vehicle, where did they get information, and will they buy the same vehicle again?

The four reasons most frequently mentioned by the 89% of BEV owners who say they will buy a BEV again are economy of use, environmental performance, future proof technology, and the free usage of toll roads without paying. Less than 1% will not buy a BEV again. The reasons not to buy again are range and charging issues.

The three main reasons why 80% of PHEV owners say they will buy one again are economy of use, environmental performance and that the technology is future proof. Only 2% will not buy a PHEV again. The main reasons not to buy again are the short range in E-mode and inability to use E-mode when it is cold.

Peer-to-peer influences is particularly important to diffusion of BEVs, being the biggest source of information leading to the purchase. PHEV buyers received most information leading to the purchase from dealers and advertising material. The dealer also played a large

role for ICEV owners but they also got information from peers. BEVs require more adaption of travel patterns than ICEVs. When their friends say that range is manageable it is more likely that people will consider BEVs as an option. The average BEV owner have influenced about 1.2 persons to buy and 1.2 persons to consider buying BEVs. This peer-to-peer communication may thus be supporting a self-sustained sale of BEVs in Norway.

Trip types and total travel

BEV owners use their BEVs more for all types of trips in everyday traffic but less on non-routine trips and vacation, than PHEV and ICEV owners do. BEV owners have about 7 km longer distance to work than owners of a PHEV or owners of an ICEV. BEV owners drive their BEVs about 15 500 km per year which is slightly more than PHEVs that are driven 15 200 km. ICEVs are used the least, around 15 000 km. Part of the difference may be due to higher share of ICEVs being owned by retired people.

Recurring long distance travel over 300 km, for instance to holiday houses, friends and family, is undertaken by close to 50% in all three owner groups. The share not doing recurring trips above 100 km, and trips in the interval 100-150 km, is somewhat higher among BEV owners, 12% versus 7-9% in the other groups. About 64% of BEV owners use their BEVs on at least one of the recurring trip types. On these trips, 74% charge their vehicle along the way using fast chargers, and 60% at the destination. PHEV owners do not need to charge to be able to carry out these trips but over half of them do it at the destination. About 20% of both groups stop at friends or family and charge.

BEV owners have a particularly vehicle based travel pattern and seems to be a sub group of new vehicle buyers that use vehicles very actively in everyday life. Their reasons to do so, is probably related to their larger households with many children and long distances to work.

PHEV share of driving in the «all electric mode» and users range estimates

PHEVs are on average driven about 55% of yearly km in «E-mode», the «all electric drive mode». The share is higher for trips to work and in the summer and lower in the winter. Longer range in E-mode in general leads to higher E-mode share, but the spread is large for most vehicle types. Only the vehicle with the longest range, the Opel Ampera, has a positive correlation between increased annual vehicle mileage and increased E-mode share. All the other vehicles have a negative correlation, indicating that their e-mode range is not optimal from a user perspective.

User estimates for E-mode range is on average about 20% lower than the official range in E-mode in the summer and 30% lower in the winter.

Changes to travel pattern and vehicle ownership

BEVs have substantial incentives in Norway, such as access to bus lanes, reduced purchase taxes, access to toll roads and free public parking, on the assumption that they replace ICEVs. Most BEVs in use in Norway have a limited range and people may not be able to replace all their driving with a BEV when replacing an ICEV, further highlighting a need to verify if BEVs are an addition to the fleet or a replacement. There is also a possibility that

the total vehicle based travel increases, i.e. that people drive more with BEVs than they would have with ICEVs, since the variable cost per km is much lower for BEVs than ICEVs, and attractive user incentives are available. On the other hand, BEV owners may belong to an age group and in a family situation where it is common to buy an extra vehicle.

The vehicle was for 22% of BEV, 5% of PHEV and 12% of ICEV owners, an additional vehicle in the household. For the others, the vehicle usually replaced an ICEV, 6% of BEV owners, however, replaced a BEV and 2 % a Hybrid Electric Vehicle (HEV), whereas 4% of PHEV owners replaced a HEV, 1% a PHEV and 1% a BEV.

The driving pattern remained unchanged for 67% of BEV owners, 87% of PHEV owners and 89% of ICEV owners, after buying their vehicles. The majority of the rest of the owners tended to have negative modal shifts for the environment and the target to limit vehicle based travel in cities, regardless if they bought an electric, plug-in hybrid, diesel or gasoline vehicle. Driving increases in general in all groups. Few say they drive less. The same is true of cycling, walking and using public transport, which many more people say they have reduced than increased. It is unknown how much more or less they travel. BEV owners have the largest mode changes. Their long distances to work, and that they have more children than the other groups, could be the reasons for these larger mode changes.

In another question, 72% of BEV owners, 90% of PHEV owners and 81% of ICEV owners stated that the total km in the household's vehicle insurances had not changed after buying a 2011 or newer model vehicle as a replacement for an ICEV. 8% of BEV owners said it had been reduced, 20% that it had increased. The corresponding figures for PHEVs were 4% and 6% and for ICEVs 11% and 8%, indicating that there is a potential rebound effect related to vehicle kilometres driven for BEVs, although there could be other reasons for the differences.

Changes to the household, such as the household or workplace having moved, an addition to the family or an increased need to escort children in general, were for about half of the BEV owners the main reason to buy an extra vehicle. If these people would have bought an extra vehicle anyhow, had it not been for the BEV incentives, or continued using another transport mode, is not possible to find out from the survey. Such issues could potentially also lead to an increase in the mileage when a BEV replaces an ICEV. The other half of buyers of extra vehicles seemed mainly motivated by "insufficient public transport" and wanting to "use the other household vehicle less". The latter could indicate that they want to reduce the environmental impacts of their driving and/or motoring cost. PHEV and ICEV owners had many of the same reasons for buying an extra vehicle apart from "use other vehicle less", which was not motivating ICEV owners.

Charging is mostly done at home

94-95% of BEV and PHEV owners, charge their vehicles at home in their garage, carport or parking space. Few report challenges with planning or establishing charging facilities at their home location.

The peak period for starting charging is in the period 16-18 but many also start before 16. The peak charging period drags out into the evening as more people start to charge, and those that have already started continue. The result will be that the peak time for charging with maximum charging power will coincide with the peak power drain from the grid, when people come home from work, turn up living room heaters, start cooking, watching

TV etc. The peak will be higher and longer in the winter since more people will need to recharge their vehicle every day, as the range in winter is shorter.

About 50% of BEV owners and 75% of PHEV owners never charge their vehicles at work. 28% of BEV owners, but only 16% of PHEV owners, do it mostly daily.

Standard public chargers are less regularly used, but 60% of BEV owners use them at least monthly or yearly. Only about 10% use them on a weekly basis. Over two thirds of PHEV owners never use public chargers. Less than 10% do it more than a few times per year.

Fast chargers are used a bit more in the 2016 survey than in the 2014 survey, but 30% of BEV owners and 90% of PHEV owners never use them (Mitsubishi Outlander is the only PHEV that can use fast chargers). 8-9 % of BEV owners use fast chargers weekly and 28% monthly with almost no difference between summer and winter. About 70% of users plan to use fast chargers before going on a trip. In addition, running out of range occasionally during a trip is sorted out using fast chargers, and more so in the winter. BEV owners use fast chargers more often for irregular long distance trips, than recurring long distance trips or daily trips.

Charging problems have, by 29% of BEV owners and 10% of PHEV owners, been experienced. The most frequent problem is "no power". At home, the second most important problem is damaged vehicle cable and for public chargers damaged charge sockets. About 2% of those that had problems, had experienced "burned charge socket" at the home location or a public, work place or destination charge socket, indicating that about 1 600 owners in the total EV fleet had experienced this problem. A burned charge socket could potentially escalate to a fire and EV owners should use home chargers (wall boxes) having robust plugs and sockets. Public charging stations should use Mode 3, Type 2 sockets, to avoid future problems. Some modern BEVs with temperature sensors in the connector on the cable supplied with the vehicle, stop charging when detecting an over-temperature.

PHEV owners rate public chargers much more negatively than BEV owners but also know less about them. A third of BEV owners rate them as good, a third poor and the rest neither nor. Only about a tenth of PHEV owners rate them as good.

Challenges using the vehicles are manageable

The average BEV owner has avoided travelling due to range being too short or the charging infrastructure being insufficient, on five days per year, but the majority (83%) never had to avoid a trip. Those who have cancelled trips on average did it 18 days per year. Tesla owners had much fewer problems, on average less than half a day per year, indicating that the Model S has enough range and that the Tesla supercharger network provides a stable service.

The average BEV driver have aborted trips less than one day per year, and only 6% of BEV drivers have aborted trips. Those who have aborted trips experience it 12 days per year on average.

Half of avoided and aborted travel relate to the availability and quality of the charging infrastructure. These issues should be addressed by authorities that provide support for charging station establishment, and those with operational responsibility for the infrastructure.

The other half of cancelled or aborted travel is mostly due to miscalculated range or unexpectedly high consumption of energy. Technical faults on vehicles are very rare.

Overall, these problems seems relatively small, which could be a result of self-selection, i.e. that consumers buy BEVs when their driving pattern is compatible.

When range is too short, the typical behavioural adaptation will be to fast charge, and drive more efficiently while turning down auxiliary loads. Before embarking on trips, people plan for instance where to charge, or get hold of an alternative vehicle or switch their mode of transport. Multi vehicle households will predominantly swap vehicles within the household.

Female drivers seem to be less aware that the low noise of BEVs could be a problem in traffic. Three times higher shares of women driving BEVs than those driving ICEVs, have perceived situations were pedestrians, cyclists or children did not hear the vehicle as dangerous. Male BEV drivers experience the same but to a much lower degree. The gender differences could be due to, exposure, experience, different perception of situations or that women take more notice of such situations. Female ICEV owners, strangely enough, experience this problem least often of all groups, but the survey cannot give further insight into this issue.

Value and use of incentives

BEV owners enjoy local incentives such as access to bus lanes, free public parking exemption from toll roads, and reduced rates on coastal main road ferries. PHEV owners do not have any of these incentives.

BEV owners pass toll road gates on the way to work twice as often as owners of ICEVs and owners of PHEVs. Their estimated savings on toll roads is twice of what the other groups' reported toll road cost. The average reported saving on ferries is rather small on a national scale. Since ferries still cost about half price for BEVs, BEV owners actually spend about the same as other groups, but should have spent twice as much. BEV owners also say the save more on parking than the other groups say the pay for parking. BEV owners can also charge at no cost on many public charging stations, but not on fast chargers. The bus lane time saving is an important part of local incentives, accounting for 32% of the average yearly value per BEV owner, which was estimated to be 14 000 NOK/year.

Perceived advantages and disadvantages of BEVs and development since 2014

All three groups consider environmental effects, operating cost and home charging as big advantages of BEVs. BEV owners are the most positive followed by PHEV owners. Range and charging time are significant disadvantages of BEVs, particularly for ICEV owners. ICEV owners are rather indifferent to comfort, safety and design and image of BEVs, whereas BEV and PHEV owners rate these items more positively, especially comfort. ICEV owners are somewhat negative to the size of BEVs, whereas BEV owners and PHEV owners are rather neutral. BEV and PHEV owners seem to think that handling cables is not a big deal, whereas ICEV owners are more negative. BEV and PHEV owners rate second hand value of BEVs relatively neutral whereas ICEV owners think it is a disadvantage.

Both BEV and ICEV owners rate second hand value much more positively in 2016 than in 2014. BEV owners also see less problems compared to ICEV owners when evaluating charging time, heating system, and handling cables, but slightly more challenges with range and vehicle size. The latter items could indicate that they want to use their BEV for more trips than their BEVs range and size currently allow for. For issues such as charging time, comfort and size, ICEV owners have reduced both positive and negative assessments between 2014 and 2016, thus moving towards a more neutral position.

Opinions on measures to expand the PHEV and BEV market

For PHEVs, "competitive price" is the most important factor for increasing sales according to the respondents, followed by increased range in E-mode. BEVs already have a competitive price so the most important measure to expand the BEV market is increased range.

The median *winter range* that people say is required for more people to become interested in PHEVs ranges from 75 km among PHEV owners, 85 km among BEV owners to 175 km for ICEV owners. Up to 2016, no PHEV had the ability to drive 175 km in E-mode. The closest is the BMW i3 REX that, according to BEV variant users with the same battery, can be driven over 100 km in the winter. It is unlikely that many PHEVs will match these desired ranges in the near future, even the range desired by PHEV owners. Such winter ranges are only achievable with purpose designed EREVs, i.e. vehicles that were designed primarily to be used in electric drive mode, with the ICEV assisting long distance trips, whereas the strategy of most vehicle manufacturers is to make PHEV variants of standard vehicles. There is not enough space in most standard vehicles for a large battery. BMW i3 REX, an example of a purpose designed EREV, will come with a larger battery in the fall of 2016 having a range compatible with ICEV owner's needs.

The median *winter range* the respondents say will make more people interested in buying BEVs, range from about 230-250 km stated by BEV and PHEV owners, to 300 km by ICEV owners. Tesla Model S is already capable of such ranges and the second generation BEVs arriving on the market in 2017-18 are likely to be capable of such ranges.

For BEV owners increased availability of fast chargers and retaining the exemption from purchase taxes are also very important measures for increased appeal to consumers according to the respondents. Reduced ferry rates and bus lane access are the least important local incentives, whereas toll road exemption is highly valued by BEV owners. PHEV owners would like to have free toll roads and free parking to spur more PHEV sales, and the other groups agree. The possibility to drive in cities when other vehicles are banned, increased taxes on polluting vehicles, as well as better public and workplace charging, are factors that are even more important in all groups apart from ICEV owners, who do not want higher taxes on polluting vehicles. Better availability of makes and models is not as important as the other measures and incentives.

Competition or complementarity between BEVs and PHEVs

Nothing in the survey results indicates that BEVs and PHEVs currently compete for the same customers. Owning a HEV, BEV or PHEV does not seem to lead to substantial recruitment to the other two technologies, a somewhat surprising result. One could have imagined that PHEVs would be attractive to disillusioned BEV owners tired of congestion at public chargers or with the short winter range. In fact, only one percent of PHEVs replaced a BEV, and, as stated earlier, most BEV manage their transportation needs

effortlessly and that should make it less interesting to replace the BEV with a more expensive PHEV with no local incentives.

BEVs and PHEVs are also partly in different size segments. Apart from the large Tesla Model S, BEVs are mostly compact, small and mini vehicles. PHEVs are mainly in segments compact, medium, large and SUVs. Buyers of PHEVs actively choose to forego BEV incentives and pay a premium over BEVs. In the survey one sees that they also have different socio-demographic characteristics; BEV owners being younger, having families with children and longer distances to work. Recurring long distance driving on the other hand differs very little between the groups, BEV owners on average only having slightly fewer of these trips. Tesla owners have an extreme long distance driving pattern, which could not only be related to the vehicles long range, but also to the free access to the supercharger network giving owners zero energy cost on long distance trips.