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# HyWays: The Norwegian Hydrogen Energy Vision

## Introduction

The Norwegian hydrogen energy vision in HyWays builds upon NOU 2004:11[1] . This is a national strategy document where the potential future role for hydrogen as an energy carrier is outlined, and the importance of national resources like hydropower and natural gas is pointed out. The vision can also be traced back to earlier studies such as the German/Norwegian research project on hydrogen technology "Norwegian Hydrogen Energy in Germany (NHEG)" conducted in the years 1990-93. The idea was to produce hydrogen in Norway, for use in Germany, but the project did not lead to commercial results. Other more recent studies, e.g the SINTEF energy chain analysis for ENOVA in 2002, have also influenced the vision.

The Norwegian Hydrogen Energy Forum is an influential interest organization promoting a transition towards more use of hydrogen energy. The vision has also been influenced by the opinion of the hydrogen strategy groups from industry set down by the Government.

The relatively strong awareness of the importance of interdisciplinary research in Norwegian society has also influenced the vision. In line with the position of the European Commission research policy, the combination of social and natural sciences as well as balancing technological and non-technological issues characterize WNRI input.

The Scandinavian context is also relevant in the process of opinion development. The Nordic Energy Research group has a clear interest in fuel cells and hydrogen. There is even a Nordic Roadmap being developed within the frame of The Scandinavian Hydrogen Highway Partnership.

The vision is developed with major input from the Norwegian HyWays partners (Statkraft, Hydro, DNV and WNRI). In addition a range of other stakeholders has participated in the process of opinion development. These include the research institutes SINTEF and IFE, the governmental agency NVE, the oil company Statoil and NGOs being more or less influential such as Bellona and Zero.

## Development of the energy system (excluding hydrogen)

The national hydropower resources have made Norway the world 6$^{th}$ largest producer of hydropower, which today is utilised in the Nordic electricity network (Nordpool). Currently, the oil and gas industry is about three times larger than any other industry sector in Norway (based on financial contribution). Norway is rated as number seven worldwide regarding oil production, and is the third largest oil exporter in the world. Norway also export significant quantities of natural gas to the EU, and is the forth largest gas exporting country world wide. The concern for overall domestic energy supply is not an issue in Norway in contrast to many other European countries.

[1] NOU 2004:11. "Hydrogen as the Energy Carrier of the Future". Report from the Official Norwegian Hydrogen Commission.

NOU 2004:11 state the potential of environmental friendly production of hydrogen from Norwegian natural gas, if the $CO_2$ is handled appropriately, and points to environmental benefits, if hydrogen is produced by renewable energy based water electrolysis.

In Norway, the potential to foster new economic development is a key motivation for hydrogen initiatives. The main reasoning for the national focus is the potential for utilisation of Norwegian natural gas resources to produce hydrogen, together with environmental benefits and potential to foster new economical development.

It is expected that the development of the national energy system will have a continued high reliance on electricity from mainly renewable sources. A large number of hydro power sites have been built during the last century and in parallel a nationwide power transmission and distribution system was developed. This has resulted in a high dependence on electricity as a primary energy carrier. This electricity is used for electricity specific processes in power intensive industry and, to an unusually large extent for heating of buildings. In the latter, the electricity use is supplemented by a large share of biomass utilization, mainly in the form of firewood in wood-burning stoves. This is again supplemented with small, but rapidly growing district heating and small heating networks relying on wood chips, and stoves and boilers using wood pellets.

Today the Norwegian electricity mix today is more than 95 % renewable based, mainly based on hydroelectric power. New large hydro power developments are politically difficult, and instead a development is foreseen where the increased energy demand will be met by transition to bioenergy and other renewable sources for heating purposes and new renewable electricity generation from small hydro, modernised existing hydro, wind (on- and offshore), solar and biomass. Resource availability and demographic factors will determine the regional distribution of these energy forms. A development of domestic energy production based on natural gas with $CO_2$ capture and storage (CCS) has also started.

Norway is a major exporter of fossil oil and gas. Domestic use of natural gas is very low but expected to increase. Establishment of distribution networks for natural gas has only recently been incepted by build-up of local distribution grids, mainly for heating purposes. However, such developments will probably be limited to densely populated areas in close proximity to the gas terminals.

The development of the energy system is expected to rely on how it affects the beautiful natural sceneries Norway is known for such as fjords, mountains, forests, waterfalls, glaciers and a long coastline stretching far north. The unspoiled nature is the basis for an extensive tourism industry, which in combination with relatively high environmental consciousness, challenges further exploitation of both fossil and renewable energy resources.

Utilization of fossil energy resources is closely linked to transportation. The Norwegian maritime sector (with 12 000 coastal vessels and a large international fleet) is important in the national economy. The energy use in this sector is expected to remain high, but with a gradual change to less polluting energy carriers.

**Long term contribution of hydrogen: 2030-2050 and beyond**

The long-term vision for hydrogen use in Norway is that of a sustainable energy system. This implies that the main parts of the energy consumed will come from renewable sources. Even

though expected to diminish, fossil energies - whether in the form of oil or gas, still play important roles, but only associated with extensive use of CCS at important point sources.

Norway continues to play an important role in exporting energy to other European countries. The energy export is either as natural gas or hydrogen produced from natural gas with CCS.

*A long-term vision of the energy system:*
Electricity is continuing to be one of the dominating energy carriers, and is produced from hydro, wind (on- and offshore), solar and wave power. Biomass also contributes to the electricity production.

In addition to electricity, bioenergy plays an increasingly important part for meeting the energy demand, both through use of biomass for heating purposes and transport through the use of various types of biofuels. Fossil fuels are losing ground, but still play an important role, particularly in the early phase of the period.

*The role of hydrogen in this energy system:*
As was also pointed out in NOU2004:11, hydrogen in the long term is expected to play the main important role as a fuel for transportation. This encompasses road-based use in passenger cars, vans, buses and lorries. The use in maritime applications is also expected to be established, and build on the high national competence in this important sector of Norwegian industry.

The hydrogen will most likely be used in the gaseous form. Liquid hydrogen is not viewed as having good prospects, but this could change over time, e.g. as a result of developments in small scale condensation, currently being investigated at SINTEF.

Stationary hydrogen use (for electricity needs of individual households, buildings and industry) is foreseen at small scale in remote locations without access to the main electricity grids. In addition, in combination with export of hydrogen, some stationary larger scale use could be seen, e.g. for offshore installation and in areas with limited el. grid capacity.

The dominating production of hydrogen is expected to be water electrolysis based on electricity from renewable energy sources. Hydrogen production based on natural gas with CCS also plays a role, particularly in the early phase of the period.

Renewable energy resources will contribute significantly to local hydrogen production in the most favourable regions. This encompasses coastal regions where wind and wave energy are developed into important sources to power water electrolysis, and in parts of the country with biomass utilisation mainly connected to wood waste.

Even though the main hydrogen production is envisaged for local and regional use, the transport of hydrogen by pipeline may gradually become a more attractive option for transportation of larger quantities of hydrogen, e.g., to densely populated regions and ports requiring larger amounts for maritime use. In addition, pipelines are likely to be seen for export to other European countries (based on offshore wind or reforming natural gas with CCS). The export of this hydrogen (produced without $CO_2$ emissions) is a long term option for replacing part of the natural gas export.

The transport by truck is preferred for smaller hydrogen quantities. The hydrogen is then delivered to the consumers, i.e. the refuelling stations, for hydrogen cars, buses and trucks. However, the national electricity net is more extensive and has higher capacity than in many other European countries, and could be made available for distribution of electricity to hydrogen production, especially in situations where this would be connected to improved capacity utilisation of the grid. Even with the energy distribution loss, this could be a cost competitive alternative to the energy-demanding hydrogen transport by truck.

**Hydrogen in the intermediate period: 2020 - 2030**
Hydrogen demand is rapidly increasing, mainly as a fuel for the road-based passenger transport forms private cars, taxis and buses, and in lorries and vans. Maritime use of hydrogen is developing and infrastructure build-up is making hydrogen available as a real fuel alternative for ferries in specific ports.

The increased demand expands the range of options for local and regional hydrogen production. Industrial by-product hydrogen is important to satisfy local demand in some areas. However, if the hydrogen taken out is replaced with natural gas in the industrial facilities, no overall $CO_2$ reduction is to be expected.

The large-scale central hydrogen production based on fossil fuels that is expected in other European countries is not foreseen to be the most favoured option for domestic use in Norway, but could be a possibility connected to hydrogen export.

CCS from natural gas reforming facilities has high focus and is envisaged to be cost-effective at industrial scale. This option could play an important role for Norway, with a potential for export of Norwegian CCS technology.

Another interesting option is combined hydrogen and el-production from large natural gas plants. This option is a flexible solution for both stationary and transport energy demands.

Export of hydrogen to other European countries (e.g. Germany and The Netherlands), in addition to export of natural gas and green electricity for hydrogen production in these countries, is part of the vision for this period. The export of hydrogen (produced without $CO_2$ emissions) could replace part of the natural gas export, which is being criticised for not adding value. This could offer hydrogen a specific role and economic chance (provide $CO_2$ free energy) as a value added energy replacement for oil and natural gas.

Export of hydrogen produced from offshore wind is another especially interesting option for Norway.

**Short term period: By 2010**
Utilisation of energy sources and technology, in comparison with conventional sources, can reduce $CO_2$-emissions is already important. The energy system can only absorb small quantities of hydrogen. Commercial markets have yet to be developed; the hydrogen energy utilization is limited to a few demonstration projects (incl. HyNor, Utsira and HyTrec).

The small amounts of hydrogen needed to meet the demand are provided from industrial by-products, on-site electrolysis, small scale steam methane reforming and maybe biomass utilisation.

A national strategic plan for development and utilisation of hydrogen in Norway established.

**Policy support**
For the short term period major financial support is foreseen for the demonstration projects. A large share of this will be provided by Norwegian governmental ministries, primarily Ministry of Transport and Communications with their funds channeled through the National Research Council programme “Clean energy for the future” (RENERGI). EU support through participation in the 7$^{th}$ RTD framework programme is also expected.

National regulation like exemption for road toll, vehicle tax, fuel tax, parking fees etc. is necessary for introducing hydrogen vehicles in Norway. This year (2006) the Norwegian government has proposed exemption of tax for hydrogen vehicles. The vehicle tax is Norway makes a large share of the total cost.

The national and international support is needed both in the short and intermediate term until hydrogen is cost effective and no policy support is required.