Institute of Transport Economics
Norwegian Centre for Transport Research

Summary:

Electricity for road vehicles

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Electricity for road vehicles is a future-oriented concept in Norway. Electric Vehicles are most likely to continue being small vehicles driven over relatively short distances. Increased battery capacity and costs kept to a minimum will have to be realized if a large market share is to be attained. In the period 2015 to 2025, Plug-in hybrids will become competitive and Fuel–cell vehicles may become a more relevant alternative than they are today.

Main objectives in the report

The Norwegian government and the European Union (EU) have drawn up regulations aimed at reducing fossil CO_2 emissions from road traffic. This is a challenge that has to be met through a spectrum of measures, and in this report the focus is on the possibilities and constraints connected with "Electricity for cars", i.e. technology by which cars can be charged through power grids and Norwegian hydroelectric power.

In Norway, *EV (Electric Vehicle)* is the term given to vehicles using electric power stored in batteries. Norway is one of the countries in the world with the highest number of *EVs* per inhabitant and with economic policies strongly stimulating purchase, import, production and development of *EVs*. Norway is a frontrunner although the international car industry has not yet started the mass production of *EVs*.

Plug-in hybrid Vehicles (PHEV) will operate on energy stored in batteries and with more conventional energy carrier. *PHEVs* that will soon be available for sale are cars with a combustion engine, a power generator and an electric engine. In addition, they will have a series of batteries that can be charged directly from power grids.

Fuel–cell Vehicles (FCEV) use hydrogen as an energy carrier, and have electric drive (after transformation of the hydrogen to electric power). In Norway, electricity can be the energy source of choice in the production of hydrogen for *FCEVs*.

Some of the main questions in the report are:

- Will *Electricity for road vehicles* become competitive alternatives to the traditional combustion-engine car?
- Will electricity be practicable and economically feasible for cars?
- What kind of electrified vehicles will be best suited for use in Norway?

A literature review, a survey among owners of hybrid cars in Norway, technical and economic analyses, together with information from our partners DEFA, Toyota Norway, Statoil and Energy Norway form the base for our results and conclusions.

Advantages and disadvantages of electric drive

The main argument supporting electric drive is that the energy efficiency is much higher than that of combustion engines. *EVs* may have an efficiency of about 85% "Tank to Wheel" and that is superior to competing alternatives; see table S.1.

Table S.1: Energy efficiency, in percent.

	"Well to Tank"	**"Tank to Wheel"**	**"Well to Wheel"**
EV (Hydroelectric power)	90	85	77
HEV (Hybrid Electric Vehicle)	90	40	36
PHEV	90	58	52
FCEV	70	60	42

Fast-charging for *EVs* would solve the problem of range, but the possibilities are limited because neither the regional nor the local infrastructure for the supply of electricity are dimensioned for high amounts of tapping during short periods. Fast-charging will reduce range anxiety (the fear of empty battery) and make the driver use his *EV* for longer driving ranges than without this possibility.

The major challenge with electricity to road vehicles is coping with batteries that are heavy, expensive, and with durability still uncertain. For practical distances of about 100 kilometers, the batteries will weigh about 200 kilograms (including the control electronics) and cost approximately NOK 100 000. In 2011, batteries even for a small car often cost more to produce than the rest of the car put together. The potential for development and improvement is there, but the cost of racks of batteries with long-range capacity remains an obstacle. *EVs* have simple technology and a inexpensive propulsion systems, and since small vehicles can function with a smaller, lighter and less expensive battery rack than larger vehicles, competitive *EVs* should be as small and as light as possible.

The torque and efficiency of electric drive along with the practical advantages of a combustion engine in a *PHEV* car give the best of two possible worlds. The Opel Ampera is one example of a plug-in hybrid that will be on the Norwegian market in 2011–2012. Opel/GM say that the car will have re-chargeable batteries giving 60 km on electric drive, and that the combustion engine will re-charge the batteries when they are about to run out. The concept of Opel Ampere is in the future expected to become available with different engine sizes and different battery capacity from several car manufacturers.

The first hybrid vehicle (*HEV)* sold in high volumes was the Toyota Prius. This car has a hybrid system with both an electric motor, a combustion engine and a separate dynamo. The hybrid system will in differentiated driving conditions, reduce the petrol consumption by approximately 30 percent. With re-chargeable

and bigger battery rack there is more energy to save. Commercial production of the *PHEV* version of the Toyota Prius will begin in 2012.

Carbon neutral electric power supply is not a problem in Norway. Using 7 TWh, which is just 5 percent of Norway's total electric power production, all light vehicles in Norway can be powered by electricity. Connecting to the grid in the owner's own garage is a practical way to charging the batteries for an EV, and requires no more power than would a 1 kW electric heater on for 24 hours.

Motives for choosing HEVs and EVs

A survey of 991 owners of *HEVs* has shown that they are: men over 60 years of age, have at least 6 years of higher education, live in the eastern parts of Norway, and in one or two-person households.

In this study, *HEV* owners are compared with owners of *EVs* and of combustion-engine cars whenever possible. *EV* owners are younger and usually live in a household with three or more persons. To a higher degree than *HEV, EV*-owners have access to a second car in the household. The possibility of free use of bus-lanes (thereby avoiding congested traffic) in and out of city areas is a major factor influencing purchase of an *EV*. The *HEV*-owner does not have this advantage – and is aware of it.

HEV-owners like the car they have, and say that they would buy *HEV* the next time around, too. The major motivation for buying *HEVs* is that it is "environmental friendly", but "interesting technology" is also a reason given by about half of the owners.

What can be done to persuade a higher percentage of drivers to buy an *EV* or partly electrified car? Further improvement of batteries and their range, as well as extended license to use bus-lanes, are mentioned as important factors. In Norway, an *EV* is often car number two in the household, and is used mainly on work-related journeys.

Battery's range is also important, although less so for *PHEVs* than for *EVs*. Price and more testing are also important premises for future purchase of PHEVs.

HEVs and *PHEVs* are more likely than *EVs* to be the sole car in the household, because these cars can be used over both short and long distances, and at the same time have lower petrol consumption than conventional cars. Until the distance that *EVs* can travel between each battery charge is much greater, and charging much quicker, these cars are primarily suitable for shorter and predictable journeys between places where the driver spends some time and where there are charging facilities in place.

Conclusions

Determining priority and considering the environment, one's economy and practical use of a car, the private cars of the future will probably be:

- *EV* – a smaller vehicle driven over short driving ranges
- *PHEV* – larger vehicles used over longer distances
- *FCEV* with hydrogen as energy carrier if prices become competitive

For our project partners, new technology and new types of transport can be a threat, but technological development and change will provide new business opportunities. Technology for reduced climatic influence is of major social interest and with great economic potential. However, gambling on technology that does not prove economically sustainable will lead to loss. The challenge is in understanding what technologies that will be competitive, and in determining when it is economically viable to become an active participant in the market.

DEFA are world-leading producers of engine and coupé heating for cars. An electric engine-heater is always an advantage. A warm combustion engine reduce emission of greenhouse gases the first five minutes, and lower emission of gases injurious to health for the first 1-2 minutes. The need for electric heating of the coupé during winter is important in all types of plug-in cars, because heating using power from the batteries will reduce the driving range. For DEFA, one of the challenges for the future will be in adapting to a market where a lot of new cars already at delivery have electric wiring.

Toyota develop *EVs, HEVs, PHEVs, FCEVs* and market these vehicles in Norway. Batteries and lack of carbon neutral produced electric power are the main reason why electrified vehicles not are produced in high volumes world-wide. Toyota state that, at some point, all their cars will have hybrid drive. The extent to which *EVs* and *PHEVs* will be sold in Norway will depend on the Norwegian system of taxation on new vehicles, and on world-wide demand. The HEV-owner survey shows that in HEV-owners are older than EV-owners. The HEV-owner is also more likely to live in a small household (1-2 persons). It is a challenge to get younger people and families with small children to buy PHEVs and HEVs.

Statoil and Statoil Fuel and Retail supplies the market with energy to vehicles – traditionally petrol or diesel from mineral oil. Fast charging of cars at a limited number of petrol stations is likely to become a positive market approach. Large scale charging of *EVs* would however put new and costly constraints on space for parking and the infrastructure for supply of electric power. *PHEV*s are likely to dominate the market for electricity to road vehicles and there will be a demand for more practical carriers in addition to electricity that can be charged at home.

EnergyNorway is preparing for increased use of electricity for road vehicles in Norway. Docking stations and fast-charging stations for vehicles are necessities for comfortable use of EVs. Energy saving and electrification of vehicles offers a number of opportunities for EnergyNorway and power companies, but the development of new services will take time.

There is need for increased knowledge of the processes that can contribute to new energy-efficient car technology and renewable energy carriers. When working towards environmental–technological solutions, the responsibilities of society, the industry and individuals need to be defined. It is also important that technological and other means are seen in connection with one another, so that the gains from technological improvements are not “eaten up” by the growth in traffic.