The way ahead for hydrogen in transport in Norway.

Which lessons can be learned from the successful implementation of battery electric vehicles?

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Background paper for the IFP/IEA/ITF Workshop on “Developing infrastructure for alternative transport fuels and power-trains to 2020/2030/2050: A cross country assessment of early stages of implementation” OECD, 30th November 2012

Transnova is a public funding body established to reduce greenhouse gas emissions from transportation in Norway. Transnova is financed by the Ministry of Transport and Communications and organized under the Norwegian Public Roads Administration. Views expressed in this article are views of the authors and do not necessarily represent official policies.
Introduction
This is a discussion document to provide inputs to the policy discussions at the IFP/IEA/ITF Workshop on infrastructure for alternative transport fuels and power-trains. The document aims at addressing some lessons learned and unsolved issues relevant for building-up of infrastructures for improved fuels. We will focus on Norway and will to a very limited extent refer to more general documents or developments in other countries.

Hydrogen for transportation has been on the agenda in Norway for quite some time. One very concrete step was when the environmental organization Bellona Foundation imported a converted Mercedes Sprinter from the German WEIT project in 2002 and had Norway’s first hydrogen filling structure operational one year later. Existing rules and regulations in Norway needed adaptation to accommodate hydrogen vehicles and related technologies and the project was an important first step to initiate this. The project was supported by the Norwegian Ministry of Transportation and Communications from 2004. Since then, seven more filling stations have been built and around 35 cars and five busses have been imported.

Norway’s battery-electric vehicle (BEV) car sales are today amongst the highest in the world and there are presently more than 9000 EVs running in Norway – out of a car fleet of nearly 2.4 million vehicles. The EV share of total car sales is just above five per cent and is still growing. Strong incentives for buying and operating BEVs combined with infrastructure build-up have contributed to this.

Today, as hydrogen vehicles are expected to be commercially available in few years, Norway is struggling to maintain its existing infrastructure and has no central government plans to develop and scale it up. This paper will look into which lessons can be learned from the successful implementation of BEVs in Norway and which issues would need to be solved in the near future.

Background
In 2010, road transport was responsible for approximately 19% of Norwegian greenhouse gas emissions, making it the third largest and the fastest growing source of emissions. Introducing a large number of battery-electric vehicles and fuel cell electric vehicles (FCEVs) could substantially contribute to reverse the trend of rising greenhouse gas emission from transport, especially as Norwegian production of electricity mainly stems from emission-free hydropower.

Norway has long been an energy exporter through exports of oil and gas. Annual electricity consumption more or less averages annual production but import- and export through power lines to Sweden, Denmark, Finland, Russia and Holland are significant – directions changing depending on time of the day, season, climate and electricity markets. Norway’s electricity production is around 95% hydroelectric and price stability and security of supply etc benefits strongly from interaction with other countries. For this reason there are plans to construct power connections also to Germany (scheduled operational in 2018) and to England (2021).

Implementation of the Renewable Energy Directive in Norway will increase our share of renewable energy from 61 % in 2010 to 67,5 % in 2020 and is expected to lead to a significant surplus of electric power production. Neither the role of hydrogen to facilitate increased introduction of renewable energy or the use of vehicle batteries to balance demand and supply is high on the Norwegian agenda – systems based on hydroelectric power are very flexible. However, how a surplus of electric energy may be used is an on-going discussion, a discussion that includes BEVs, FCEVs and the export of centrally produced hydrogen.

Norway has been an early mover both in the field of BEV’s and hydrogen. The first electrical car was imported to Norway in 1989 – a rebuilt Fiat Panda – and after hard lobbying BEV’s were exempted
from purchase taxes from 1995, followed by a general exemption from VAT in 2001. Exemption from purchase taxes for fuel cell electric vehicles followed in 2005. Norway is a country with very high vehicle taxes, so these measures can have very strong effects.

Although there is on-going work by municipalities, interest groups and network organizations, there is presently no government sanctioned roadmap or plans for developing a hydrogen infrastructure in Norway. Government commitments to support FCEVs have repeatedly been expressed, last in the 2012 White Paper on Climate\(^2\) where it is stated that Norway shall “continue to be leading internationally to facilitate the use of electric vehicles and hydrogen vehicles”\(^3\). To materialize, this statement will need to be followed up with some very concrete long term planning and actions.

There are important incentives in place for zero emission vehicles in Norway. The political consensus on climate policy reached on 8 June 2012\(^4\) guarantees the existence of financial incentives until 2018 or until 50 000 zero emission vehicles are in use\(^5\). This must be seen in relation to the Norwegian government’s commitment to limiting the average rise in global temperature to no more than 2°C compared to pre-industrial levels. Norway will undertake to reduce global greenhouse gas emissions by the equivalent of 30 % of its own 1990 emissions by 2020. About two-thirds of the cuts in emissions should be made in Norway, the rest through trading systems. The development of more CO2-efficient solutions for conventional cars will make a substantial contribution towards reaching these objectives. But this will not be enough for reaching the target of average CO2-emissions of new cars below 85 grams per kilometer. It will be necessary to develop markets for zero emission or plug in hybrid vehicles to make up a significant part of new vehicles sold in 2020. In September 2012 one in twenty cars was a BEV (the sales of plug-in hybrid and FCEV are not yet significant). The sales of BEVs have boosted the two last years and sales are expected to continue to increase.

The main incentives for zero emission vehicles today are:

- No purchase taxes (in Norway such taxes are very high for ordinary cars),
- Exemption from 25% VAT (Value Added Tax)
- No charges on toll roads (incl. congestion charge) or state ferries
- Free municipal parking
- Free access to bus lanes.
- No fuel taxes for hydrogen and electricity

\(^3\) Our translation
\(^4\) Innst. 390 S (2011–2012): Innstilling fra energi- og miljøkomiteen om norsk klimapolitikk (in Norwegian only)
\(^5\) With the present high sales figures for BEV’s there is a risk that these incentives would need to be extended or modified to benefit FCEV’s
These incentives are important since car taxes in Norway are high. They are calculated on the basis of vehicle value (VAT), vehicle weight, engine power and CO2-emissions. Typical total purchase taxes range from around 35% of the purchase price for smaller cars (1.8 liter/85 HP VW Golf) to more than 65% for larger powerful cars (4.2 liter/340 HP VW Touareg). The CO2-emission component in the purchase tax contributed to a faster reduction of average CO2-emissions for new cars in Norway than in the rest of the EU, from just below 200 g/km in 2003 to 125 g/km presently.

Present incentives, combined with the infrastructure build-up discussed below make BEV’s competitive in today’s market, but have so far had very little effect on sales figures for FCEVs. Half of the Nissan Leafs sold in Europe are on Norwegian roads and the car has been the bestselling model in parts of the country. These are powerful indications of what can be achieved within hydrogen in transport in Norway when prices for FCEV’s get right (below 60-70 000 €?) and the availability of hydrogen filling stations is adequate. So let us have a look at developments within the hydrogen sector in Norway.

Hydrogen
Background
Hydrogen for transport has been on the agenda in Norway for quite some time. Norway’s first hydrogen refueling station (HRS) opened in Stavanger in 2006. This was part of the HyNor project, which planned to connect Oslo in the east with Stavanger in the west, through a hydrogen highway via the south of Norway. As Statoil and Hydro gradually reduced their activities and as the supply of FCEVs was low, HyNor refocused and put their efforts into creating a hydrogen cluster around Oslo. HyNor collaborates with other Scandinavian countries through the Scandinavian Hydrogen Highway Partnership.

The two main oil companies Hydro and Statoil had some interesting early initiatives including the world’s first full-scale stand-alone wind-hydrogen project in the world at the island Utsira (Norsk Hydro, 2004-2010). After establishing the Stavanger station, the two energy companies continued building three more hydrogen stations. The companies merged in 2007 under the name Statoil and withdrew gradually from hydrogen related activities. The division developing atmospheric hydrolysers was sold in 2011, in 2012 downstream activities were split off into the independent company Statoil Fuel and Retail. Losing the two main industrial forces behind hydrogen developments in Norway represent a significant set-back, threatening Norway’s position as a hydrogen pioneer. Statoil transferred their three filling stations to the recently established hydrogen infrastructure company HYOP, which at present is the main actor managing and developing Norway’s filling infrastructure. The company is today heavily supported financially by Transnova, and by some of the municipalities and regions surrounding the infrastructure.

Today there are five publicly accessible HRS available in the greater Oslo region and one for busses in Oslo. The Stavanger station has been dismantled and alternative use is presently being discussed. 17 FCEV are running, the early phase hydrogen ICE vehicles are about to be phased out. In addition there are 5 fuel cell busses from Van Hool in regular traffic. An overview of the Norwegian hydrogen filling stations is given on the next page.

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6 http://hynor.no/en/ or www.hynor.no
7 SHHP, http://www.vatgas.se/shhp/
9 After a short period as Statoilhydro from 2007 to 2009
10 Hydrogen Technologies, now NEL Hydrogen
12 15 reengineered Toyota Prius and four Mazda Rx-8 RE came to Norway from 2006. The last car will leave Norway by early 2013.
There is no official road map for developing a hydrogen infrastructure in Norway. The Norwegian Hydrogen Council, an advisory body appointed by the Ministry of Petroleum and Energy and the Ministry of Transportation and Communications and consisting of individuals from research, industry and network organizations, has developed a number of recommendations. So far there has been no government commitment or official follow-up on the outputs of the 2012-2015 action plan that was handed over in May 2012. Transnova, with a total budget of around 10 million Euro, has presently far too limited funds and no mandate to engage in large scale roll-out of hydrogen infrastructure. However, Transnova funds three pilot and demonstration projects with hydrogen fuel stations and is presently funding operational cost for the three HYOP hydrogen stations.

### Hydrogen stations in Norway (all in the greater Oslo area)

- **Porsgrunn (HYOP)**, In operation since 2007, Capacity 130 kg/day, 350 bar car/bus, 700 bar autumn 2012. Hydrogen comes from chlorine production at Rafsnes nearby and is supplied by pipeline.
- **Drammen (HYOP)**, In operation since 2009, Capacity 20 kg/day, 350 bar, 700 bar. Presently hydrogen is trucked in to the station, but there is on-going work to supply the station with hydrogen from biogas produced from waste.
- **Oslo (HYOP)**, In operation since 2009, Capacity 20 kg/day, 350 bar, 700 bar. Hydrogen is trucked in, but will be replaced by on site generated hydrogen from electrolysis.
- **Oslo (H2Moves13)**, in operation since 2012, capacity 200 kg/day, 700 bar, on site generated hydrogen from electrolysis.
- **Lillestrøm (Hynor Lillestrøm14)**, in operation since 2012, capacity 24 kg/day, 700 bar, presently from electrolysis (partially photovoltaic), later also generated on site from reforming of biogas.
- **Oslo (CHIC Oslo15),** in operation since 2012, capacity 250 kg/day, 350 bar generated on site from electrolysis.

Norway has a strong process industry and a number of companies involved in hydrogen production. Hydrogen is an intermittent product in the production of fertilizers and the fertilizer company Yara has produced hydrogen both with electrolyser as well as through steam methane reforming (SMR) at Herøya (Porsgrunn, south of Oslo). Hydrogen is also a by-product in the production of chlorine related products where the company Norsk Hydro is active at Rafnes (Porsgrunn). Finally, Statoil’s hydrogen production as a part of both their methanol production at Tjeldbergodden (Mid-Norway) and at their refinery at Mongstad close to Bergen is worth mentioning.

There are other examples of Norwegian companies positioning themselves in hydrogen related early markets: Raufoss Fuel Systems and Hystorsys are active within hydrogen storage, Nordic Power systems is developing fuel cells, ZEG Power, GasPlas, NEL Hydrogen, RotoBoost and others are active within technologies to improve hydrogen production, and a number of very central maritime companies are positioning themselves within battery electric and fuel cell electric propulsion for

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13 [http://www.h2moves.eu/project.html](http://www.h2moves.eu/project.html)
14 [http://hynor-lillestrom.no/english/](http://hynor-lillestrom.no/english/)
ships. We will mention only one example: The ship owner Eidesvik, together with DNV, Wärtsilä and Westcon are developing systems to run a molten carbonate fuel cell from MTU in parallel with batteries and gas powered engines on an offshore supply vessel\(^\text{16}\).

Except for the maritime and hydrogen producing companies, none of the companies mentioned above are large or do have the financial power to involve themselves in infrastructure build-up. Norwegian energy companies tend to be either dominated by oil and gas\(^\text{17}\) or by hydro-electric power\(^\text{18}\), and are presently very reluctant to engage in hydrogen related activities. Norway’s very privileged access to energy and very limited need for additional grid balancing capacity may contribute to this\(^\text{19}\).

**The way ahead for Hydrogen**

Even though Norway’s low population density poses important challenges when developing infrastructures for clean fuels, rolling out infrastructure in and around the four major cities and connecting them would be a far more limited task and would still cover very large parts of the population. If politically feasible, this could be a potential strategy for the first phases of infrastructure roll out. On the positive side counts the fact that Norway is a high income country with a population of fast implementers of new technologies. A very strong history on facilitating and making use of electric cars, and a positive history for private-public collaboration in important strategic areas such as energy, maritime industry and seafood is another important point in this regard.

The County of Akershus is leading an interesting process of developing a hydrogen strategy for the Oslo region. Preliminary results from the strategy process identify three phases for hydrogen developments in Norway. The first phase (2013-2015) is a pre-commercial phase, dominated by small test fleets and early users depending on today’s small scale infrastructure. The early commercialization phase (2015 – 2020) is characterized by more and more cars and busses being available and a need to gradually develop HRS. In the maturing market phase (2020-2025) incentives will gradually be phased out and HRS will be operated and developed by a commercial market. Early development of a financially viable infrastructure should cover south-eastern Norway and be linked to potential fleet users. A successful development would require predictable public finance and support. The establishment of larger fleet users (taxi fleets and others) would be central to create income for today’s infrastructure prior to deployment of new stations. Timing of incentives for vehicle procurement and station development is crucial and a feed in tariff is recommended for station development as soon as standardised solutions are agreed upon beyond 2015. The County of Akershus has reserved 20 million NOK (approx. 2.5 mill Euro) on their 2012 budget and have stated that they want to develop their role as a promoter of hydrogen in the transport sector.

A study performed by LBST for Statoil\(^\text{20}\), analysing infrastructure build-up in the greater Oslo area, provides valuable inputs to the possible strategy of developing hydrogen infrastructure around high population density clusters. *LBST conducted a case study for infrastructure build-up in the greater Oslo area calculating costs and needs for three scenarios. We will only present results for the base*

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\(^{17}\) Statoil has some engagements in offshore wind projects

\(^{18}\) Some companies are engaged in power generation from wind

\(^{19}\) One interesting exception is the project, “Hydrogen for transport from renewable energy in mid-Norway”, led by SINTEF. The project partners include regional energy companies and potential users of hydrogen

\(^{20}\) Ulrich Bünger and Christoph Stiller (2010) Case Study for Infrastructure build-up in the Greater Oslo Area. Ludwig Bölkow Systemtechnik (www.lbst.de)
scenario of 55 000 vehicles in 2025\textsuperscript{21}. The study assumes that 30 HRS are to be built until 2025. In the early phase (2015 – 2018) hydrogen demand will be low and hydrogen cost very high, above 60€/kg. Overall cost during this phase adds up to 1 – 10 million €/year. Assuming hydrogen will continue to be exempt from fuel taxation until 2020, the cost of hydrogen is calculated to reach a competitive level of 15€/kg by about 2019 and of 8-9 €/kg by 2024-25. A total investment of 100-220 million € is estimated for the hydrogen infrastructure in the greater Oslo area until 2025. The amount required to fill the gap between per-km-parity price compared to diesel every year from 2010 to 2025 would require a total of 43-49 million €.

The \textit{Norways study}\textsuperscript{22} conducted by NTNU, IFE and SINTEF in 2009, analyses hydrogen production, distribution and refuelling in Norway until 2050. The study concludes that complete national coverage of HRS is deemed attainable by 2040. Hydrogen would be available at 1100 of today’s refuelling stations, each serving an average of 1600 vehicles, supplying hydrogen to a total of 1.760,000 vehicles. Hydrogen would be produced by a combination of central steam methane reforming (SMR), biomass gasification and electrolysis and as a by-product from industrial processes and distributed partly by trucks and partly through a pipeline grid. In addition, some stations would rely on onsite electrolysis and onsite SMR. Projections of hydrogen prices correspond to the LBST report (competitive by 2019), but results indicate that there would be large local variation in cost between regions. The study therefore recommends cost levelling policies to ensure consumer attractiveness also in less populated regions. The total estimated investment in a nation-wide hydrogen refuelling station infrastructure is estimated at 1.5 billion €\textsubscript{2005} up to 2050. This equals around 850€ per car. This figure corresponds relatively well with the results from the \textit{Coalition study}\textsuperscript{23} estimating a cost of 1000 – 2000 € per car or approximately 5% of the overall cost of FCEV’s. This figure can be compared to the € 1500-2500 per vehicle figure for BEV’s \textsuperscript{24}

The Coalition study points out that hydrogen manufacturers have an incentive – as soon as the economics work – to race to beat their rivals. Infrastructure providers on the other hand bear a high first-mover risk, making a heavy up-front outlay to build a retail station network that will not be fully utilized for some years.

The environmental organization Zero\textsuperscript{25} is presently conducting a study to assess the various regulatory regimes and incentive schemes available to accelerate the introduction of hydrogen in Norway and reviews approaches in leading countries and regions. Preliminary recommendations include giving direct support to cover OPEX for HRS in the period up to when more market based incentives will be efficient. In addition, support for investment cost could be made available. From 2016, a legal commitment for fuel retailers to provide a certain level of HRS could be implemented. This model would be very similar to the Swedish approach for securing access to biofuels. Alternatively feed in tariffs could be used.

The Norwegian Hydrogen Council’s report, mentioned above, includes recommendations on the following steps\textsuperscript{26}:

\begin{itemize}
  \item An incentive scheme securing the running of hydrogen stations should be established
  \item Policies to secure an efficient phase-in of zero emission vehicles should be maintained and strengthened
\end{itemize}

\textsuperscript{21} The “high-scenario” of 110 000 cars and the “low scenario” of 22 000 cars will not be discussed here. Multi-purpose vehicles, delivery vans and public busses are not considered in the study
\textsuperscript{22} NTNU, IFE, SINTEF (2009) Recommendations to the Norwegian Government for the implementation of hydrogen as transportation fuel in Norway, available at \url{http://www.ntnu.no/ept/norways}
\textsuperscript{23} McKinsey (2011). A portfolio of power-trains for Europe: a fact-based analysis
\textsuperscript{24} Quoted above, assuming home charging 50%, cost 2-400 €/car and 50% public charging at 5000e serving two cars
\textsuperscript{25} \url{www.zero.no}
\textsuperscript{26} Hydrogenrådet, Handlingsplan 2012-2015, our translation. The action plan will soon be published in English.
- Transnova should be strengthened and support to transport research should be increased
- The potential to export sustainable hydrogen from Norway should be explored
- Public entities should require zero emission vehicles when purchasing or running transport services

**Battery-electric vehicles**
There are today more than 9000 BEVs on Norwegian roads, and the sales figures have grown substantially in recent years. Figure 1 shows the quarterly growth in number of EVs in 2011 and 2012. The large majority of EVs in Norway are private cars; only 26% are owned by businesses or public services. In this respect Norway is unique, which may provide valuable information as private owners usually have a different and less predictable driving pattern than professional users.

![Number of EVs in Norway in the different quarters of 2011 and 2012. The orange line shows a forecast of the sales growth necessary to reach the unofficial goal of 10% BEV and plug-in-electric vehicles in 2020.](image)

This fleet is served by an infrastructure of 3500 public charging points at 1000 charging stations. 65 of the established charging points are quick chargers, where the EV can be charged up to 80% capacity within 20-30 minutes. For the regular charging stations it takes between 6 and 9 hours to achieve full charging.

The locations of the charging stations are illustrated in figure 2.
The roll-out of the charging infrastructure started in 2009, parallel to the establishment of Transnova – a Norwegian governmental tool for climate-efficient transport\textsuperscript{27}. The technical solutions chosen have been in line with the charging specifications of the vehicles. In brief, while the charging stations funded by Transnova in the past were standard charging stations (mode 1 based on 230V 1-phase connection), those of today are quick chargers based on the Japanese Chademo standard. Those of the near future need to be more diverse. The use of AC (alternating current) as an alternative and supplement to DC (direct current) fast charging must be implemented into the existing and new charging infrastructure.

Governmental role in creating a market
During the past two decades, Norway has established a framework to promote the use of EVs and support Norway’s former EV manufacturers. This was not introduced as a master plan, but evolved

\textsuperscript{27} http://www.transnova.no/english
year by year to facilitate the market. The origin of the incentives can be traced back to Norway’s EV manufacturers in a coalition with environmental non-governmental organisations (NGOs). The environmental argument for EVs is particularly strong in Norway, as nearly 100% of the electricity produced is hydro-electric, giving extra validity to the claim of the EV as a zero emission vehicle.\(^{28}\) As early as in the 1980s industrial actors started working for incentives for what could become a future industry for Norway. With the 2011 bankruptcy of Think (an EV manufacturer), there is not much EV industry left in Norway. Though the OEM Buddy still has some production and there is an automotive industrial group collaborating under the umbrella “Electric Mobility Norway” which explores the possibilities for industrial developments.\(^{29}\)

Nonetheless, the 2012 political consensus on climate policy guarantees the existence of financial incentives discussed in the background section until 2018 or until 50 000 ZEVs are in use. Other incentives – as access to bus lanes or parking privileges – will be phased out when capacity issues so dictate.

**Governmental role in establishing a charging infrastructure**

Norway has developed a model for the charging infrastructure where the state has funded or co-funded investments, but with ownership and operating responsibility in private hands. There are some exceptions to this rule, with the municipal charging stations programme of the capital, Oslo, as the most notable exception.

Whether the state or local authorities should have the ownership of the fast-charging infrastructure has not been an issue. Private companies have shown a strong interest in taking this responsibility, especially within the energy sector. We believe this will be a sustainable and functional model also in the coming years. Still, governmental co-funding seems to be crucial if the network of charging infrastructure is to meet the needs of a growing BEV-fleet. Today normal “slow” charging is free, but in the long run it will be necessary to start collecting payment for energy and the use of the charging points. Many private actors are currently planning for this. To be awarded funding for fast charging, the applicants are required to submit a long-term business model describing how they intend to finance and operate the infrastructure. Currently the financial returns from operation a charging point are minimal, but it can be serve to attract customers to businesses along the road or at shopping destinations. The governmental funding of fast chargers has a limit of up to 45% with a maximum funding of 200 000 Norwegian kroner (approximately 27 000 euro per charging point).

**Public charging stations database**

The charging stations database NOBIL (Norwegian database for infrastructure for charging stations), was launched by Transnova in 2010 to serve as the backbone for ITS (Intelligent Transport Systems) services and business related to electromobility.\(^{30}\) The database contains information for generating internet, app and GPS guides to 3500 charging points, and provides:

- key data (practical and technical information, availability for users, map coordinates and photographs)
- free access to data for profit or non-profit purposes
- capability to handle real-time data

The database is continuously expanded as new charging stations are built, with EV users keeping the information that is posted up to date. Transnova has made the strategic choice of keeping NOBIL in public ownership. We regard charging stations and the database providing information about them as part of the transport infrastructure, like traffic lights and roads. A situation where the public has to use different digital applications to get a comprehensive picture of the charging infrastructure should

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\(^{29}\) http://www.electricmobility.no/

\(^{30}\) http://www.nobil.no/
be avoided. Transnova is committed to keep the information on NOBIL open, updated, using open source software and non-proprietary technology. A Nordic extension is to be integrated by the end of 2012. Transnova offers the use of the NOBIL database tool to governmental agencies or other public service actors committed to enhancing electromobility in their country.

Challenges and future strategies
Important challenges remain to be solved and there is still no a common national standard for payment, booking and access to charging points. Interoperability is achieved as a “mainstreaming” operation after installation of the charging points. However, private actors have received funding from Transnova in order to progress this development, among them are a coalition representing 19 of the largest electric utility companies.

A report on strategies for expanding the infrastructure has recently been published31 (in Norwegian only). Norway’s BEV success has taken place despite the country’s specific challenges, including a harsh climate, uneven topography and sparse population density. Though there are examples of BEVs in use throughout the country, the strategy for further build-up of infrastructure pinpoints areas with the most favourable climate combined with a relatively dense population. These two criteria largely overlap. The exemption from this rule will be the placement of a few quick chargers in three different corridors connecting the two major strategic regions, as illustrated in figure 3. According to the report, ninety per cent of the population will be served by providing 105 quick chargers in the Oslo region, 143 quick chargers in the coastal region and 9 quick chargers in corridors. The total cost of this will be between 15 and 20 million Euro. At present the demand for more chargers among users is high, especially in areas without quick chargers.

Figure 3: Strategy for the build-up of the fast charging infrastructure covering 90% of the population.

31 Pöyry Management Consulting AS (2012), Strategier og kriteriesett for utplassring av hurtigladere (Del 1), Norwegian Only. Available at http://www.transnova.no/hurtigladeutredningen
Conclusions
Some elements of Norway’s hydrogen related developments and challenges are very similar to other countries’ challenges – of which many, at least partially, are about to be addressed in countries like Germany, Japan, South Korea, USA and others: There is a need for stable, efficient and predictable policies to promote the use of hydrogen in the transport sector. Large amounts of funds will be needed up-front to secure a sustainable production and distribution of hydrogen and the availability of fuel cell electric vehicles at acceptable prices. In this respects Norway is just like most other countries.

But Norway has some more unique characteristics that should influence policy choices. Some of these will be addressed very briefly below. A special emphasize will be put on potential lessons learned from the very successful implementation of battery electric vehicles in Norway.

A number of positive Norwegian characteristics for a successful phase-in of hydrogen in the transport sector should not be overlooked. The country has a growing surplus of electricity production and a limited exchange capacity with neighbouring countries. This can be a driver for production and possible export of sustainably produced hydrogen. Similarly for natural gas - if combined with carbon capture and storage (CCS): Natural gas prices are pointing downwards and could lead Norwegian energy companies to try to identify new markets. On the other hand, the set-up of Norway’s energy sector with energy companies focussed on either oil and gas – or hydroelectric power may limit motivation to engage in hydrogen related activities.

Norway’s industrial base is also pointing in diverging directions. In some areas – like the maritime industry or automotive supply industry – Norway is manufacturing and exporting technologically advanced products to the rest of the world. Industrial engagement in hydrogen related activities is still limited though, notwithstanding the growing numbers of small companies working on emerging technologies.

Norway’s relatively high taxes for traditional cars combined with a comprehensive incentive scheme for zero emission vehicles proved efficient for BEVs and may also help the introduction of FCEVs as vehicles may be competitive in Norway far earlier than in other markets. But moving from fossil fuels to hydrogen represents a larger transformation than moving from fossil fuels to electricity. A comprehensive electricity infrastructure has existed for decades and people are familiar with the energy carrier. Electric transport “merely” means using electricity for yet another application. Hydrogen on the other hand is about starting to use a new energy carrier, to establish rules and regulations and new technologies and infrastructure for its use. People will need to change attitudes and beliefs. As often stated by others: The technology will soon be ready for the market; will the market be ready for the technology?

Early BEV users were not dependent on availability of a public charging infrastructure. The use of EV’s started as a kind of grass root movement charging at home or at work. Significant public infrastructure investments were not available until many years later when the number of users was on the rise and prospects for large OEMs entering the BEV-business were good. In contrast, investments for a hydrogen infrastructure will have to be available up-front. And even though per-car infrastructure cost in the long run will be similar for electricity and hydrogen (ref the coalition study results), economies of scale play a much larger role for hydrogen infrastructure where small units are relatively expensive and low utilization rates represent a more serious challenge.
When financing fast chargers in Norway, a ceiling of 45% public funding has not prevented strong interest from private companies and regional authorities. A variety of actors, dominated by electricity utility companies, have applied for funds. A study by Pöyry Management Consulting on business models to establish fast chargers in Norway\textsuperscript{32} assesses cost and profitability for fast chargers in various locations and under various assumptions. In a model with only pay as you go (no subscriptions) a fast-charging point in urban areas may be profitable if utilized at least 5.5 times per day\textsuperscript{33}. Similarly fast chargers may be profitable under realistic assumptions\textsuperscript{34} in urban areas if electricity is sold at equivalent fossil fuel vehicle kilometre cost (0.5 €/kWh) to non-subscribers and if at least 50% of users are paying monthly subscription fees of 25€. In transport corridors in rural areas with higher needed electricity network investment cost (70 000 €), 0.75 €/kWh for non-subscribers and a subscription rate of 60% as well as higher BEV deployment rates (more then 85 000 BEV by 2020) would be needed to generate profitability.

In the field of hydrogen, interest from the private sector is still very limited, and funding at far higher percentages has been necessary to establish and manage HRS. One example of potential profitability for a HRS is provided in figure 4 below, showing that a station – under the given assumptions – would not be profitable until around 2030, due to low utilisation rates.

\[\text{Figure 4, the economics of a HRS with on-site hydrogen production.}\]

\[\text{Source: Presentation from Ulf Hafseld, the manager of HYOP, November 21}\textsuperscript{2012}\]


\textsuperscript{33} Assuming a charging price of 6.6 € per time (equivalent to around 0.5€/kWh), low investment needs in electric infrastructure, 100% debt financing and around 5000€ yearly maintenance cost.

\textsuperscript{34} 10 years payback time, 10% internal interest rate, 30% debt at 6% interest rate, more than 60 000 electric vehicles on the road by 2020
Engagement from industry and prospects for employment and economic growth is an important factor legitimizing public engagement in a sector. The two early BEV producers in Norway probably played an important role to motivate public engagement into BEVs, corresponding industrial gains from engaging into hydrogen may be more difficult to detect. The very limited and expensive access to FCEVs may delay the public engagement into hydrogen. Money spent on electrification today may be perceived as more legitimate, having positive effects fast. Money spent on hydrogen will at best have effect on emissions and transport patterns in years. Hydrogen is still perceived by many as something at best for a distant future.

The discussion in this last section indicates that a copy-cat approach to Norway’s own BEV history to Norwegian initiatives towards hydrogen would be impossible. However, important lessons can – and should be - learnt to facilitate energy transformation also in the transport sector. Important elements would include a tax regime and incentive scheme not very unlike the one in place today, and public funding for hydrogen infrastructure. But cost structures for HRS and industry interest in Norway differs significantly from the electricity sector and creates additional challenges. Early public engagement and financial support into especially HRS would therefore need to be more substantial than for electricity - and put in place before vehicles are introduced large scale. Whether the political backing to provide funds for this is sufficient in Norway will be a crucial question for scaling up the use of hydrogen in the transport sector in the months and years to come.