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Nordic Council of Ministers

Foresight Analysis – Nordic Strategies for Renewable Transport

Final Report – March 2010

THE NORDIC WORKING GROUP FOR RENEWABLE ENERGY

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LIST OF ABBREVIATIONS

BAU	Business as usual
CCS	Carbon capture and storage
CHP	Combined heat and power
EC	European Commission
EEA	European Environmental Agency
EU	European Union
EV	Electric vehicle
FCV	Fuel cell vehicle
GHG	Greenhouse gas
GJ	Giga Joule
Gpkm	Giga passenger kilometres
Gtkm	Giga tonnes kilometres
IEA	International Energy Agency
Ktoe	Kilo tonnes of oil equivalents
Mtoe	Million tonnes of oil equivalents
PIH	Plug-in hybrid vehicle
RE	Renewable energy
SEV	Faroese Energy

Preface

In 2009 Iceland had the Chairmanship of the Nordic Council of Ministers, and during this year sustainable transportation was a top priority on the Nordic energy policy agenda.

The Icelandic Chairmanship Project on Sustainable Transportation aimed to tackle a number of issues in the transition to a more sustainable transport system in the Nordic region. Besides this Foresight analysis the project also produced a whitepaper, *“Spatial Planning and its contribution to climate friendly and sustainable transport solution”*. The results of the project were presented in September 2009 at the International Conference “Driving Sustainability” in Reykjavik and have laid the foundation for the Nordic Council of Ministers globalization initiative on Energy & Transport.

This foresight analysis was made by Henrik Duer at COWI Denmark, as part of the 2009 Icelandic Chairmanship in the Nordic Council of Ministers and the Nordic Council of Ministers’ Working Group for Renewable Energy.

For more information about the project, see the project website at www.nordicenergy.net/transport or consult www.norden2009.is for more information about the 2009 Icelandic Chairmanship in the Nordic Council of Ministers.

Helga Barðadóttir
Icelandic Ministry of Industry, Energy and Tourism
Chairman of the Nordic Committee of Senior Officials for Energy 2009

1 Executive summary

The transport sector, including shipping, is responsible for a large share of the global energy related green house gas emissions, and for approximately 2/3 of world oil consumption. The demand for transport and for energy to the transport sector is increasing, and also in the Nordic countries. Alternatives to present oil consumption are needed to ensure security of the energy supply and to reduce emissions of greenhouse gases.

The purpose of this study is to identify options for a long term massive switch from oil to renewable energy (RE) for transport in all of the Nordic countries and assess the effects that this will have on the energy sector in the Nordic countries. The key findings include:

Electricity for transport: Electric vehicles are 3 to 4 times more energy efficient as traditional gasoline and diesel vehicles and offer an opportunity to reduce the energy consumption for land transport. The Nordic countries have high shares of RE electricity production, and electrification offer an energy efficient and realistic path to RE transport.

Need for markets and lower costs for electric vehicles: The production costs of electric vehicles are still very high due to small scale production and high battery costs. Costs are rapidly declining, but markets need to be stimulated to establish critical demand for electric vehicles and to establish basis for scale production and reduced costs. There is also a need to test electric vehicles and for the sector as well as consumers to get experience. The Nordic market with its large incentives for electric vehicles is attractive and attracts significant interest from producers. Nordic coordination could establish a Nordic testing ground and promote a rapid introduction of electric vehicles.

Focus on Iceland as a testing ground: Iceland has excess RE electricity capacity, is able to provide electricity to the transport sector without investing in new RE electricity capacity, and is independent of other electricity systems. Iceland therefore could work as a testing ground for electric vehicles in a larger scale, allowing both authorities, the energy sector and car manufacturers to gain experience that can find use in other countries.

Development of the electricity infrastructure: The RE electricity production capacity needs to be increased, and the electricity grid need to be further developed to support a better balance electricity consumption with the electricity production as the share of wind and other fluctuating electricity producing sources is increasing. Electric vehicles should be charged when there is large or excess electricity capacity, and possibly even deliver electricity to the grid at times with shortage of electricity capacity. Smart grids and metering, the right institutional framework, and adequate pricing systems need to be developed. Nordic coordination and harmonisation is needed and projects to develop smart systems and right pricing must be promoted.

Promote 2nd generation biofuels for inland shipping and fishery: With present technologies biofuels seems appropriate to sea transport, but the amount of biomass available for biofuels is limited. Much more energy can be produced per hectare land with 2nd generation biofuels technology than with present day biofuels technology. Development and implementation of 2nd generation biofuels require targeted promotion as the risks to both farmers and 2nd generation biofuels producers is much higher than for farmers and producers of 1st generation biofuels. This is primarily because of larger invest-

ment costs and longer time horizon both for farmers and producers. Production and utilization of biogas for transport is also an efficient technology that could be further developed.

Avoid being exclusive: Decision makers should not at pick winners for RE for transport. Even though electricity is a very promising and efficient energy carrier also other technologies need to be tested and developed. Transport services differ and so do the demand for energy for these services, e.g. long haul versus short trips, sea versus land, heavy duty versus light transport etc. Particularly efficient bi-fuels technologies are needed, but also other technologies as hydrogen may prove succesful.

2 Renewable transport

The transport sector, including shipping, is responsible for a large share of the global energy-related greenhouse gas emissions, and for approximately 2/3 of the world consumption of oil. In order to move towards more sustainable energy systems and ensure future competitiveness of the Nordic transport and shipping sectors, there is a need to identify ways to increase the share of renewable energy and increase the energy efficiency in these sectors.

There are alternatives to the present fossil fuel-based transport. There are several Renewable Energy (RE) options available for transport and shipping, ranging from utilising biofuels, particularly biofuels based on wastes, wood and other lingo-cellulosic feedstock (often referred to as 2nd generation biofuels), to increasing utilisation of electricity and hydrogen. The RE transport technologies, particularly those based on electricity produced on RE, will establish a much stronger link between the transport and energy sectors. Additional electricity demand for transport increases the load on the Nordic electricity system but if this additional demand is managed in a flexible way it may actually help the Nordic electricity system to accommodate increasing shares of wind energy in the electricity system. This call for the development of the right framework conditions, support systems and cooperation between sectors.

Using electricity as an energy carrier improves energy efficiency and enables the transport sector to utilise RE. In the coming decade the rise of new power grid technologies, energy storage technologies and electric vehicles may make RE more competitive and practical at large scale, benefitting both the energy and transport sectors. To exploit this opportunity, innovative energy and transport technologies (e.g. smart grids) and crosssector institutional setup (e.g. cooperation and tariff systems) need to be developed and implemented, and investment needs to be promoted.

Using bio fuels for transport and shipping also affects the energy sector, as both sectors will be competing for the – limited – biomass resources. The level of competition depends on a sustainable biomass supply and on the bio fuels technologies applied, e.g. 1st or 2nd generation.

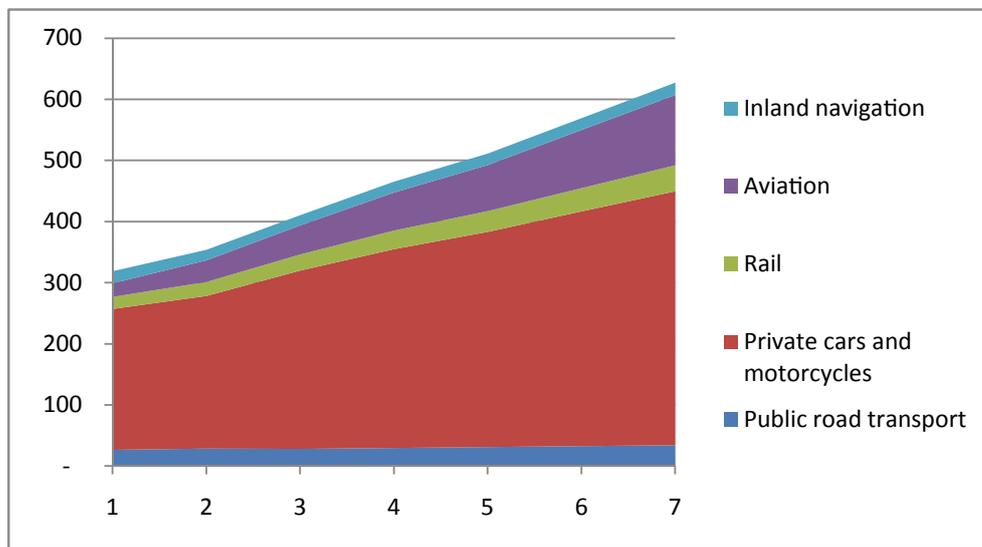
This report presents the findings of a study undertaken to provide the Nordic decision-makers with guidance on developing strategies for promoting solutions to enhance the use of renewable energy in the inland transport and shipping sectors. International shipping and aviation is not included in the study. Focus is on renewable transport solutions and their integration into the transport and energy systems in the period 2009 to 2050 and with a geographical focus on the Nordic region.

The study is part of the Nordic Renewable Transport Project “Sustainable Transport – the Nordic countries chart the way”, which was launched by the Nordic Working Group for Renewable Energy under the Icelandic Chairmanship Project 2009. The study is conducted by COWI A/S and was completed in December 2009.

3 Baseline for the Nordic transport sector

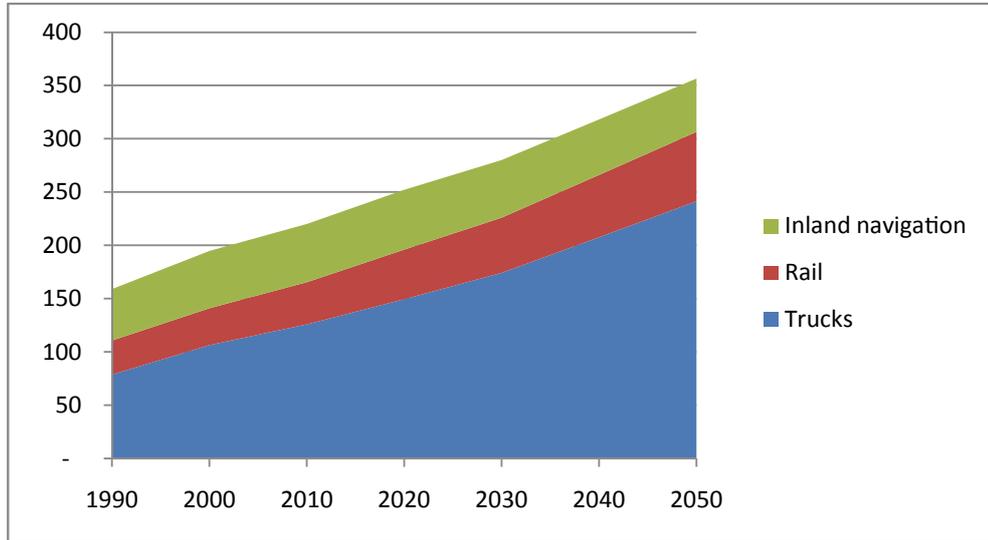
The inland transport demand in the Nordic countries is steadily growing, and according to European Commission projections, which is used as baseline for Denmark, Finland, Norway and Sweden in this study, this trend is expected to continue. Long time forecasts are obviously uncertain, but based on the EC projections, the transport demand may double in the coming 40 years unless additional action is taken.

FIGURE 3.1 PASSENGER TRANSPORT ACTIVITY BY MODE IN DENMARK, FINLAND, NORWAY AND SWEDEN. GPKM/YEAR



Source: Own calculations and EC 2006 and 2008.

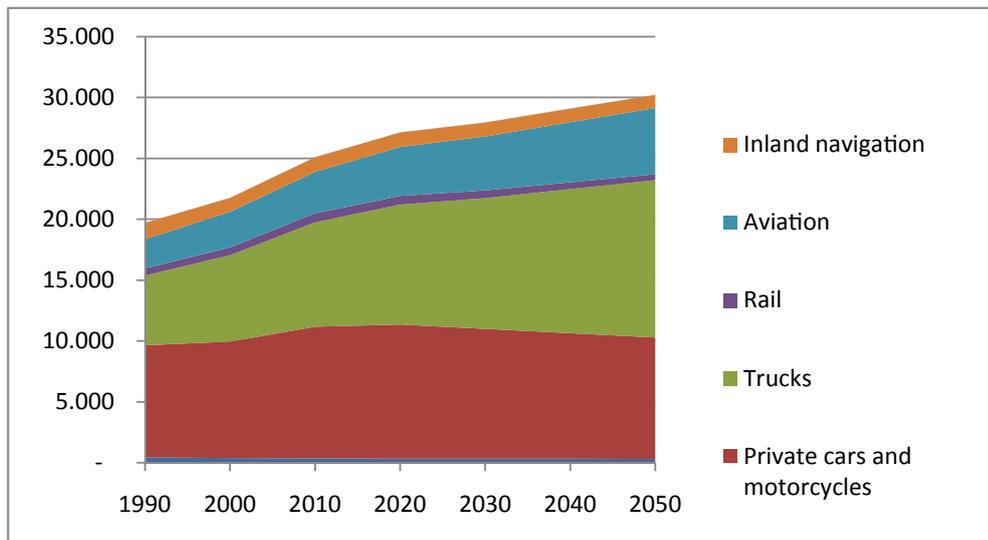
FIGURE 3.2 FREIGHT TRANSPORT ACTIVITY BY MODE IN DENMARK, FINLAND, NORWAY AND SWEDEN. GTKM/YEAR



Source: Own calculations and EC 2006 and 2008.

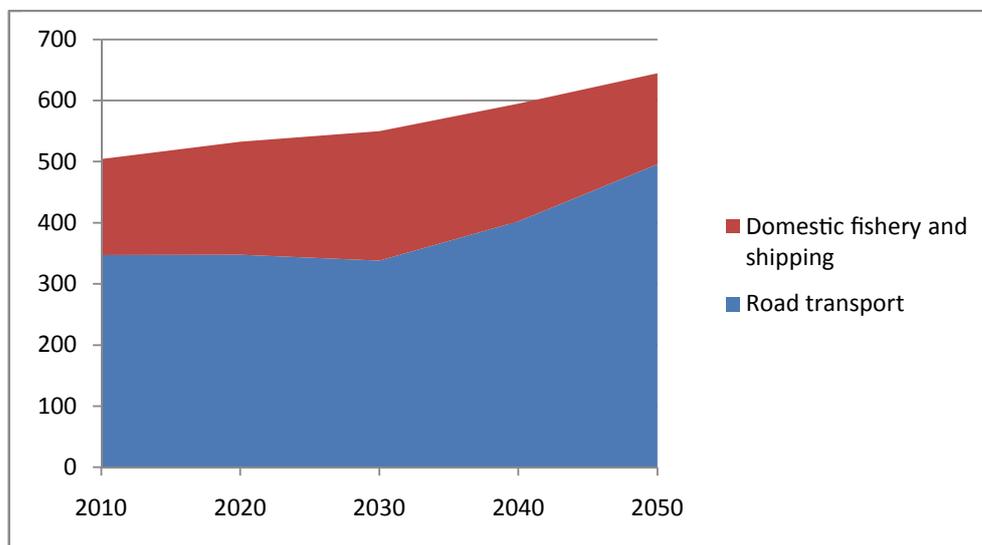
The energy consumption of for the transport sector is also expected to increase towards 2050. The figures below show projections of the energy demand in domestic transport by mode in the east Nordic countries and Iceland respectively, if no additional action is taken, apart from policies and measures already decided by governments.

FIGURE 3.3 ENERGY DEMAND IN TRANSPORT BY MODE IN THE DENMARK, FINLAND, NORWAY AND SWEDEN. KTOE



Source: Own calculations based on EC, 2006 and 08.

FIGURE 3.4 ENERGY DEMAND IN TRANSPORT BY MODE IN ICELAND. KTOE/YEAR



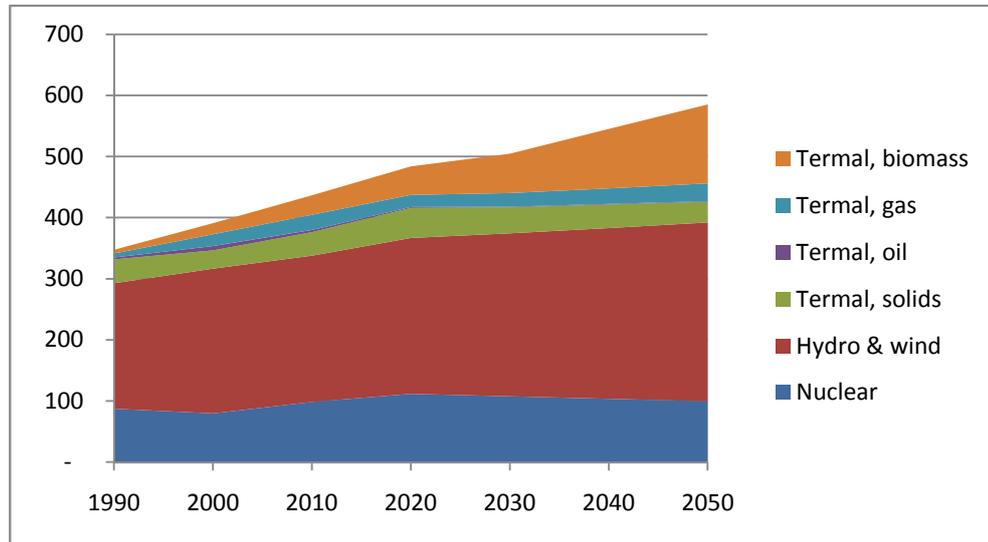
Source: Orkustofnun, 2008, and own calculations.

The electricity system in Denmark, Finland, Norway and Sweden is an integrated system, and therefore these countries are presented together, whereas Iceland, which is not connected to the Nordic electricity system, is presented separately.

Transport energy demand in Denmark, Finland, Norway and Sweden is projected to increase by 18 per cent from 2005 to 2030. This is less than the expected increase in passenger- and ton-kilometres as the fuel efficiency is expected to improve, particularly in passenger transport (e.g. private cars). Nevertheless, the projected final energy demand for transport is growing rapidly compared to all other sectors.

The expected development of the electricity sector in the Nordic countries is interesting as electricity is likely to become an important energy carrier for the future transport sector. The electricity production in Denmark, Finland, Norway and Sweden is expected to increase by 37 per cent from 2005 to 2050. Figure 3-5 below shows that this growth will be almost entirely met by increased production based on renewables (biomass, hydro and wind).

FIGURE 3.5 ELECTRICITY GENERATION BY SOURCE IN DENMARK, FINLAND, NORWAY AND SWEDEN. TWH/YEAR



Source: Own calculations based on EU, 2006 and 08.

Electricity production in Iceland is based on renewable energy. In 2007, hydro power plants produced 70 per cent of the electricity whereas 30 per cent was produced by geothermal power plants¹. The reliance on hydro and geothermal power is expected to be maintained towards 2050 as hydro and geothermal resources are abundant.

¹ Icelands Statistics.

4 Renewable transport technologies

The RE technologies for transport available in the distant future, and the performance of these technologies, are obviously uncertain and it is not possible to identify the winner technologies or the optimal solutions for the use of RE in transport in 2050.

Therefore, the selection of technologies in the Foresight study is based on a few, fairly simple criteria:

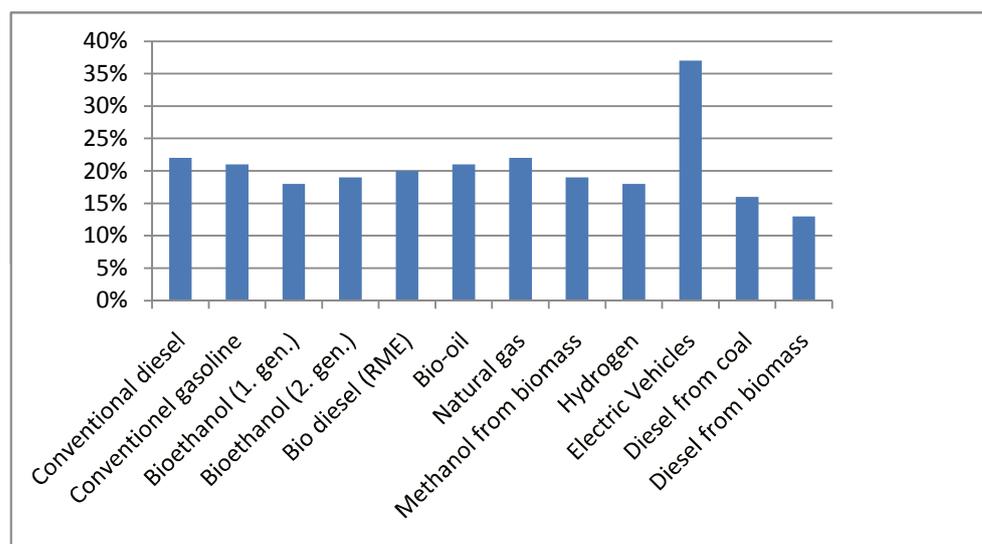
- Energy-efficient transport technologies are given high priority as there will be costs involved in and limitations on the supply of RE, also in the distant future
- Only realistic and demonstrated technologies are considered
- Long-term flexibility in terms of RE sources for transport is given priority.

The traditional internal combustion engine technology has a limited potential for increased energy efficiency, which may make it possible for a vehicle to reach an onboard energy efficiency of around 25-30 per cent.

The only alternative featuring a significantly higher energy efficiency is the electric vehicle (EV). The EV has an onboard efficiency around 80-90 per cent, meaning that an EV drives what corresponds to 60-70 km per litre of petrol or diesel ². Switching to EVs will reduce energy demand (at vehicles) by a factor 3-4 compared to continued reliance on vehicles with internal combustion engines. Introducing EVs therefore provides an opportunity to secure a more energy efficient transport sector. However, the overall energy efficiency of EVs will depend on the technology used for electricity production.

The energy efficiency of vehicles using alternative fuels, including the energy used for producing and distributing the fuels (Well-to-wheels) is presented below.

FIGURE 4.1 W-T-W ENERGY EFFICIENCY OF ALTERNATIVE TRANSPORT FUELS, DANISH CONDITIONS



Source: COWI 2007.

² Electric vehicle fact sheet. Energistyrelsen 2009 (http://www.ens.dk/da-DK/Info/Nyheder/Nyhedsarkiv/2009/Documents/Elbiler_COWI_final_120709.pdf).

Electricity can be generated by a number of technologies, allowing for a high level of flexibility, and allowing for future adaptation to changing conditions and technologies. However, the main challenge to this technology is that efficient batteries at significantly lower costs than now needs to be developed.

Example: Wind power for passenger electric vehicles

If the Danish passenger car fleet was converted into EVs, the electricity needed could be supplied by 360 offshore wind turbines (3.6 MW capacity each and a capacity factor of 45 per cent, corresponding to 3900 hours a year).

Costs:

Total investment costs in wind turbines:	15 billion DKK
Annual operating costs:	0.5 billion DKK

Savings:

Annual pre-tax costs of gasoline and diesel:	8.8 billion DKK
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At a 6 per cent calculation rate, the pay back time of the wind turbines in the example is 2.2 years.

This shows that the key problem is not the costs of producing electricity from RE but the cost of the EVs. The challenge is to bring down the costs of the EVs compared to traditional vehicles, particularly the batteries needed for the EVs, to reach a level that is comparable with traditional vehicles.

Source: COWI calculations based on Danish statistics, Technology Data for Electricity and Heat Generating Plants, DEA et al, 2005 and Danish Petroleum Association .

Based on these criteria priority in the foresight study is given to RE for land transport based on electricity.

Electricity may, however, not be the best fuel for all transport purposes. Certain long haul and heavy duty transportation tasks may be served better by vehicles and ships equipped with internal combustion engines rather than with electricity-based technologies. For these types of biogas and biofuels are attractive RE substitutes for fossil fuels.

Research is being made on all-electric ships, e.g. using hydrogen as fuel for electricity generation in fuel cells , but limited experience has been gained so far. Therefore, the foresight study assumes that biofuel is used for inland fishery and shipping as this represents a proven technology. This should not be taken as an indication that alternative RE options for marine transport will not be developed in the coming decades, rather as a conservative assumption as the study relies on proven technologies.

³ E.g. see <http://www.ivt.ntnu.no/imt/electricship/>.

5 Renewable transport scenarios

There are many possible ways of achieving a high deployment of RE in the transport and shipping sectors, involving different RE technologies. However, and generally speaking, two main alternative scenarios can be followed. One is to keep the existing vehicle technologies and replace fossil fuels with bio fuels. Another is to switch to electric or hydrogen vehicles and produce electricity from renewable sources such as wind, solar or hydro power. Therefore, rather than listing a number of scenarios with different specific combinations, a scenario is applied that assumes that 60-70 per cent RE in land transport is achieved by switching to electric vehicles. The electricity used for the transport sector is assumed to be produced from RE and will be added to the electricity generation on RE in the baseline scenario. The remaining RE for transport is assumed to be based on biofuels. The biofuel share for land transport in the scenario ranges from the 9 per cent (in the baseline) to 20 per cent, and the remaining 20 per cent is assumed to be fossil fuels. Fishery and inland shipping is assumed to be based on bio fuels.

5.1 DENMARK, FINLAND, NORWAY AND SWEDEN

5.1.1 SIMPLE AND INTELLIGENT LOADING OF ELECTRIC VEHICLES

Table 5-1 shows the electricity demand for land transportation in the East Nordic region in 2025 and 2050, assuming a distribution of 60 per cent electricity, 20 per cent biofuels and 20 per cent fossil fuels respectively.

TABLE 5.1 ELECTRICITY DEMAND FOR TRANSPORTATION IN 2025 AND 2050.

	Electricity demand [TWh]				
	Denmark	Finland	Norway	Sweden	Total
2025	1,9	1,9	2,0	3,6	9,4
2050	8,1	7,7	9,1	15,5	40,4

The electrification of land transport will add an 8 per cent electricity demand to the projected demand in the 2050 baseline. This additional demand may, however, affect the electricity system in different manners, depending on the way the vehicles are charged and how the interface between the electricity system and the vehicles is organised.

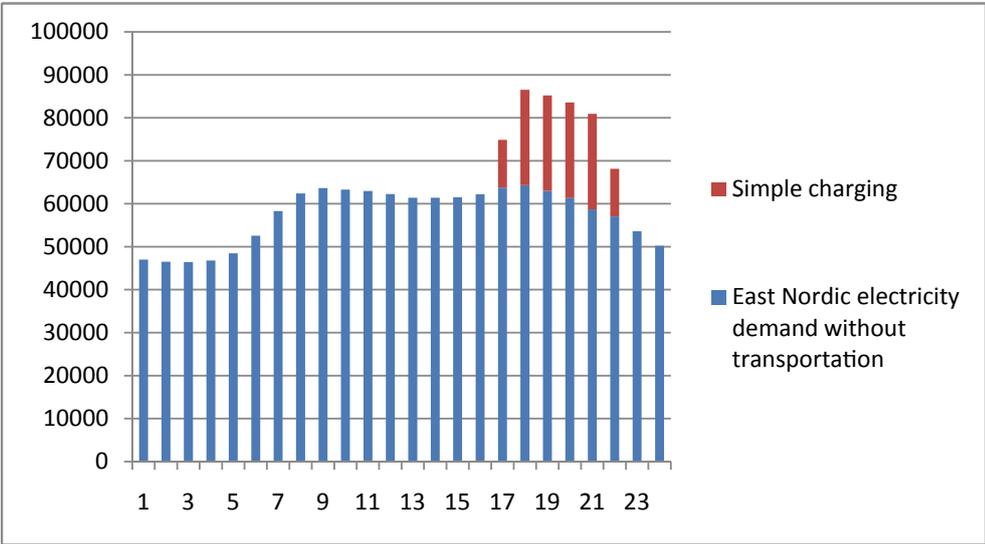
The options for charging of the EV are often referred to as simple or intelligent charging respectively. These terms refer to the level of integration of the charging system with the electricity system, and consequently to the additional burden that the demand for electricity to transport will impose on the production and distribution of electricity.

Intelligent charging requires that the electricity system is further developed and is able to communicate with the EV. This will enable EVs to charge their batteries at times when there are excess electricity production capacity, for instance from wind turbines. If done intelligently, smart grid and EVs in combination could help to balance the electricity system. The reason for this is that smart grid can help adjust the demand for electricity better to the production of electricity, rather than vice versa. This will be particularly interesting when growing amounts of wind, and possible other fluctuating electricity sources, are phased into the electricity system. Widescale use of intelligent charging, how-

ever, require that electricity prices at consumers are set to provide an economic incentive, and possibly also that electricity taxes are designed to provide an additional incentive to consumers for intelligent charging.

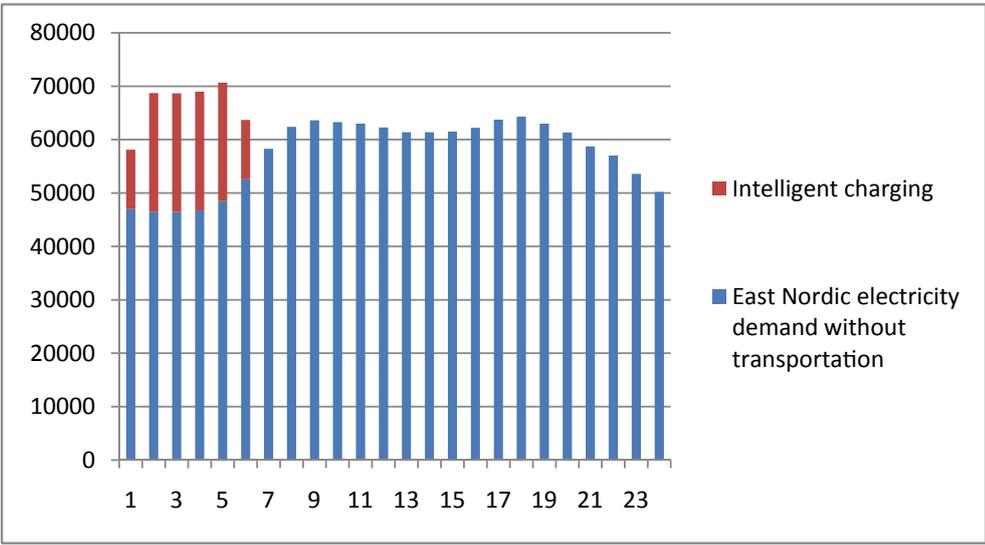
The figures below shows the daily variation in the electricity demand without electricity use for transportation, and the effects of adding a significant demand for electricity for land transport. The figures show the variation in demand during the 24 hours of one day. The total electricity demand varies over the year, but the daily fluctuation is much the same. Figure 5-1 shows the electric demand with simple

FIGURE 5.1 ELECTRIC DEMAND IN THE EAST NORDIC REGION WITH SIMPLE CHARGING. MW



Source: Balmorel, COWI.

FIGURE 5.2 ELECTRIC DEMAND IN THE EAST NORDIC REGION WITH INTELLIGENT CHARGING.MW



Source: Balmorel, COWI.

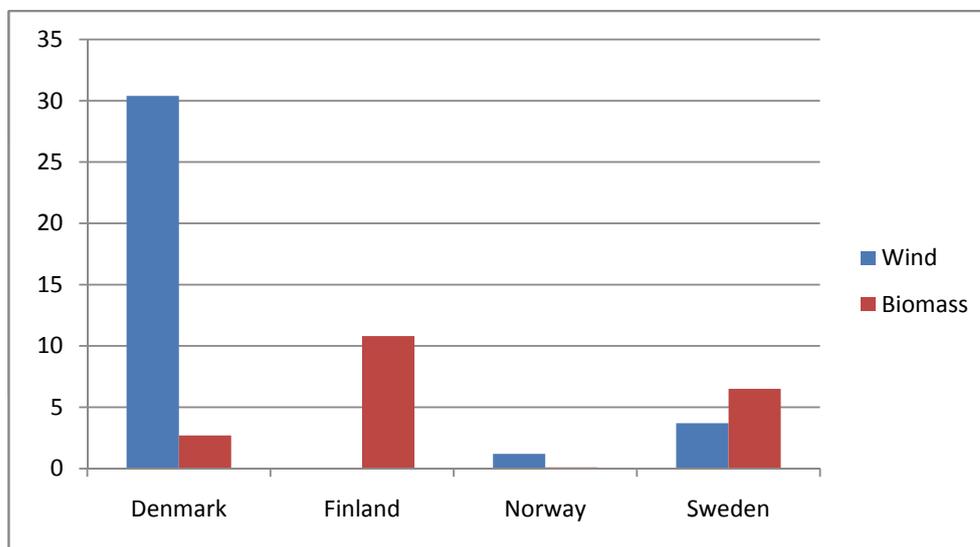
charging, assuming that EV owners charge their vehicles at peak hours when they get home from work. Figure 5-2 displays the demand with intelligent charging, assuming that the batteries are charged during night time when electricity demand is low.

The peak demand is significantly lower with intelligent charging than with simple charging, reducing the need for electricity production and distribution capacity. A third system is being considered by TSOs in many countries, namely the option to utilise the batteries in EV as short term storages, which could be used to supply electricity to the grid at times with shortage of electricity production capacity (vehicle-to-grid). This option is not included in this study but would increase the value of EVs to the electricity system.

5.1.2 PRODUCTION OF ELECTRICITY

Additional RE electricity generation capacity is needed to supply the transport sector with RE. The hydro power potential in the East Nordic countries is assumed to be fully utilised in the baseline projection for 2050, so that no additional hydro power capacity is assumed available. The RE sources available for electricity generation is assumed to be wind and biomass. The investments in RE electricity generation capacity to meet the increased demand for electricity is illustrated for in Figure 5-3.

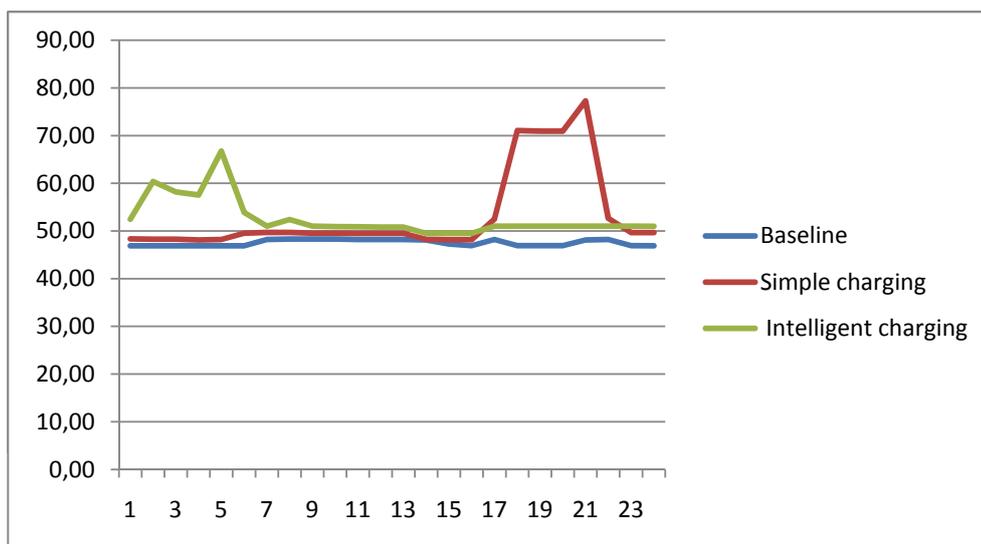
FIGURE 5.3 RE ELECTRICITY PRODUCTION FOR TRANSPORT IN SCENARIO, 2050, SIMPLE CHARGING. TWH/YEAR



Source: Balmorel, COWI.

Increasing the electricity demand and the electricity production capacity will affect the electricity prices. To illustrate the impact of the charging pattern, the electricity price in 2050 is simulated in the Balmorel model. Figure 5-4 shows the electricity price for one day in April 2050 in Southern Sweden. The same pattern will be seen in other parts of the electricity system. As seen in the figure, the electricity price could increase significantly when batteries are charged. The level of increase, however, depends on the charging pattern. Simple charging will increase the price of electricity significantly more than the intelligent charging.

FIGURE 5.4: ELECTRICITY PRICE IN SOUTHERN SWEDEN FOR THE BASELINE SCENARIO AND SCENARIO – SIMPLE CHARGING AND INTELLIGENT CHARGING (WEEK 18).EURO/ MWH



Source: Balmorel, COWI.

Intelligent charging reduces the overall costs to the electricity system of supplying electricity to the transport sector. The importance of intelligent charging increases concurrently with the demand for electricity for transport. The socio-economic saving by intelligent charging compared to simple charging increases from approximately EUR 34 million annually in 2025 to EUR 531 million annually in 2050 for the integrated Nordic electricity system. This cost reduction is obtained through a reduced peak load on the electricity system and better utilisation of the RE electricity capacity and of the capacities with low marginal production costs.

5.1.3 BIOFUELS

Part of land transport and inland fishery and shipping is assumed to be based on biofuels to allow for the long range and heavy duty requirements.

There is a limited supply of biomass resources for energy production in the Nordic countries. The demand for biomass covers feedstock for biofuels production and biomass for thermal power plants, supplying energy to the transport sector in addition to the consumption of biomass in the baseline scenario. The domestic biomass resources can, however be supplemented by import of biomass or biofuels from the world market.

Table 5-2 below provides an overview of the projected sustainable biomass resources available for energy purposes in 2030, and the projected demand for biomass for energy purposes in the baseline scenario in 2030. The table shows that most of the biomass resources will be used in the baseline scenario for 2030, leaving 1.4 Mtoe available for additional energy or biofuels production.

TABLE 5.2 SUSTAINABLE BIOMASS RESOURCES AND BASELINE DEMAND FOR BIOMASS FOR ENERGY IN THE EAST NORDIC COUNTRIES, MTOE/YEAR

Mtoe	2010				2030				Baseline demand
	Agri-culture	Forestry	Waste	Total	Agri-culture	Forestry	Waste	Total	
Norway	0,4	1,8	1,6	3,8	0,4	1,8	1,6	3,8	2,0
Sweden	0,6	2,2	8,9	11,7	1,4	2,4	9,7	13,5	12,0
Finland	1,9	1,7	6,1	9,7	1,3	1,8	6,2	9,4	10,4
Denmark	0,4	0,1	2,3	2,8	0,1	0,2	2,2	2,5	3,4
Total	3,3	5,8	18,9	28,0	3,2	6,2	19,7	29,2	27,8

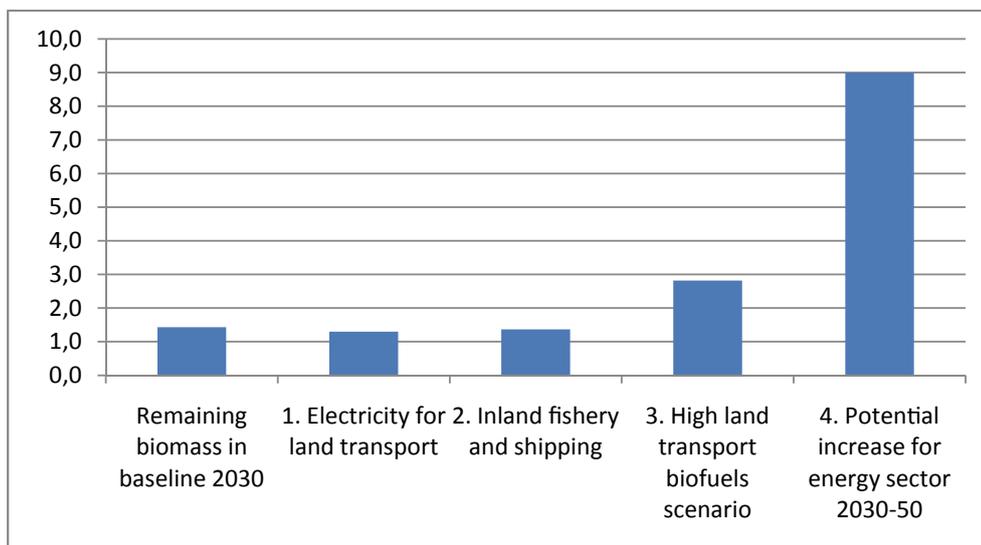
Sources: How much bio energy can Europe produce without harming the environment, European Environment Agency (EEA), 2006, and Bioenergiressurser i Norge, Norges vassdrag og energidirektorat, 2003, and EU 2006 and 2008.

The use of biofuels in the baseline scenario roughly covers around 9 per cent of the Nordic land transport. Areas of additional demand for biomass for energy purposes include:

- Additional biomass for electricity production for land transport. According to the model simulations, the additional RE electricity needed to supply land transport in the scenarios in 2050 is based on wind (75 per cent) and on biomass (25 per cent)
- Biofuels for inland fishery and shipping
- Possibly additional biofuels for land transport, of up to 20 per cent compared to the 9 per cent of the Baseline.
- Increased demand for biomass in the energy sector in the baseline scenario between 2030 and 2050.

Assessment of the sustainable biomass resources available in 2050 is subject to much uncertainty. Better technologies may increase the sustainable biomass production, but increased demand for food may reduce the land available for biomass production. The additional demand from the energy sector is also very uncertain, but potentially large. Given these uncertainties, the key message is that there is likely to be a fierce competition for the scarce, sustainable biomass resources available for energy and fuel purposes. This is clearly illustrated in Figure 5-5 below presenting the potential additional demand for biomass for the transport and energy sectors in 2050, compared to the available biomass resources in the Nordic countries in 2030.

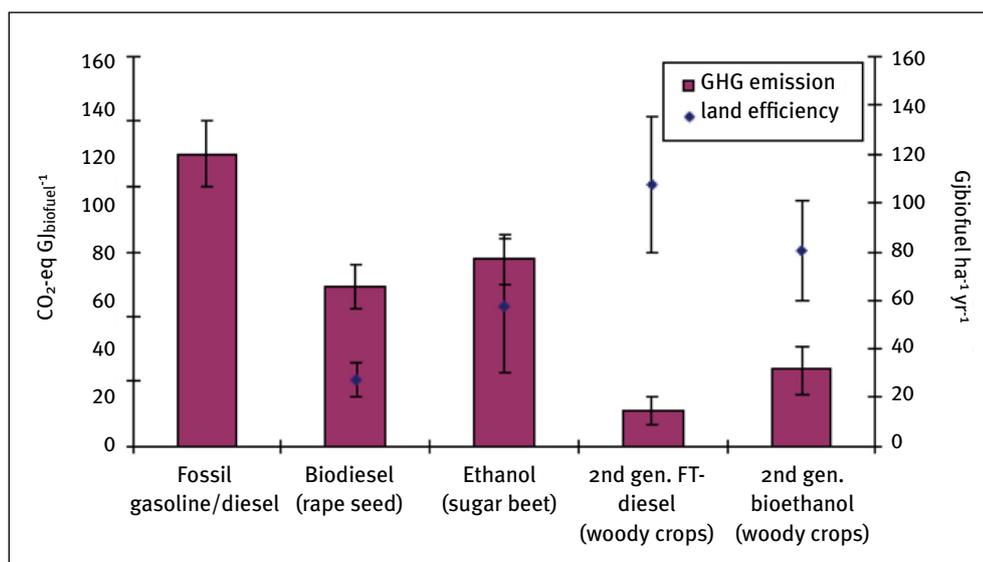
FIGURE 5.5 BIOMASS RESOURCES AND POTENTIAL DEMAND IN 2050, EAST NORDIC COUNTRIES, MTOE/YEAR



Source: Balmorel, COWI.

It is important to develop efficient biomass and biofuels policies. 2nd generation biofuels technologies and crops needs to be promoted as 2nd generation biofuels offer a much better energy yield per hectare of energy crops than 1st generation biofuels. This is illustrated in the figure below.

FIGURE 5.6 GHG EMISSION AND GROSS ANNUAL BIOFUEL YIELD PER HECTARE¹



Note 1: Yield assessed on a wells-to-wheel basis.

Source: Refuel roadmap. Marc Londo et al., Biomass and bioenergy, Elsevier 2009, 1-7.

2nd generation technologies are quickly being developed and demonstrated, also by major Nordic stakeholders, and the integration of biofuels and the energy sector in biofuel production facilities with high efficiency is progressing⁴.

At the same time sustainable but effective production of lignocellulosic biomass (woody and grassy crops) for energy and biofuel production is needed. The East Nordic countries have long experience in the field of agriculture and forestry. This experience must be utilised in combination with new research into ways of combining agricultural practices (typically one-year plantation cycle) with forestry like practices of perennial practices. New lignocellulosic energy crops such as grasses and trees have perennial cycles of maybe 10 to 20 years. It is a challenge to present agricultural practices and financing models. New energy crops gradually find their way into the agriculture and forest sectors rendering the need for reliable demand and pricing of the crops important to limit the economic risk to farmers and forest owners.

5.2 ICELAND

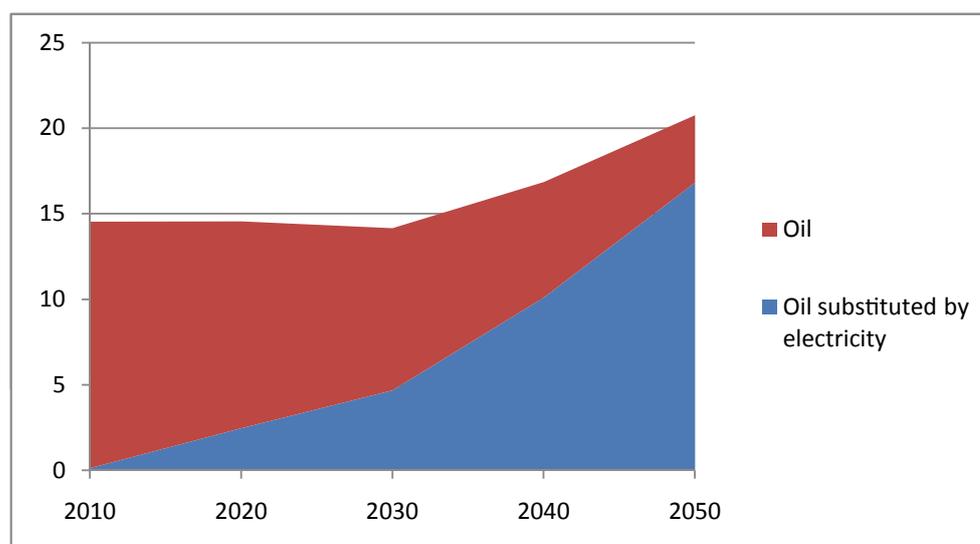
The RE transport scenario for Iceland follows the same pattern as the scenarios for the East Nordic countries, namely large-scale implementation of electric vehicles for land transport, and reliance on biofuels for inland fishery and shipping.

5.2.1 LAND TRANSPORT

As an important means to reduce CO₂ emission, the Icelandic Ministry of the Environment has identified an ambitious electrification of land transport, gradually replacing petrol and diesel vehicles with electric vehicles to reach a share of 81 per cent electric vehicles in 2050⁵.

Figure 5-7 below shows how the phasing in of electric vehicles will reduce the use of fossil fuels for land transport in Iceland. The blue area indicates oil consumption replaced by electricity as fuel.

FIGURE 5.7 SUBSTITUTION OF OIL PRODUCTS FOR LAND TRANSPORT, 80 PER CENT ELECTRIC VEHICLES. PJ/YEAR

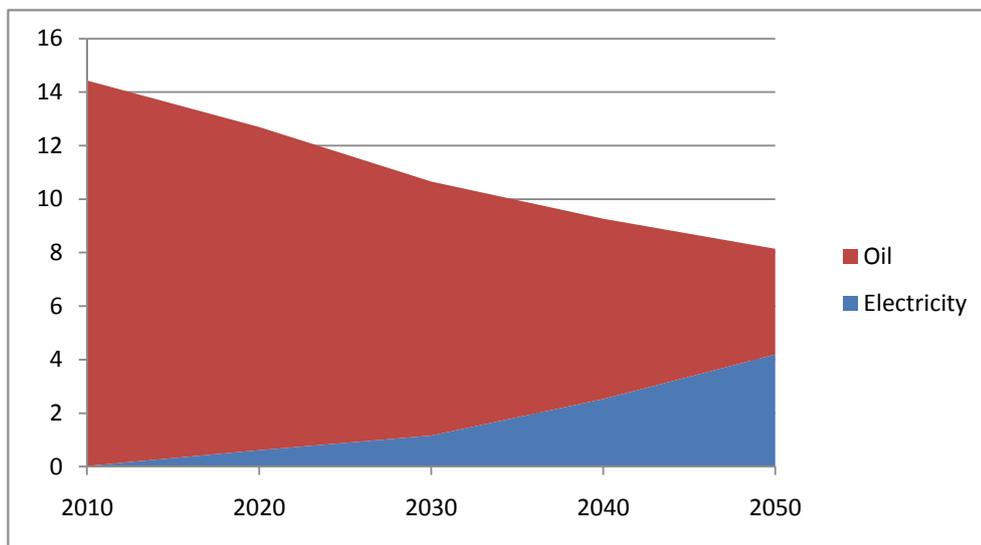


Source: Orkustofnun 2008, Umhverfissraduneytid and own calculations.

4 E.g. the INBICON biomass refinery for ethanol production in Kalundborg, Denmark <http://www.inbicon.com/pages/index.aspx>.

5 Móguleikar til að draga úr nettóútstreymi gróðurhúsalofttegunda á Íslandi, Umhverfissráðuneytið 2009.

FIGURE 5.8 ELECTRICITY AND OIL DEMAND FOR LAND TRANSPORT, 80 PER CENT ELECTRIC VEHICLES. PJ/YEAR



Source: Orkustofnun 2008, Umhvervísráðuneytið and own calculations.

However, switching to EVs will significantly reduce the energy consumption for land transport. Figure 5-8 illustrates how the total energy consumption is gradually reduced as petrol and diesel vehicles are replaced by electric vehicles. The high energy efficiency of the electric vehicles reduces the total energy demand for transport to only 8.2 PJ (200,000 toe) compared to the consumption of 20.7 PJ (500,000 toe) in the baseline scenario in 2050.

5.2.2 RENEWABLE ELECTRICITY GENERATION POTENTIAL

In the EV scenario the annual demand for electricity for land transport in 2050 amounts to around 100,000 toe, or 1.2 TWh. This corresponds to approximately 7 per cent of the 2008 electricity production of 16.4 TWh.

Iceland has a very large potential for RE electricity production. The hydropower potential is theoretically estimated to about 64 TWh per year, of which 40-45 TWh per year may be technically and economically feasible. Considering also the environmental aspects, the potential will probably be 25 -30 TWh per year⁶. So far only 12.4 TWh⁷ per year have been harnessed.

An estimate has also been made for the geothermal resources. Geothermal resources are not strictly renewable in the same sense as the hydro resource. An assessment of the total potential for electricity production from the high-temperature geothermal fields in the country gives a value of about 2500 TWh or 25 TWh per year over a 100-year period⁸. In 2008, electricity production from geothermal fields was 4 TWh⁹.

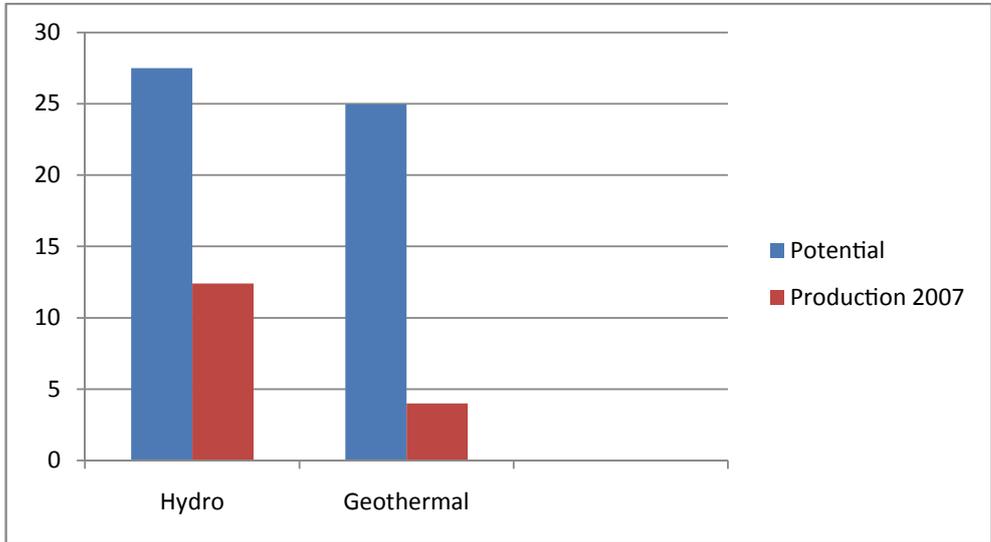
⁶ Orkustofnun, direct information 2009.

⁷ Iceland Statistics.

⁸ Orkustofnun, direct information 2009.

⁹ Iceland Statistics.

FIGURE 5.9 HYDRO AND GEOTHERMAL RESOURCES AND UTILISATION. TWH/YEAR



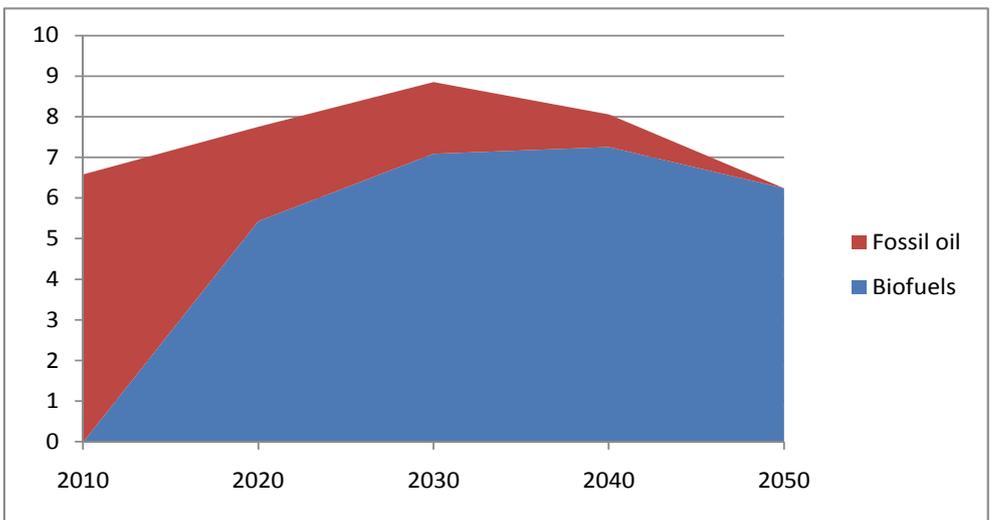
Source: Orkustofnun, direct information 2009.

Currently, only around 30 per cent of the feasible and environmentally sustainable RE electricity generation potential is utilised, leaving space for new production capacity of electricity for the transport sector.

5.2.3 INLAND FISHERY AND SHIPPING

Biofuels are a realistic option for using RE for inland fishery and shipping. Furthermore, technical options for a 10-20 per cent energy efficiency improvement of the fleet of vessels have been identified¹⁰, but these are not included in the Figure 5 10 Fuels for inland fishery and shipping. PJ/year.

FIGURE 5.10 FUELS FOR INLAND FISHERY AND SHIPPING. PJ/YEAR



Source: Orkustofnun 2008, Umhverfissraduneytid and own calculations.

¹⁰ Substituting around 70 per cent of the oil consumption in fishery already by 2020 is indicated in *Möguleikar til að draga úr nett óútreymigróðurhúsalofttegunda á Íslandi*, Umhverfissráðuneytið 2009.

Iceland only has limited resources available for domestic production of biofuels. Wastes from fishing industry and agriculture may provide some feedstock for domestic production. Capital costs of establishing 2nd generation biofuels production facilities are very high, and only large-scale production facilities are likely to be financially feasible. Therefore, it is assumed that such production will not take place on Iceland. Landfill gas extracted and used for transport purposes is assumed to continue from existing and new landfills, including for inland fishery and shipping. However, to substitute all fossil fuels, around 160,000 tons of biofuels (6.6 PJ) for inland fishery and shipping will be needed, the main part imported.

5.3 GREENLAND AND THE FAROE ISLANDS

5.3.1 GREENLAND

The cold climate and the natural conditions in Greenland pose a challenge to the transport sector. Fuel must meet arctic requirements and to limit risks to passengers, it is critical that transport modes are reliable under arctic conditions. Still, RE can also be introduced to the transport sector in Greenland. To limit the demand for RE to transport, priority should be given to reducing energy consumption by introducing efficient vehicles and vessels and by improving the utilisation of the transport modes.

ELECTRIC VEHICLES

Electricity generated by hydro power is available in Nuuk and four other cities and will be available also in Sisimiut and Illulisat in the coming years. The grid is not interconnected between the cities, but electricity may be used for land transport within these cities.

The limited road network within the cities of Greenland reduces the length of most vehicle trips. This means that the issue of the limited range of EVs with the current technology is not likely to be a major issue in Greenland. A range of 150-200 km on a fully charged battery will be sufficient for most users of the vehicles. The combination of short trips and frequent low temperatures makes the energy efficiency of petrol and diesel vehicles particularly poor in Greenland. These factors imply that the use of electric vehicles may be an even greater advantage in Greenland than in other countries.

With the present technology, the cold winter climate may, however, pose a challenge to the performance of EV batteries. Li-Ion batteries are currently considered to be the most promising group of batteries for EVs, but the performance of most existing Li-Ion batteries drops at temperatures below -100C. However, Li-Ion batteries with better temperature characteristics which can deliver up to 80 per cent of their capacity at temperatures of minus 50 oC has been developed and may be more widely applied¹¹.

Wide scale introduction of electric vehicles utilising RE in Nuuk and other larger cities is possible if hydro power capacity is available during all or parts of the day in these cities. Currently excess hydro power capacity is frequently used for heating district heating water to utilise available capacity.

¹¹ Li-Io battery electrolytes designed for wide temperature range. K. Tiknov et al.

Electrification of 50 per cent of all vehicles in Greenland would increase the electricity demand by 15 GWh/year, corresponding to approximately 5 per cent of the total electricity demand in Greenland in 2007.

The hydro power capacity needed to supply the electricity for a 50 per cent share of EVs of the vehicle fleet is in the range of 2 MW, assuming that the vehicles on average are randomly charged over the day. The use of electricity for district heating production could be reduced somewhat if the limited hydro power capacity at certain times is used for EV rather than for production of district heating. From an energy point of view, the largest oil substitution per kWh is obtained in EV as the energy efficiency of petrol and diesel vehicles is low (around 20-25 per cent) compared to the energy efficiency of oil boilers in the district heating system (up to 90 per cent).

BIOFUELS FOR VEHICLES

All land transport cannot realistically be based on RE electricity, even in a 2050 perspective. The use of liquid fuels such as biofuels and fossil fuels are likely to continue for several reasons:

- RE electricity is not available in all locations in Greenland, and in these locations biofuels may be an attractive RE technology.
- Certain demanding transport activities may require internal combustion engines
- The technology used for transport must be simple and reliable, particularly in isolated areas where the users themselves must maintain the vehicles and make simple repair works.

Like imported fossil fuels, also biofuels for transport need to meet arctic requirements in order not to gel at low temperatures. Biodiesel normally is more sensitive to low temperatures than petroleum diesel¹². However, biofuels that meet low temperature requirements can be produced, and several airline companies are testing biofuels for aviation which takes place at low temperatures.

RENEWABLE ENERGY FOR FISHERY AND INLAND SHIPPING

Fishery and inland shipping is projected to account for an annual consumption of 46,000 toe and 8,500 toe respectively, in 2012 (compared to 10,000 toe for land transport).

Production of biofuels is not likely to be financially viable in Greenland. Imported biofuels with the right temperature properties for fishery and shipping is a realistic option for replacing fossil fuels with RE. The amount of biofuels needed may be somewhat reduced through improved energy efficiency in the existing and particularly the coming fishing and shipping fleet.

Other options may be developed, for instance based on hydrogen. The hydrogen produced on electricity needed to meet the energy demand for fishery and inland shipping would more than double the present demand for electricity¹³ and consequently also require significantly increased hydro power capacity. It is therefore assumed that the significant energy consumption for fishing and shipping will mainly be served by imported energy, and that this will also be the case for RE for fishing and inland shipping.

¹² *Biodiesel Performance, Costs, and Use*, Anthony Radich, <http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/>

¹³ This is due to a combination of the high energy consumption for fishing and inland shipping and the relatively low energy efficiency of a hydrogen-based transport system.

5.3.2 THE FAROE ISLANDS

The Faroe Islands depends heavily on imported oil and the transport sector accounts for approximately 60% of total oil consumption¹⁴, of which fishing accounts for the main share

The road transport consumption is expected to increase by 30% until 2015, leading to increased energy consumption unless the energy efficiency in the sector is significantly increased. The fishing sectors energy consumption is expected gradually to decline as the fisheries resource base in the Faroe territorial waters is not expected to increase and as energy efficiency improvements and optimization of fishery is expected to take place.

Total consumption of electricity amounted to 275 GWh/year in 2008, and the consumption is expected to grow by 2% annually¹⁵. Approximately 40% of the electricity is produced on hydro power plants, 5% is produced on wind turbines and the remaining is produced on oil based power plants. 4 hydro power plants are operating (Eidi, Vestmanna, Strond og Botni) with a total annual production of approximately 100 GWh.

Electric vehicles

A significant share (approximately 45%) of the electricity produced and provided to the grid is based on RE. If 80% of the present road transport was undertaken by EV's this would require approximately 70GWh of electricity per year, which is approximately 25 percent of present total electricity demand of 275 GWh/year. With expected growth in land transport there is a view to increasing energy demand for land transport as in other countries. Electrification of land transport therefore will have a relatively strong impact on the electricity system in the Faroe Islands, also compared to most other Nordic regions.

There are different options for providing the additional electricity needed for land transport as RE:

- **Hydropower:** Ministry of Trade and Industry has assessed that approximately 50% of the potential hydropower resources are being utilised, leaving an annual potential additional production of 127 GWh per year. This would require estimated 1.3 billion DKK investments in new hydropower plants¹⁶.
- **Wind power:** Options for increasing the share of wind energy in the power system is being assessed. The Faroe electricity company SEV assessed that wind turbines could be increased from approximately 15 GWh/year to 25 GWh/year without compromising the power system. There are excellent wind conditions and large potentials for wind turbines, but including large shares of wind power in the electricity system will require additional management of both production and demand of electricity.
- **Other sources:** Wave and tidal energy is being considered, and one option is to build the power plant within sea cliffs to protect the facilities. Also options for growing seaweed for energy purpose in the fertile waters surrounding the Faroe Islands is being considered.

There is a large potential for increased RE electricity production in the Faroe Islands. Intelligent elec-

¹⁴ General Energy Policy, Faroes Ministry of Trade and Industry, 2006.

¹⁵ Ibid, pg. 27.

¹⁶ General Energy Policy, Ministry of Trade and Industry, 2006.

tricity grid needs to be developed in parallel with the introduction of EV to help the transport system to stabilise the electricity system. This is increasingly important as more wind and other fluctuating energy sources are included in the electricity system.

Biofuels for vehicles

Not all land transport can realistically be based on RE electricity even in a 2050 perspective. Particular demanding transport activities may be difficult to undertake with EV, and in these cases biofuels may be an attractive solution. Biofuels can either be imported or produced locally.

RENEWABLE ENERGY FOR FISHERY AND INLAND SHIPPING

Fishery and inland shipping accounts for 70% of the transport sectors energy consumption, or 75.000 toe per year. This share is expected gradually to decline, and a goal of 15% reduction in energy consumption in the fishing fleet is defined in the General Energy Policy¹⁷.

Currently there is not sufficient biomass available to provide feedstock for a domestic large scale production of biofuels on the Faroe Islands. However, ideas about cultivate seaweed for energy purpose in the nutrient rich waters surrounding the islands are being considered¹⁸. Such ideas may provide long term alternatives to imported biofuels and need to be further developed.

¹⁷ General Energy Policy, Ministry of Trade and Industry, 2006, p. 14.

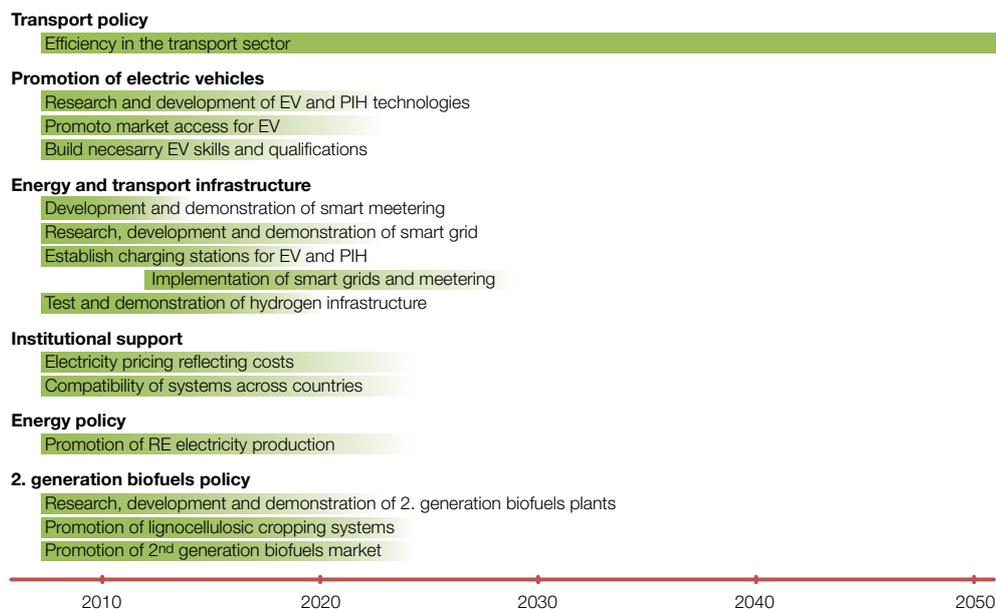
¹⁸ Ocean Rainforest spf <http://www.oceanrainforest.com/>.

6 Roadmap and recommendations

The scenarios represent pictures of a future energy consumption/production pattern in relation to transport. These pictures clearly suggest that there are large potentials for renewable transport in all Nordic countries. The basic technologies exist, but realising the potential for RE in transport requires further technological development and structural changes in the transport and the energy sectors. The overriding challenge is to find the right modes of transport and get the RE fuels to the consumers. To achieve this, the traditional division between the energy sector and the transport sector must be replaced by a co-evolution of the energy and the transport sectors.

FIGURE 6.1 KEY POLICY AREAS

Moving in that direction requires initiatives, policies and regulations across sectors and stakeholders. Below the key challenges facing these policy areas are presented.



Efficient transport sector

The challenges of switching to RE in transport will be reduced if the energy consumption for transport is reduced. The demand for transport should be limited, and the transport sector must operate efficiently. This requires a permanent effort throughout the period and a wide range of measures, including

- limiting the demand for transport, e.g. through physical planning, efficient location of industries, and the right pricing of transport. Locating jobs and residential areas closer to each other, locating industries closer to markets and/or suppliers and letting the full socio-economic costs of transport being reflected in the market prices through roadpricing and other economic instruments that can affect and limit the demand for transport.
- improving the transport structure. Promoting public transport and rail transport, efficient logistics, improving the utilisation of the capacity of trucks, vans and trains, reducing empty driving, and in-

creasing numbers of passengers in each bus, train and passenger car. This will reduce the total vehicle kilometres driven and thereby the energy consumed.

Promotion of electric vehicles

The electric vehicle is an energy-efficient technology that may significantly reduce the energy consumption in the transport sector. At the same time, electricity can be produced from a variety of RE sources and thereby enabling RE for transport. The costs of EVs and Plug-In Hybrids (PIH) are, however, significantly higher than similar vehicles based on traditional fuels due to the low scale of production of these vehicles and due to battery costs. Some or all of the Nordic countries could become testing grounds for EVs and PIHs with a view to promoting the technology development, and promoting the efficient use of RE in transport. In this way, the Nordic countries would rapidly gain experience of electric vehicle technologies both for consumers and in the transport and energy sectors, and would be able to accustom consumers and the transport sector to electric transport.

Measures include:

- Promoting research, development and demonstration of EV and PIH vehicles in the Nordic countries. A long term effort is needed to make the technologies competitive even though rapid advance is seen.
- Developing a Nordic testing ground EV and PIH by supporting early market entrance of these vehicles in the Nordic region. This includes maintaining transparent financial incentives for electric vehicles to overcome the financing barriers facing customers of EVs and PIHs, public procurement of EVs and PIHs, demonstration programmes, information campaigns. This is particularly important in the short term, but support is also likely to be needed at the medium term towards 2020.
- Promoting capacity building and training of mechanics and other personnel needed for servicing EV and plug-in hybrid technologies. Presently there is no, or very few, persons qualified to repair and service EVs and PIHs, and when market uptake of these vehicles starts it is important to avoid bottlenecks in the workshops and in the service sector. This is particularly important in isolated communities if new transport technologies shall become realistic alternatives.

Develop infrastructure

The required electricity grid is in place for providing RE electricity to EVs and PIHs. However, additional infrastructure is needed for large-scale implementation of EVs and PIHs, and the electricity grid also needs to be further developed to ensure that the electricity can be provided but most importantly to make sure that the transport sector and the electricity system will support each other and co-evolve efficiently. Nordic countries measures include:

- Establishing charging stations that allows EVs and PIHs to charge in parking lots at work places, shopping areas and residential areas. This is a chicken and egg problem, and if charging stations are not available fairly soon, it could threaten the successful market entrance of EVs and PIHs. Furthermore, it is important to support the development of international charging standards that allow different EV and PIH models to use the same charging systems.
- Research, development and implementation of smart grids and metering systems. These systems helps the electricity system and the transport sector support each other and help balance demand and supply in the future electricity system. This allows batteries to be charged in times with avail-

able electricity production and distribution capacity, and to deliver electricity to the grid at times with peak demand and shortage of low cost and RE generation and distribution capacity. Demonstration of smart meters is taking place and should be continued. Research and development of smart grid and metering systems is needed in the medium term.

- Testing and further developing infrastructure for other RE energy carriers (besides biofuels), particularly hydrogen and current effort needs to be continued on the short and medium term.

Institutional set-up and pricing

The smart technical infrastructure must be supported by the right institutional set-up and the right pricing to work properly. Important elements include:

- Initially, charging of the EV connected to a smart grid may be based on a control signal provided through the grid to the vehicle. However, on the longer term electricity prices should reflect the actual and real time costs of producing and distributing electricity to EVs and PIHs. Prices should indicate when the production and distribution costs of electricity are low, for instance when excess wind energy is available. Combined with smart meters this will provide incentives for intelligent charging and allow a better match between the demand for electricity and the production of electricity. The effort on getting prices and price signals right must follow and support the effort for developing and implementing smart grid systems.
- Also, on the longer term, smart grid and right pricing may provide the right incentives for the owners of EVs to supply electricity to the grid when there is scarce electricity generation capacity, for instance from wind turbines. This would enable EV batteries to work as electricity storage that can further balance the electricity system.
- Promotion of the compatibility of the charging system so that EVs and PIHs can operate across the Nordic countries without difficulties.

Promotion of renewable electricity

RE energy for transport through the electricity system requires that additional production of electricity is based on RE and supplied to the grid. In most Nordic countries/regions this additional RE electricity production for transport requires investments in electricity generation capacity based on wind, biomass and other RE sources. Incentives for establishing wind turbines and other new RE electricity generation capacities include procurement of new RE capacities by the TSO's, economic instruments as feed-in subsidies to RE electricity and RE certificate systems for RE electricity, price regulations and other measures.

Focus on 2nd generation biofuels

2nd generation biofuels are needed to ensure efficient use of the limited biomass resources if biomass is also used for biofuels besides for electricity and heat production. Development and implementation of 2nd generation biofuels require targeted policies promoting the development of these technologies and their penetration on the market. The risks to both farmers and 2nd generation biofuels producers are much higher than for farmers and producers of first generation biofuels, primarily due to higher investment costs and a longer time horizon both for farmers and producers. Key policy measures to overcome these difficulties include:

- Research, development and demonstration of 2nd generation biofuels production technologies. 2nd generation production facilities are capital intensive, and the investment costs are expected to amount to half of the production costs per litre, against only around 10 per cent of first generation biodiesel. Development and demonstration of full-scale production plants is still needed and an effort both on research and on demonstration is needed on the short and medium term.
- Promotion of lignocellulosic cropping systems. Farming of 2nd generation biofuels lignocellulosic feedstock (woody and grassy crops) differ significantly from traditional agricultural crops, particularly as they are perennial instead of annual crops, and therefore less flexible and less well-known to farmers. Several agro-economic, cultural and institutional barriers face the agricultural sector in connection with a switch towards perennial crops, and therefore information, training and financial incentives are needed. This takes time and measures to sustain a switch towards perennial crops are likely to be needed on the medium term.
- Promotion of 2nd generation biofuels through fiscal incentives, direct regulation (e.g. mandatory mixing) and target setting. Certainty about the market for 2nd generation biofuels for at least five years is important to persuade farmers to invest in 2nd generation biofuels feedstock farming. A significantly longer time horizon is needed for biofuels producers to invest in large-scale 2nd generation biofuels production facilities and measures are likely to be needed on the medium term.

FIGURE 6.2 RECOMMENDATIONS ON INITIAL INITIATIVES

Cooperation and Nordic coordination of selected initiatives may provide added value to initiatives taken by the individual Nordic countries to promote RE in transport. As there are several existing and probably more future technologies and tracks for integrating RE into the transport sector it is important not to choose only one route (e.g. electricity versus hydrogen versus biofuels) but to keep more routes open and allow experience from different options and technologies to be gathered.

Possible initiatives with added value of Nordic cooperation that could be initiated immediately include:

Promotion of EV and PIH market in the Nordic countries

Promote a rapid market entrance and market uptake of EVs and PIHs on the Nordic markets. This will help the development and large-scale production of EV and PIH, development of the infrastructure, provide real life experience with EV and PIH, and very importantly allow consumers and industry to become accustomed to EVs and PIHs. Specific measures include both country activities and initiatives at the Nordic level:

- Establishment of incentives for PIH vehicles. All Nordic countries offer reduced taxation and/or other fiscal incentives, and other types of preferential treatment in place to promote the market uptake of EVs. PIH is, however, treated differently due to their dual nature. PIH will be marketed in short time and may help pave the road for EVs. At country level the right incentives for PIH therefore need to be in place at that time. To the extent coordination between the Nordic countries is feasible and beneficial this should be done to increase the visibility of the Nordic markets to vehicle producers.
- Public procurement of EV and PIH. Public procurement of fleets of EV and PIH at local and/or country level and possibly also across Nordic countries is needed to help creating markets. Nordic coop-

eration could be used to coordinate procurement of larger series of vehicles, and thereby provide increased volume and help reduce vehicle prices.

- Training of EV maintenance staff. Qualified mechanics are needed to service the coming EVs and PIHs, and a sufficient number of qualified mechanics are needed to avoid that servicing of the vehicles becomes a bottleneck and a cause of frustration. Training should be coordinated across the Nordic countries.
- Continue ongoing effort on establishing charging stations. At country level promotion of charging stations is needed (develop transparent regulation, identify adequate locations, and possibly subsidize investment costs). A reasonable number of charging stations at shopping centres, workplaces, parking lots at train stations and airports etc. are needed to allow EVs and PIHs to charge at relevant places also outside their home base. The standards even on the first generation of charging stations should be compatible across the Nordic countries.

Development of intelligent infrastructure

R&D in intelligent infrastructure for EV is taking place in the Nordic countries and demonstration projects are also being undertaken. Most activities take place at country level, but also initiatives at Nordic level can be suggested:

- Nordic exchange of information about R&D on smart grid and metering to utilise the findings and experiences optimally
- Nordic studies and analyses. A wide range of analysis, studies, and demonstration projects are being undertaken in the Nordic countries. There is a need to establish an overview of these activities to be able to identify areas where further Nordic studies and analyses could provide added value. Therefore it is suggested to initiate a Nordic oversight study of current studies and other activities in the Nordic countries concerning RE transport and development of the energy system to absorb large amounts of RE.

Depending on the outcome of the oversight study possible issues for Nordic studies could concern the need for strengthening and developing the Nordic electricity system to meet additional demand from the transport sector and the potential for using EVs to balance the Nordic electricity system.

Iceland as a testing ground for EV

Iceland is in a unique position to test the implementation of EVs and PIHs. There is access to RE-based electricity, and being an island important learning about the effects on the electricity system could be made, not only relevant to Iceland but to all interested parties (electricity system operators, car manufacturers, policy makers etc). There is a strong political interest in Iceland, and Mitsubishi being an EV producer has expressed an interest for such a project¹⁹. Development of a detailed road map and implementation plan for Iceland as a VE testing ground could be prepared with the support of the Nordic Council of Ministers.

EVs in Greenland

The special temperature conditions in Greenland make EVs very attractive, but also challenging. The energy efficiency benefit will be very large in a cold climate, and the limited range of EV's is not a ma-

¹⁹ Vice President Ichiro Fukue, Mitsubishi Heavy Industries, presentation at the Driving Sustainability conference, Reykjavik, 15 September 2009.

major problem as trips generally are short and take place within the city boundaries. Low temperatures during winter, however, pose a challenge to the functioning of the batteries. Testing of EV would provide important information about the practicability of current EV technology in Greenland, and such a test could be made with the support of the Nordic Council of Ministers.

EV's and intelligent grid in the Faroe Islands

Wind energy, and other RE sources, are available in large scale in the Faroes. But the large share of electricity that is produced on such fluctuating sources, the larger is the challenge to the stability of the electricity system of the islands. There is a need for analysing and testing the options for co-development of the transport and energy systems. Further more the experiences gained could be valuable to other isolated island communities. A detailed study of the options and challenges for ambitious development of RE electricity, intelligent grid and electrification of the transport sector in the Faroe Islands and in similar isolated locations could be launched by the Nordic Council of Ministers.

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