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## **Charging infrastructure experiences in Norway - the worlds most advanced EV market**

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### **Summary**

In this paper, we will look at the experiences with charging infrastructure in Norway, the worlds most advanced EV market. We will go through the historic development, discuss lessons learned from public support for charging services and private charging operator's business models. We mainly focus on the fast charging infrastructure. The user perspective is also essential and results from the Norwegian EV owners survey 2017 is presented.

*Keyword: charging, consumers, fast charge, business model, market development*

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### **1 Introduction**

As of June 2017, the market share for battery electric vehicles in the Norwegian passenger market was 19%, closely followed by plug in hybrid electric vehicles (PHEV) with a 16% market share (figure 1). The milestone of 100.000 BEVs registered was reached in December 2016 (figure 2). The fleet number represents around 3% of the total fleet of 3 million passenger and light commercial vehicles in Norway. This gives Norway a unique opportunity to serve as a testing laboratory for charging services with customers in an early market. Furthermore, the Norwegian parliament has agreed upon a 2025 target where the new passenger and light commercial car market should consist of 100% zero emissions vehicles (ZEVs). This puts Norway on an ambitious course towards a zero-emission transport sector and an increasingly aggressive pace of introduction of ZEVs.

In this paper, we will present the experiences with public and private charging infrastructure investments and the user experiences from the 2017 Norwegian EV owners survey. We will also discuss the importance of fast charging infrastructure for EV adoption. We also include a brief introduction to the Norwegian EV policy package as important background information.

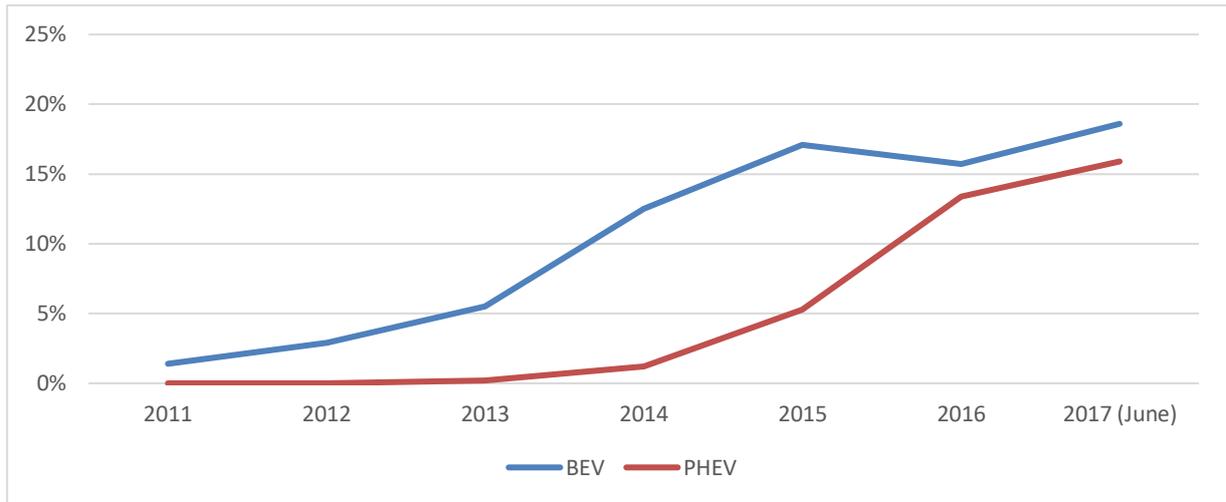


Figure 1: Norwegian EV market share development in the new passenger car market. Source OFV AS [1].

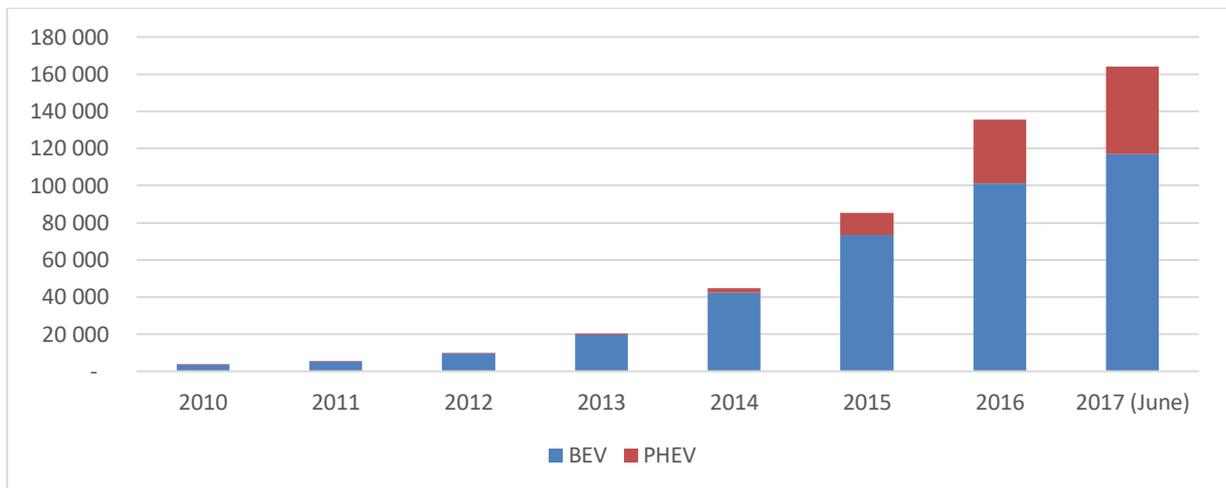


Figure 2: Norwegian EV fleet development. Source: Norwegian Public Roads Administration [2] and OFV AS [1].

The Norwegian BEV market started early and boomed after the introduction of Mitsubishi i-MiEV in 2010 and Nissan LEAF in 2011. In the early market, the customers to a large degree consisted of commuters in the cities who charged at home or at work and had a limited need for a public network of charging stations. Today we see a growing need for a public fast charging infrastructure to help expand the customer base beyond the initial buyers. Also, a well-developed fast charging infrastructure is needed as BEVs to an increasing degree is the only type of vehicle in a household, as made evident by the 2015-2017 Norwegian EV owners surveys, which shows that the percentage of BEV owners who have BEV as their only vehicle(s) has increased from 23% to 30% from 2015 till 2017 [3].

## 2 Historic development and where we are today

### 2.1 Norwegian BEV policy

Below we very briefly outline the Norwegian BEV incentives. Norway has a comprehensive BEV incentive package, and many of the incentives dates to the 1990s (table 1). The original rationale behind the incentives

was to help foster the incumbent Norwegian BEV industry. After the local EV industry almost disappeared, the reasoning behind the incentives have gradually shifted towards local and global emissions.

Table 1: Norwegian BEV incentives development. Source: Norwegian EV Association [4].

Incentives for zero emission cars	Year
No purchase taxes (around NOK 95 000 on average for petrol and diesel cars)	1990
Low annual road tax	1996
Exemption from road toll	1997
Free municipal parking (revised in 2017, now decided locally)	1999
50 % reduced company car tax	2000
Exemption from 25% VAT on purchase/leasing	2001/2015
Access to bus lanes	2003
Free access on state ferries	2009

The tax breaks at time of purchase in combination with a high purchase tax (on average around NOK 95 000 for diesel and petrol cars) on passenger cars in Norway makes BEVs able to compete on price. Many BEVs are equally or even lower priced than comparable conventional vehicles. In addition, the exemption from toll roads is a very strong economic incentive, as we have quite a few toll stations around cities and on highways. The economic incentives are the backbone of the Norwegian EV success. Also see the paper “*Put a price on carbon to fund EV incentives – Norwegian EV policy success*” by P. Haugneland et al. for more information about this topic [5].

## 2.2 Development of normal charging

In addition to the incentives mentioned above, different Norwegian governments have also supported the development of a basic charging infrastructure. Norway's first governmental support scheme for public charging infrastructure took place in 2009-2010. The support scheme was part of a financial stimulus package after the 2008 fiscal crisis, and funded 100 % of the installation cost for normal chargers, up to NOK 30 000 per charging point. The total support amounted to NOK 50 million and the scheme resulted in around 1800 Schuko-points (household sockets) spread all over the country. Many of these points can still be used, but several are also taken out of service due to high maintenance costs. The Schuko outlets have proven to be not ideally suited to long term EV charging, and this is one of the inherent challenges when building out charging infrastructure before international standards are adopted. Today new and upgraded public charging stations is mostly Type 2 outlets. As of June 2017 the number of publicly available Schuko-points was around 4400, while the number of Type 2 points stood at around 2700 [6].

## 2.3 Development of fast charging

The initial governmental support schemes for fast charging stations ran from 2010-2014, and totalled around NOK 50 million. The support scheme supported up to 100 % of installations costs, but no support was given to operating costs. There were few, but increasing demands related to the location of charging stations. From early on it was a criterion that the charging stations must be prepared for payment solutions, with a deadline for when the payment systems had to be operational. There was no national payment system, and the charging operators were responsible for the introduction of their own payment solutions.

The first rounds of support for fast charging stations resulted in a several charging operators applying for funding. Many of the operators originated from local utility companies.

From 2015 the state enterprise Enova ([www.enova.no](http://www.enova.no)) introduced a support scheme with aims to cover the Norwegian main roads with fast charging stations every 50 km (around 7500 km road network, see figure 3). To reduce the risk for charging stations being out of order and reduce charging queues all locations must have at least two multi standard fast chargers (CHAdEMO and CCS) in addition to two 22 kW Type 2 points. The road network is split into several smaller segments, and operators compete for public funding. All the stations are owned and/or operated by charging operators. Many of the fast charging operators also prepares for additional fast chargers to be installed at a later stage. The network should be operational by the end of 2017.



Figure 3. Map showing the main road network included in Enovas support scheme. Source: Enova [7]

We also see a growing trend that fast charging operators are building fast charging stations without public support, especially in the larger cities and along major highways. In other words, we are at the beginning of functioning market where governmental support is no longer needed, and the development of charging stations is based on pure commercial decisions. This development is crucial for the further development of fast charging in Norway.

The support schemes, supplemented by a growing number of points being built without support, has resulted in fast growing number of fast charging points, see figure 4.

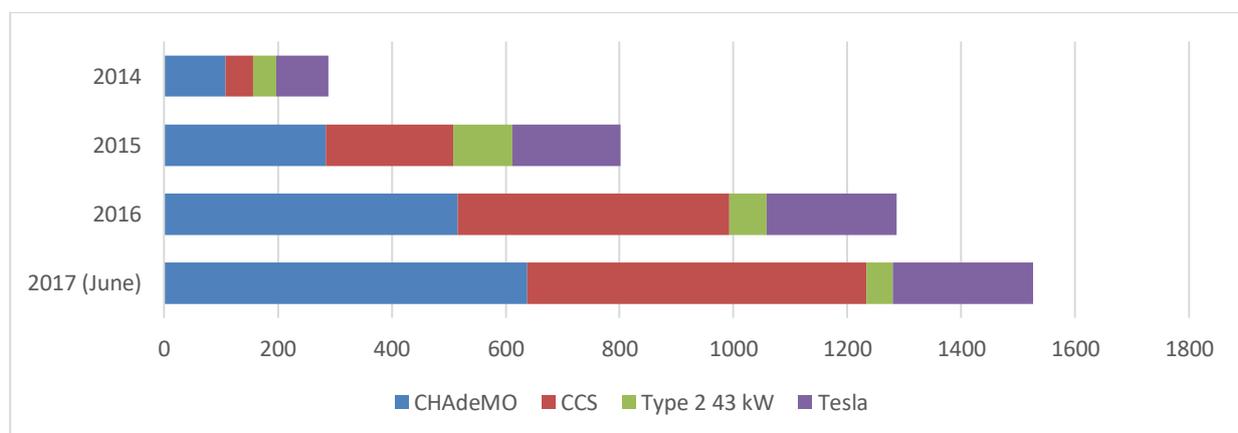


Figure 4: Historic development of fast charging points in Norway. Source: NOBIL [6].

As of June 2017, the fast charging infrastructure in Norway according to the NOBIL database [6] totals:

- 648 CHAdEMO points
- 595 CCS points
- 47 AC Type 2 43 kW points
- 246 Tesla Superchargers

As most of the CHAdEMO and CCS points are combined charging points where only one car can charge at the time, roughly 950 cars can fast charge at the same time in Norway.

## 2.4 Regional overview

To gain further insights into the Norwegian charging market, a regional approach is in order. Of the total BEV passenger car fleet in Norway, the three counties Akershus, Hordaland and Oslo are home to more than

50% of the BEVs, compared to only around 20% of the total Norwegian passenger car fleet of around 2,6 million cars. There appears to be no clear correlation between the number of fast chargers and the number of BEVs in a county. As figure 5 shows, several other counties than Hordaland, Akershus and Oslo have as high or higher number of fast chargers in combination with considerably fewer BEVs. Some of the explanation behind the high number of fast chargers is Buskerud and Oppland is that Tesla has several Supercharger stations in these counties.

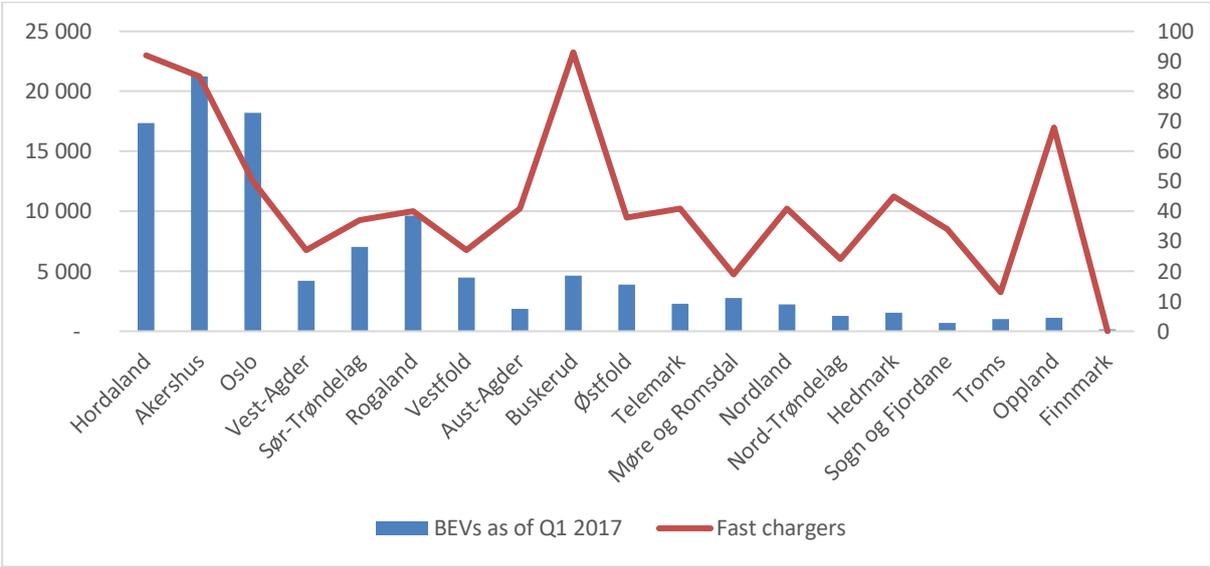


Figure 5: Number of BEV and number of fast chargers in Norwegian counties as of March 2017. Fast chargers are calculated as the number of BEVs that can fast charge at the same time. Source: Norwegian Public Roads Administration [2] and NOBIL [6].

When looking at number of BEVs per fast charger (figure 6), we also note that Hordaland, Akershus and Oslo have the highest number of cars per charger (together with Rogaland). This indicates that a high number of fast chargers per car is not a strong factor in explaining the differences in the BEV population between counties in Norway.

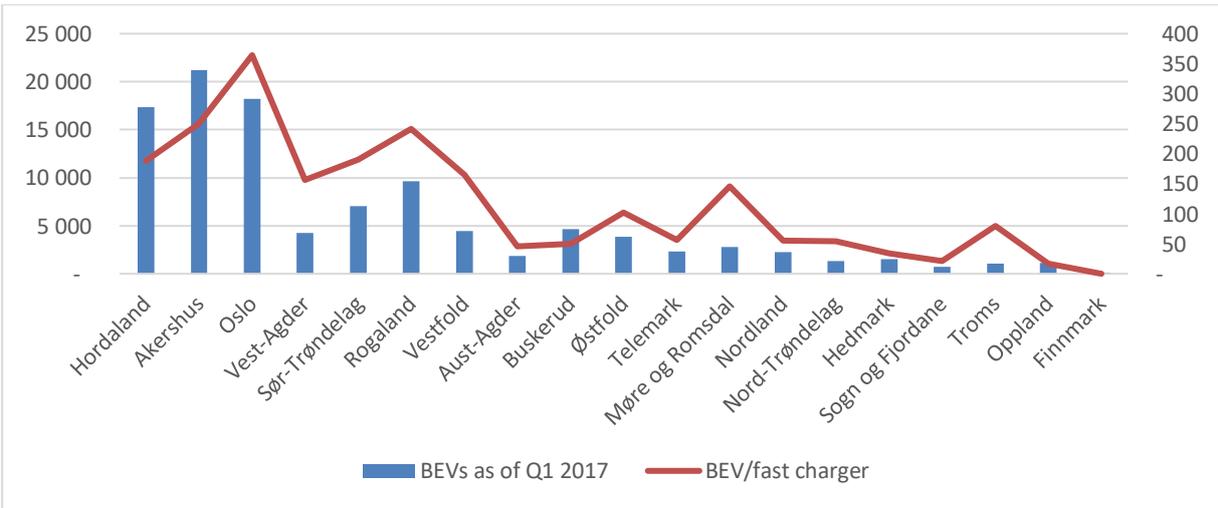


Figure 6: Number of BEV and number of BEVs per fast charger in Norwegian counties as of March 2017. Fast chargers are calculated as the number of BEVs that can fast charge at the same time. Source: Norwegian Public Roads Administration [2] and NOBIL [6].

The high concentration of BEVs in Hordaland, Akershus and Oslo is probably better explained by the strong presence of local incentives like exemption from toll roads and access to bus lanes. This is in line with research from the Norwegian Institute of Transport Economics, where one study finds that “..., which suggests that BEV market shares depend strongly on local incentives. Note that general incentives of purchase tax and VAT exemption come in addition”.[8].

### **3 Pricing and payment systems**

In Norway, the two national charging operators Fortum Charge & Drive and Grønn Kontakt have a payment model for fast charging where the customers pay per minute of charging, regardless of how many kWh the car receives. Payment for 50 kW fast charging starts at NOK 2,50/minute. This results in a kWh price of roughly NOK 3-5 depending on actual charging speed. At home, BEV users pay around NOK 1 per kWh (all taxes and fees included), making fast charging comparatively more expensive. Many users prefer payment per kWh because the charging effect can differ substantially based on state of charge, battery temperature and the on-board charger of different BEV models. This has resulted in a debate regarding the price and pricing model for fast charging. Payment per kWh will increase the risk of queues because the BEV owner will not have an incentive to move the car when charging is slow. With dynamic effect distribution between chargers, the best model will probably be to have payment with a combination of time and kWh, similar to taxi rates with a combination of time and km.

Charging operators, governmental funding agencies and the Norwegian EV Association have all strived to inform the BEV community about the cost of providing fast charging, and that it is to be expected that you pay a premium for the service of fast charging. The monthly cost for charging will still be low as long as most of the charging takes place at home.

With the coming introduction of faster fast charging we see it as natural that charging stations offers different charging speeds with different pricing structures. Then the consumer, based on his or her needs on any given day, can choose the offer that suits them, and pay accordingly. We believe that there will be a market for different charging speeds, as some people are in a hurry, while others might stop for instance for a meal while they charge.

The user perspective is essential, and for charging services it has not been easy enough to get access to and pay for fast charging. The BEV owner must relate to different charging standards, find charging stations with different map services and pay for charging with different payment systems such as charging tags, SMS or mobile apps. Conventional payment methods like credit card or cash has not been an option in most cases.

The Norwegian EV Association has from 2015 provided a universal charging tag to all their members. This tag can be registered with many of the charging operators for easier access and payment for charging services. Note that the BEV user still gets one invoice from each operator. It has been very popular offer because you get a step-by-step quick guide on how to register and use the charging tag. According to the Norwegian EV Association member survey 2017, the charging tag is the most important service that the association provides for their members. 57% of the members use the charging tag provided by the Norwegian EV Association. For those who not use it, 60% do not use public charging because they cover their need with charging at home or work.

### **4 National database for charging stations**

As the first phase of the national charging infrastructure was being built in 2009-2010, questions arose on how to maximize the benefit from it. The answer was to collect all the information in a central database (NOBIL), and distribute it with the goal to increase knowledge about the availability of charging infrastructure for electric vehicles.

Cooperation between the governmental entity Enova and the Norwegian EV Association resulted in the development of an open, publicly owned database that allows everyone to build services using standardized

data free of charge. This has been instrumental in providing BEV users with up to date information about the charging infrastructure, and the data is being used by several in-car navigations systems in addition to charging maps and apps. Especially in an early market, this information is crucial for BEV owners.

## 5 User experiences

The Norwegian EV Association conducts a yearly survey among Norwegian BEV owners. The 2017 survey had about 12.000 respondents with BEV owners from all over Norway. Several of the questions relate to charging behaviour.

Table 2 shows the charging behaviour of the respondents. We have spilt the respondents into two groups based on what sort of housing they live in. As the table shows, BEV owners who lives in detached housing to a very large degree charge at home, while those living in apartment buildings to a larger degree also charge at public charging stations and use fast charging more frequently. We also note that most BEV users don't fast charge on a weekly basis. Normal charging while the car is parked is in other words the dominating charging method. However, fast charging is crucial when needed, for instance on longer trips. Fast chargers also function as an important "safety net" for everyday use.

Table 2. Question: How often do you charge? Source: Norwegian EV owner survey 2017 [3].

	Detached housing	Apartment buildings
<b>At home, daily or weekly</b>	97 %	64 %
<b>At home, monthly or never</b>	3 %	36 %
<b>At work, daily or weekly</b>	36 %	38 %
<b>At work, monthly or never</b>	64 %	62 %
<b>At public charging stations, daily or weekly</b>	11 %	28 %
<b>At public charging stations, monthly or never</b>	89 %	72 %
<b>At fast charging stations, daily or weekly</b>	12 %	18 %
<b>At fast charging stations, monthly or never</b>	88 %	82 %

Results from the EV owner survey shows that the users prefer RFID-tags over other payment methods like SMS or phone apps, even though all major operators offer quite decent app solutions (figure 7). This can probably be explained by ease of use, and it should also be noted that it is not necessarily very desirable to use your phone outside in adverse weather conditions. Tesla, with their plug and play system, is by far the easiest system to use for Tesla owners, and is preferred by them.

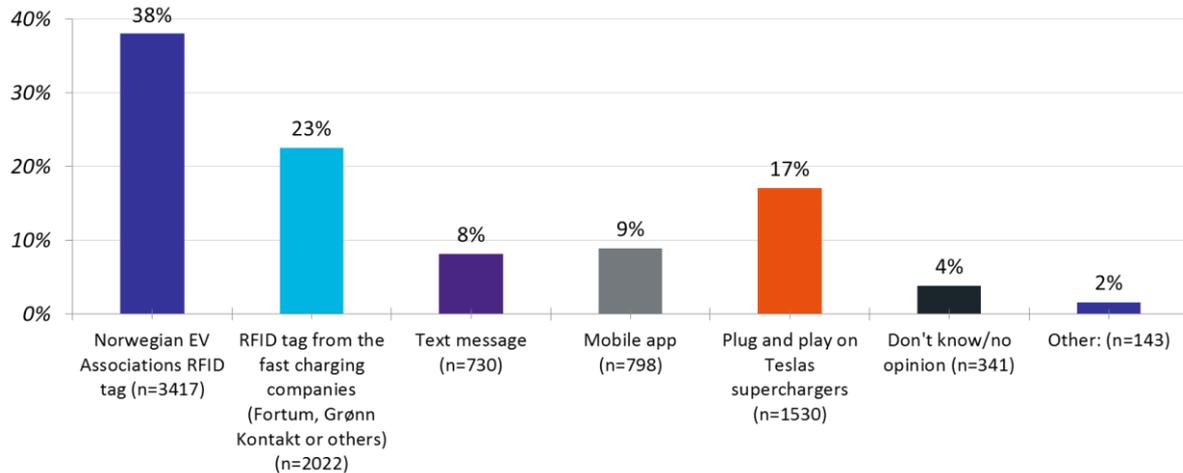


Figure 7. How do you normally start fast charging? Source: Norwegian EV owner survey 2017 [3].

When it comes to home charging, most BEV owners use the normal household socket (Schuko), se figure 7.

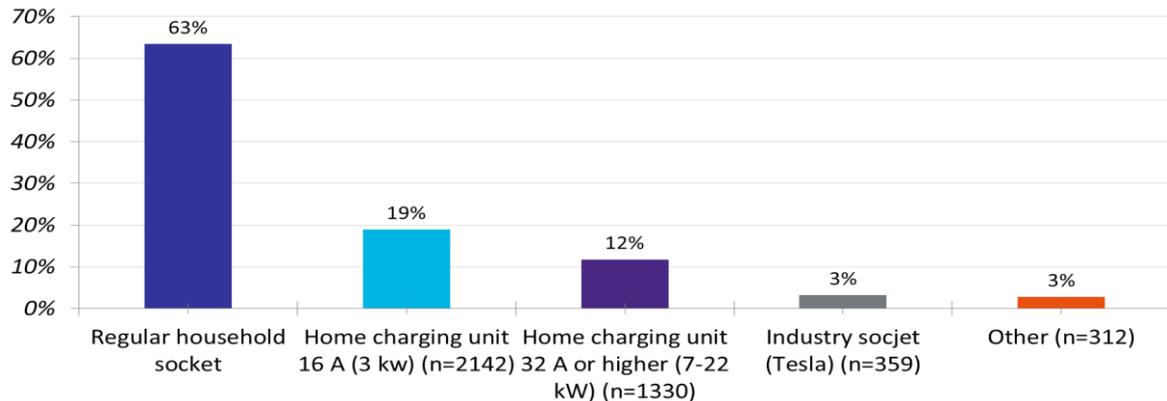


Figure 8: How do you charge your BEV at home? Source: Norwegian EV owner survey 2017 [3].

For those that charge at home using the regular household socket 2 % have experienced issues with a burnt socket. A burnt socket is not necessarily a big problem, but it constitutes a possible fire hazard. This number might seem quite small, but with a fast-growing fleet of BEVs the number quickly becomes quite large, with increased fire risks. This gives a clear indication that the regular household socket is not well suited to long term EV charging, and that dedicated charging equipment (Type 2 outlets) should be the norm.

Charging is obviously a very important topic for BEV users. However, the results from the survey also shows that the most valued incentive is the VAT exemption at the time of purchase, followed by other economic incentives like exemption from road tolls and low electricity costs. Access to public charging network is also an important incentive, see figure 9.

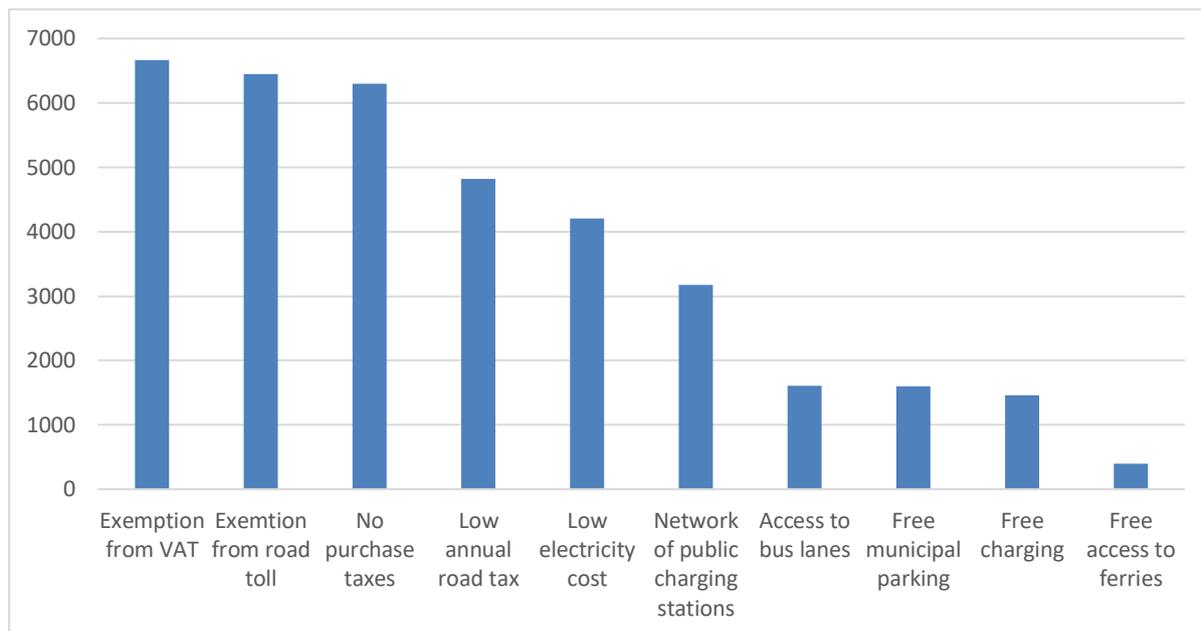


Figure 9: Most important EV incentives according to Norwegian EV owners. Question: Select the 3 most important EV incentives. Source: Norwegian EV owners survey 2017 [3].

The EV owner survey goes back to 2012, and the main results are similar from year to year when it comes to valuation of incentives. This also correlates with research from the Norwegian Institute of Transport Economics that finds that “Policies that address the purchase price of a BEV are found to be most effective in the way that they contribute significantly to BEV market shares.” [9].

## 6 Lessons learned

### 6.1 BEV adoption and fast charging infrastructure

When it comes to BEV adoption, there is often a discussion about the chicken and the egg regarding BEVs and charging infrastructure. The Norwegian experience shows that there is a substantial number of potential early users that will buy BEVs even without a comprehensive fast charging network. In for instance neighbouring Denmark, there is a quite well-developed charging infrastructure network, but the BEV sale is sluggish, and even more so after a weakening if the tax incentives when buying the car. This implies that other incentives are more important than a charging network on its own.

Norwegian BEV users values the tax breaks at time of purchase and other economic incentives the highest. This should come as no surprise, since these incentives makes it economical viable to buy BEVs.

A well-developed charging infrastructure is appreciated by EV users, but it is not on its own enough to convince consumers to buy BEVs. The Norwegian case shows that the tax breaks/incentives at time of purchase still are vital to the BEV development. However, it should be noted that as we are moving to a mass market adoption of BEVs, there is an obvious need for a large scale fast charging network as new user groups are preparing to move into the world of BEVs, and as a growing number of BEV owners don't rely on conventional cars as backup.

### 6.2 Business case and need for public support

With a very small BEV market the business case for fast charging may not seem obvious. An initial public support scheme with less strict criteria when it comes to location etc. provided an incentive for several local initiatives to build fast chargers. This has resulted in a few local and a couple of regional/national operators. Governmental support in an early market is crucial, but support to infrastructure must be matched by incentives for potential BEV buyers at the time of purchase.

The business model related to fast charging is starting to come apparent with as little as around 115 000 BEVs, or around 3% of the light car fleet being BEV. This shows that there is a limited need for public support after a relatively short introduction phase.

However, there is still no commercial interest in building charging stations in areas with low population density, especially in the North where there is a very sparse BEV population combined with long distances and harsh winter conditions. To secure the nationwide charging network needed for high volume introduction of BEVs there is still a need for targeted governmental support to fast charging stations. The need for governmental support after the initial phase seems less apparent in countries which are more evenly populated.

### **6.3 Pricing and payment systems**

For the development of a large scale fast charging network it is essential that fast charging is a paid service. The cost of fast charging installations, and that the users pay for the convenience of fast charging, not just the received number of kWh must be communicated to the BEV users to help build an understanding of the price models. Also, low cost charging at home or at work should be the backbone solution for EV users, and this will allow for the occasional use of costlier fast charging services while keeping the total cost of ownership lower than for conventional vehicles.

There is still a challenge related to payment for charging. However, this has improved in recent years due to improvement in the operators own systems, the introduction of a universal charging tag from the EV Association and the rapid development of app based solutions. In our view, it is not instrumental to have a single, national payment system or roaming solution. If there is a customer friendly drop in system for payment, the user experience is safeguarded. Charging as a service should not be something exotic that requires special payment solutions.

### **6.4 The users prefer simple solutions**

A few years ago, there was a heated debate regarding payment systems, and many users called for payment through normal credit cards and cash. As the payment systems have improved, and BEV users have gotten used to new payment solutions, this debate has cooled considerably. RFID tags is the preferred way to start fast charging sessions, and many users finds this to be an easier solution than credit cards/cash. However, the process for registering the RFID tags has to be straight forward, and it is important to have backup solutions like SMS and apps.

## **7 Challenges moving forward**

Even if fast charging is essential to prevent range anxiety and is an important incentive when people consider buying an EV, home charging is still the most important and effective way to charge an EV on a daily basis. You plug in at night and start every day with a full battery. It is cheap and it does not contribute to peaks in the power grid.

Since the population in many cities mostly live in apartment buildings, we see a big challenge that must be addressed to move towards a zero-emission transportation system. Shared apartment buildings need to be "Charging ready", meaning that they provide the basic infrastructure that every owner can connect to and install and pay for a charging station at their own parking spot. The basic infrastructure should include a dynamic effect distribution system if necessary. In new buildings, it should be mandatory to install the basic infrastructure for a future 100% EV population. In existing buildings, it should be mandatory to allow EV owners to install charging stations on demand. Today we see a lot of boards of shared apartment buildings banning BEVs to park and charge because of uncertainties with new technologies, cost and fire hazard among others. It is vital that the appropriate governmental body helps spreading up to date, neutral and correct information related to this. In Norway, this is handled by the Norwegian Directorate for Civil Protection, but there is still room for improvements.

Car owners that use on-street parking daily, and don't have access to charging at work, will remain a challenge. On street charging points are costly, and additional new solutions might be required. As we are moving towards faster fast charging, this may seem like a promising solution to this challenge, but the end user cost for this type of charging is still uncertain. As new smart charging solutions, autonomous cars, car sharing and many other innovations are evolving at a rapid pace, it is vital to have an open mind when designing new transport and charging solutions for our cities.

When it comes to long distance travel we must scale up the fast charging network along main roads considerably. The Norwegian BEV market has entered the mass market, and in the coming years the fast charging network must develop at tremendous pace to keep with the exceptionally fast growth of the BEV fleet. As business models for fast charging are starting to come apparent we see a positive trend in this regard, but it is still an open question if the market alone will be able to scale the infrastructure at the necessary pace to be able to reach the ambitious Norwegian target of only selling ZEVs by 2025.

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**Mr. Espen Hauge** is the President of Norwegian Electric Vehicle Association and Vice President in AVERE – the European Association for Electromobility. His career includes project management, system engineering and research & development, working in the oil and energy industry and in construction, for global companies like ABB and GE as well as for the City of Oslo. Roles spanning from R&D director to Head of the Project Management section. Espen has a Master level degree within Industry and Environmental engineering from the Institut National des Sciences Appliquees in France (INSA), as well as Strategic Management studies at the Norwegian Business School (BI).