HyWays

European Hydrogen Energy Roadmap

BACKGROUND DOCUMENT

Relevant Work Package	WP3
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Purpose of document	Within HyWays context Results will be used as an input for HyWays hydrogen pathway / chain selection by LBST as well as input to the energy models (e.g. potentials for biomass, wind, CCS etc.). The results will be used for end vision building by the transition analysis team run by ECN. Task Specific Reports that aim to outline the main issues that are discussed by national stakeholders regarding the identified potentials, and the future vision for hydrogen energy at the national level in a structured way that aids ongoing discussion and provides information which could be used for purposes of comparison and selection.

Member State Profiling Report – Finland

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Aims and Objectives

This profiling report has been prepared to provide qualitative socio-economic input to the HyWays hydrogen pathway selection process, and ultimately, to the energy modelling work. The report will be used in the end vision building process conducted by the transition analysis team at ECN, as shown in Figure 1.

Specifically, the report will provide an overview of the current energy system and its expected evolution, and outline the main issues regarding the present potential and future vision for hydrogen in Finland with particular reference to barriers and drivers of hydrogen development, thus providing a foundation for subsequent work.

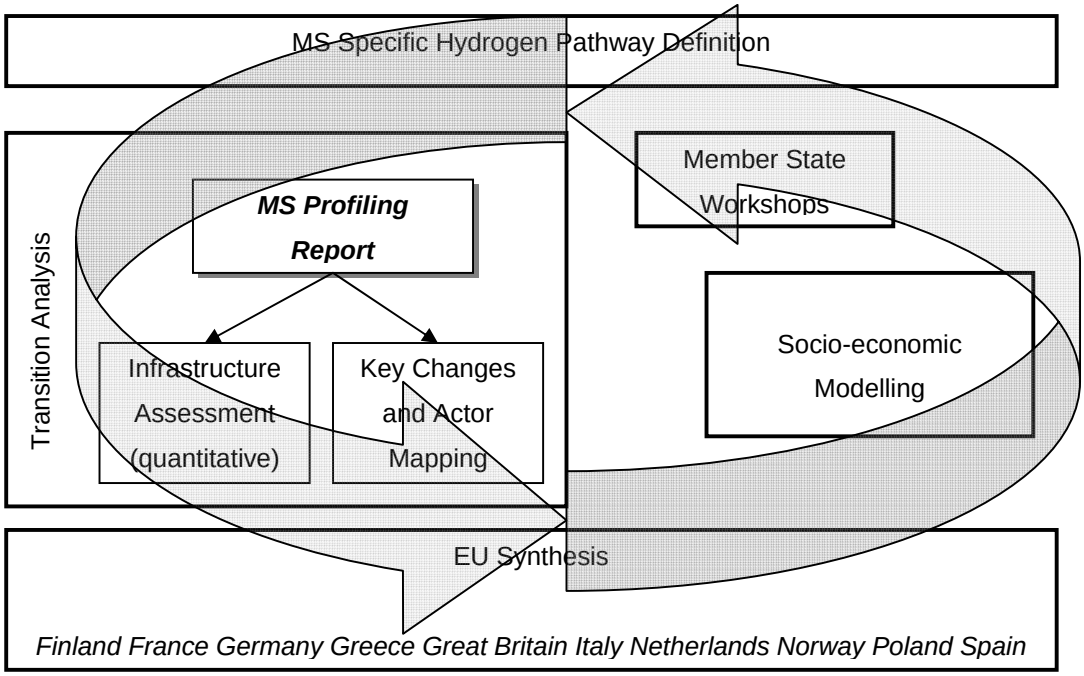


Figure 1 Member State Profiling in the HyWays process

Current Status of Energy System

Total primary energy supply (TPES) reached 37.55 Mtoe in 2003, the majority of which was imported. 15.98 Mtoe was produced domestically.[1] Energy consumption in Finland is dominated by the industrial sector, which accounted for 47% of total final energy consumption in 2001 and is expected to consume 52% by 2010. The second largest energy user is the residential sector, while the transport sector is in third place, Figure 2.

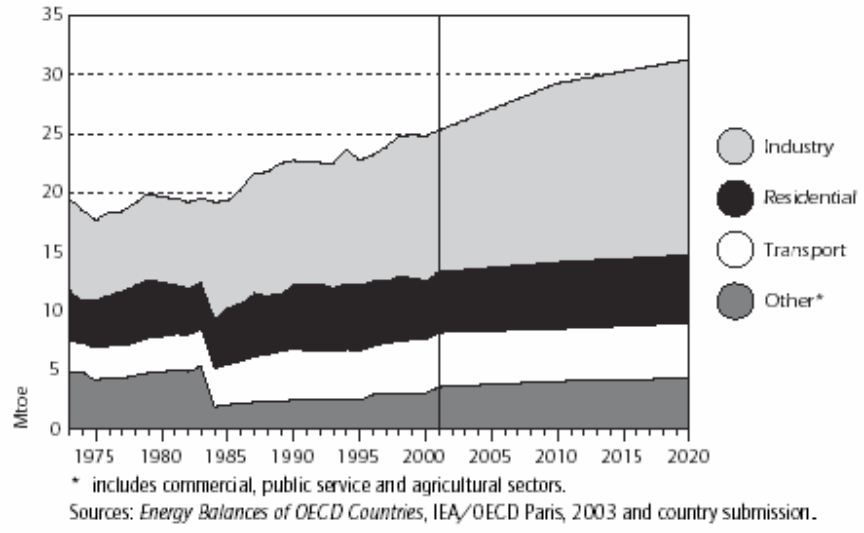
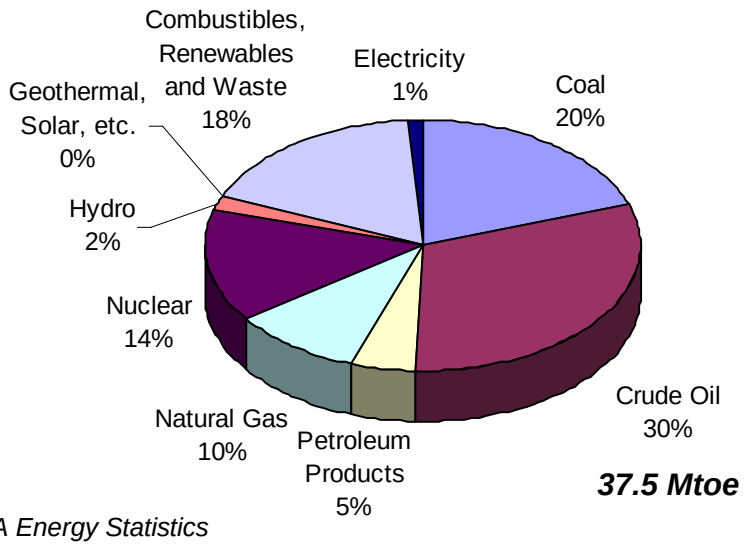


Figure 2 Total Final Energy Consumption by Sector, Finland 1973-2020

Finland has a relatively diverse primary fuel supply. The largest contributor is oil, which accounted for 30% of TPES in 2003, Figure 3. The other primary energy sources are coal, biomass, peat, nuclear and natural gas. The energy mix is expected to become more diverse in the future as the oil contribution decreases and the biofuels, gas and nuclear sectors grow. For energy supply security, coal remains in the fuel mix. Wind power is the fastest growing energy source, having increased its output by 200% between 1998 and 2001, but its overall contribution is small and is expected to reach just 0.14% of TPES by 2020. The largest domestic source of energy is biomass, followed by peat and hydro power. [2]

There is no domestic production of coal in Finland, and the country relies on imports from Russia (62%), Poland (19%) and other countries (19%). Coal is generally used for electricity and CHP production, although some (20%) is also used in steel industry. In contrast, the use of oil for electricity generation has declined since the 1970's, being today almost entirely replaced by

nuclear power, and the transport sector is now the largest oil consumer. There is no domestic production of oil, and it is imported mainly from Russia, Denmark and Norway. Natural gas supply has increased steadily since its introduction, with the majority (70%) of it being used for co-generation of power and heat. All of Finland's gas supply is imported from Russia via a pipeline. There is no front-end fuel cycle for nuclear power in Finland, so the nuclear industry also relies on imports from around the world for its fuel supply.[2]



Source: IEA Energy Statistics

Figure 3 Share of Total Primary Energy Supply in Finland in 2003

Finland is a member of the Nordic Power Market (Nordpool) along with Sweden, Norway and Denmark, allowing electricity trade between these countries. There is also a major power interconnection with Russia which makes a significant amount of electricity available to Finland and the rest of the Nordpool.[2]. A new interconnection to Estonia is also being built.

Projected Energy System Evolution

Energy supply is expected to continue to grow, reaching over 40 Mtoe by 2020, Figure 4.[2] According to a business as usual scenario developed by the Ministry of Trade and Industry of Finland, and further analysed and elaborated by VTT and other institutions, the largest increase in its contribution to energy supply will be from biomass, including peat.[3] Use of oil is expected to decrease, while biofuels, nuclear power, natural gas and coal remains in the fuel mix, mainly for energy security reasons, Table 1. No projections were available for 2050.

Consumption is also predicted to continue growing, with total consumption expected to be over 100 TWh per year by 2020. This growth is expected to be driven primarily by increases in energy use in industry and services, particularly in the forestry sector, which is projected to consume more than 30 TWh per year by 2020. Overall, this growth in energy use will necessitate an additional 4,000 MW of new generation capacity by 2020, of which 1,600 MW will be provided by a planned new nuclear power unit that will be in use by 2010. The remaining capacity is expected to be provided by increases in biofuels, hydro and natural gas. Wind power is also expected to increase, but total installed capacity is expected to remain small, contributing only about 1% to the electricity supply by 2010.[4] Targets for increases in renewable energy production in Finland are summarised in Table 2.

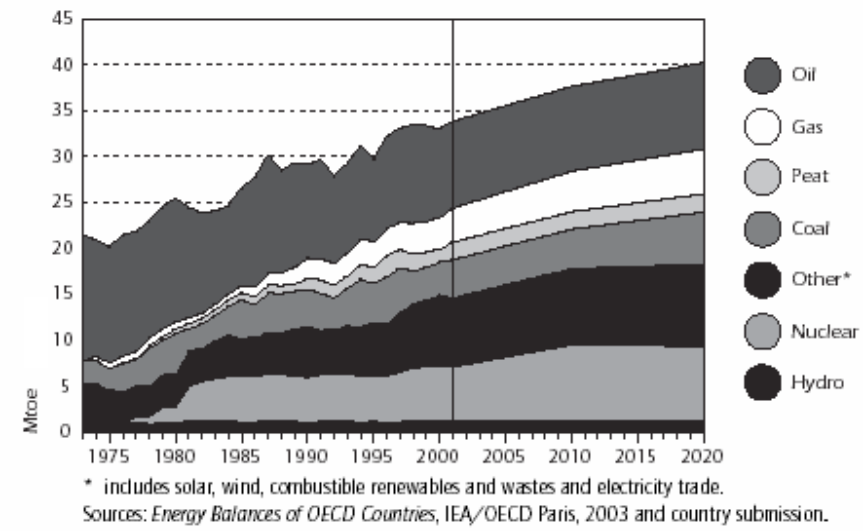


Figure 4 Total Primary Energy Supply by sector, 1973 to 2020

Growth in gas consumption in Finland will be facilitated by expansion of the gas delivery network. Gas is brought to Finland via a parallel pipeline from Siberia that enters the country at eastern border and stretches as far as Luumäki in the south-east. An extension of the parallel pipeline to the natural gas centre in Valkeala is under construction, due for completion by 2010. There are also plans to extend the pipeline to the west coast.[4] Connecting the gas network to other parts of Europe is under discussion. The options are to build a pipeline to Estonia, connect to the potential Russia-Germany Baltic subsea pipeline, or build a pipeline connecting Finland to Sweden. The Finland-Sweden pipeline could be connected to the proposed Norway-Sweden line, enabling Norwegian gas to be brought to Finland.[2]

Table 1 Primary energy supply in Finland, 2010 and 2025 [3]

Primary energy supply *(PJ; WM Scenario)*	**2010**		**2025**
Biomass (incl. peat)	401		434
Oil	387		374
Nuclear	339		377
Natural gas	189		201
Coal	104		133
Hydroelectricity	48		50
Wind	2		4
Total	**1470**		**1573**

The biomass energy sector currently uses peat as a fuel to supplement other biomass sources such as wood residues and black liquor from the pulp and paper industry. Many of the existing biomass boilers have been designed for co-firing of biomass and peat to avoid corrosion and other problems. Peat is considered a ‘slowly renewable biomass fuel’, and the peat resources have remained constant since the 1950s. However, the impact of peat use on net greenhouse gas emissions is uncertain and is currently the focus of research.[4] If life-cycle analysis shows high emissions from the use of peat, it may be necessary to reduce its use, for example through the expansion of the use of agrobiomasses as an energy source.

Table 2 Projected development of renewable energy sources in Finland

Technology Type *PJ*	**2001**	**2005**	**2010**	**2025**
Bioenergy	267	305	349	414
Hydropower (>10 MW)	42.8	44	45	46
Hydropower (<10 MW)	4.1	6	8	11
Wind power	0.25	1.2	4	17
Solar power	0.021	0.16	0.33	3.3
Heat pumps	2.73	4	7	16
Total	**317**	**359**	**412**	**508**

Source: Renewable Energy Sources in Finland 2002, OPET Report 9, Organisation for the Promotion of Energy Technologies. Cited in IEA[2]

Finland is part of the liberalised electricity market area of the Nordic countries (Nordpool), which includes Denmark, Norway and Sweden. More than 50% of the electricity in the Nordic area is hydropower. During dry periods, the shortage of hydropower is mainly compensated by an increase in coal-fired power production, the competitiveness of which has considerably decreased due to emissions trading. This situation clearly creates need for additional peak load capacity for electricity, and the use hydrogen for electricity storage and for transport fuel purposes deserves to be thoroughly assessed and evaluated.

In addition to new generating capacity, growing electricity consumption requires investments in transmission and distribution capacity as well. Especially in sparsely populated areas of Finland, distributed resource systems would offer lower system cost to the end-use customer, higher reliability and power quality, higher efficiency, and flexibility to meet a variety of industrial, commercial, residential, and transportation applications. All aspects that create potential for hydrogen/fuel cell as means to bring “power-on-tap” solutions meet this demand.

Overview of Policies and Measures

There are numerous policies and measures relevant to the introduction of hydrogen in Finland. These include funding for research and development of new technologies, and regulatory

instruments designed to reduce greenhouse gas emissions, Table 3. Key policy aims include an increase in renewable energy use of 30% relative to 2001 levels by 2010, set out in the Action Plan for Renewable Energy Sources (2002), development of new low-carbon technology, and expansion of low-carbon electricity production through the use of nuclear energy or natural gas. The National Climate Strategy (2001) sets out the government's policies and measures aimed at achieving their commitments under the Kyoto Protocol of a 0% rise in greenhouse gas emissions compared to 1990 levels. 50% of the emission reduction is expected to come from increases in energy efficiency and renewable energy, while the remainder will result from switching from coal to gas or expanding nuclear power generation. The National Climate Strategy was updated in 2005 to include EU's emissions trading and Kyoto mechanisms in Finland's energy and climate strategies.

In terms of hydrogen systems development, the ClimBus and Densy technology programmes include support for the development of hydrogen and fuel cell technologies. The ClimBus programme does not cover any specific hydrogen projects, but a number of related research areas are funded, including biomass gasification and carbon capture and storage. The Densy programme includes five ongoing fuel cell projects and one ongoing hydrogen systems project. During spring of 2006, the National Fuel Cell Strategy was formulated with the aim to increase the government funding and duration of funding of fuel cell R&D and to encourage more industrial activity. Furthermore, the Finnish Fuel Cell Council will be used to encourage the Finnish industry to participate more actively in fuel cell development work.

Table 3 Policies and measures

Policy name	Date	Description
Action Plan for Renewable Energy Sources 2003-2006	2002	Use of renewable energy should increase by approximately 30% by 2010 relative to 2001, or 50% from 1995 levels. Of this increase, about 90% is expected to come from bioenergy, 3% from wind power, 3% from hydropower, 4% from heat pumps and less than 0.5% from solar. Central actions include development and commercialisation of new technology, financial steering instruments such as energy taxation, and subsidies for the production chain of forest chip.
ClimBus technology Programme	2004	Aims to find and promote technological options to mitigate climate change.
Densy programme	2003	National technology programme for distributed energy systems, comprising local small-sized units for producing power, heat or cooling. The programme aims to assist Finnish industry to produce commercial products for several niche markets by 2010.

Policy name	Date	Description
Examples of projects relevant to hydrogen/fuel cells:		
FINSOFC project	*2002-2006*	*National project aims to support SOFC development in Finland in a number of key areas, including fuel processing, system development and modelling, balance of plant, and and cell and stack testing.*
POWERPEM project	*2004-2006*	*National project with the goal to develop a PEM based 1-10 kW power modules for various applications. The project includes development of materials, components, stacks and system.*
Streams – recycling technologies and waste management	2001	Development of new competitive technologies related to municipal waste streams.
Construction Licence for the New Nuclear Power Plant	2004	Licence for construction was granted in January 2004. The plant is expected to be ready for commissioning in 2009.
Energy Aid	1999	Discretionary state aid for the development of energy saving, to promote the adoption of new technology and increase the security and versatility of energy supply. Eligible projects include: • Increasing bioenergy use • Increasing production and processing of indigenous fuels • Promote energy conservation or efficiency • Promote production of other renewable energy (solar, wind, micro hydro, heat pumps) • Reduce environmental hazards of energy production or use
Energy Tax Overhaul	2002	All energy taxes were raised by about 5% as of January 2003. Tax subsidies were extended to include electricity from recycled fuels and biogas, and the subsidy for wood chip electricity production was increased.
National Climate Strategy	2001, 2005	Contains policies and measures to reach the Kyoto target for greenhouse gas emissions: 0% increase on 1990 levels. Increases in energy conservation and renewable energy sources are expected to account for 50% of the emission reductions by 2010. The other 50% will result from measures in electricity production: switching from coal to gas or expanding nuclear power. Update in 2005 includes EU's emission trading scheme and Kyoto flexible mechanisms as additional measures to reach the Kyoto target.
Finnish Energy Strategy	1997	General energy policy, including aims for a lower carbon content in the energy balance, promotion of the use of bioenergy and other indigenous energy, maintaining a high standard of energy technology and ensuring security of supply.

Policy name	Date	Description
Fuel cell strategy	2006	The Finnish Funding Agency for Technology and Innovation (Tekes) has formulated a national strategy for fuel cell technology development and commercialisation.

Source: IEA, VTT

Hydrogen Pathway Components

Feedstock production

- ***Natural gas***

  Although there are no domestic natural gas supplies in Finland, the country is supplied by pipeline from the Russian natural gas fields in Siberia, giving access to some of the largest gas reserves in the world. However, there are currently no alternative routes for bringing gas (except for LNG) into the country and this represents risk to energy security, and consequently a barrier to further development of the gas sector. Connection to other gas systems in Estonia, Sweden and Germany are currently being considered, although no decision has yet been taken.

- ***Coal***

  There are no domestic supplies of coal in Finland, and the supply is mainly imported from Russia and Poland. The main barrier to the expansion of coal usage is political: due to the high carbon emissions associated with the use of coal, other energy sources are favoured. Furthermore, coal-fired power plants now in use shall within near to medium future become to the end of their useful life, and shall subsequently start to retire from active duty.

- ***Nuclear power***

  Since the granting of a construction licence for a new nuclear reactor, due for commissioning by 2010, nuclear power is likely to continue to play an important role in energy production. Although no nuclear fuel is currently produced in Finland, it is available from a variety of sources worldwide, increasing security of supply.

- ***Wind power***

  Total installed wind capacity was 82 MW at the end of 2004, and the total wind energy production for the same year was 120 GWh, which corresponded to 0.1% of the annual gross electricity consumption of Finland. Targets for wind energy deployment as set in the Action Plan for Renewable Energy Sources are 500 MW by 2010, and 2,000 MW by 2025 giving an energy production of 5 TWh/yr, or 5% of projected gross power consumption. Progress towards these targets has been slower than anticipated, due primarily to the low market price of electricity together with low investment subsidies, the long lead time for planning wind projects and the differing practices in grid connection

policies for distributed generation. Under the current policy conditions, installed capacity is expected to reach 300 MW by 2010.[5] Despite of the limited onshore wind power potential in Finland, the long term off shore wind power potential may be remarkable. For example, it has been estimated that in 2010 about 15% of electricity consumption in Finland might be produced in 10 km x 100 km off shore area.

- ***Solar power***

  Solar power only contributes a very small share to energy production in Finland. Total solar production in 2001 was just 0.021 PJ or 0.0066%. However, an ambitious target for 2025 has been set for solar power to generate 3.3 PJ, or 0.65% of total projected renewable energy production. The main barrier to further development of solar energy is the unfavourable conditions in Finland – in the winter there is limited total sunlight due to the geographical location of the country.[2] However, recent research into the potential for solar power in Finland suggests that the low cloud cover and high albedo of the snow-covered ground in the north of the country make the region more suitable for solar power than previously expected.[6]

- ***Biomass***

  Biomass is the most significant renewable energy source in Finland, contributing 19.3% to total energy consumption in 2003. Of the various sources of biomass available in Finland, wood is the most important energy source, its use facilitated by the large forest industry sector. Wood is typically co-combusted with peat or coal in fluidised-bed boilers. There is a large potential for expansion of the use of wood residues – total use of forest chips in 2003 was 4.2 TWh, out of a technical potential of 23.7 TWh. Overall energy use from forestry industry solid by-products was 22.2 TWh in 2003, out of a total wood energy consumption of 107.2 TWh. Finland also trades a significant amount of biomass – total imports were 17.0 TWh in 2003, and about 21% of Finnish wood fuel consumption is based on imported biomass. The second most important biomass energy source in Finland is peat. Peatland makes up 28% of the total area of Finland. Peat provided 27.5 TWh of energy in 2003, or 6.7% of total energy consumption. There is also some production of other energy crops in Finland, the main focus being on straw and canary reed grass. The overall contribution of agrobiomass remains small, however – only 0.07 TWh is used per year.[7]

- ***Biogas***

  Finland has a well-established biogas industry with a long experience – the first biogas plant was built in Helsinki in the early 1930s to process sewage sludge.[8] Biogas is now

produced from municipal solid waste, sewage sludge and agricultural wastes. In 2004 88.6 million m^3 of landfill gas was recovered from 28 landfills across the country, and there are 15 sewage plants with anaerobic digesters, and 3 industrial plants that produce 25.8 million m^3 of biogas. There is also growing interest in biogas production from agricultural wastes. The first farm scale plant was built in 1998, and was upgraded in 2002 to produce gas to run the first biogas car in Finland, and there is growing interest in biogas for transport uses.

In general biogas is used for energy production: 360 GWh of heat was produced from biogas in 2003, most of which was used in district heating, and 62 GWh of electricity was produced, most of which was used for electricity needs at the production plants.[9] The main barrier to further use of this energy is the lack of production plants. However, 3 new plants were built in 2004-2005 and there are an increasing number of companies operating in this field since government energy tax subsidies were extended to include biogas in 2003. Also from 2004 methane fuelled vehicles were exempted from the additional fuel taxes.

- ***Other renewables***

  The only other significant renewable energy source in Finland is hydropower, but its contribution to energy production is small compared to that of biomass. Installed capacity was 3000 MW in 2004, generating about 13 TWh annually.[10] The possibilities of increasing the capacity of hydropower are very limited, because most of the economically potential rivers have already taken into use. The added capacity would be modernization of old hydropower plants and small scale hydro power. In North Finland (Lappland) there are some potential to increase large scale hydro power, but because of fairly flat geography, the spatial need for those reservoirs will be extremely large, and among other things the recent decisions to include territories in Lappland into the European Natura programme rules out the possibility to use these territories for the benefit of hydropower reservoirs.

Feedstock distribution

- ***Pipeline***

  There is a natural gas distribution pipeline in the south of Finland, particularly in the south-east. The government plans to extend it as far as the Swedish border in the near future. However, due to the low population concentration in the north of the country, there are no plans to extend the pipeline network northwards.[2]

- ***Electricity grid***

  The electricity grid in Finland is well-developed, with relatively little transmission congestion inside Finland or between Finland and other countries under normal conditions. There are constraints between Sweden and Finland in those years with high decipitation.[2]

- ***Truck and Railway***

  The road and railway infrastructure in Finland is well-developed and well maintained. The total length of the public road network is 78,000 km.[11]

Hydrogen production

- ***Steam methane reforming (SMR) of natural gas***

  The current capacity for hydrogen production by SMR in Finland is relatively limited and confined to oil refining industry plants. For example, Fortum Oil's refinery at Porvoo includes an SMR plant to produce hydrogen to be used in fuel refining, particularly in the production of diesel. As part of planned expansion of diesel fuel production activities, the hydrogen production plant is being enlarged to a capacity of 180,000 Nm^3/hr. Work is due for completion in 2006.[12] However, hydrogen production capacity would need to be expanded further so as to enable the use of hydrogen for energy purposes, but current natural gas transmission capacity is the limiting factor.

- ***Coal gasification***

  There does not appear to be any coal gasification capacity in Finland at present, and the political climate does not favour increased use of coal as an energy source (even if it will remain in the energy mix for security of supply reasons), so coal gasification is unlikely to be expanded as a source of hydrogen in the future.

- ***Biomass gasification***

  Finland has a long experience of biomass gasification for energy production and Finnish companies are some the world's market leaders in this technology. Several biomass gasification plants are in operation in Finland, using a variety of different methodologies and producing syngases of varying compositions. Examples include the plant at Lahti Kymijärvi built in 1998, the updraft moving bed BIONEER gasifiers (5 in Finland and 3 in Sweden) first designed in the 1980s, and more recently the NOVEL fixed-bed gasification plant built at Kokemäki in 2004. All of these plants produce a certain amount of hydrogen

mixed with other gases, but at present no plants include hydrogen separation and purification systems.[13] This represents a significant challenge that must be overcome to enable the production of hydrogen from biomass.

- ***Electrolysis***

  A large proportion of the hydrogen produced in Finland is made as a by-product of alkaline electrolysis to make chlorine for use in the pulp and paper industry. Finnish Chemicals, at present owned by Kemira, has two plants in Finland, one in Äetsä and one in Joutseno. Most of the surplus hydrogen is used for production of heat (Äetsä) and electricity and heat (Joutseno) by Leppäkosken Sähkö. Woikoski is the main gas company operating in this field in Finland, producing approximately 100 MNm^3 of hydrogen per year.[14] However, at present there are no electrolysis plants running specifically for hydrogen production. Labgas Ltd is producing small scale PEM based electrolysers for laboratory use.

- ***Novel hydrogen production technologies***

  The main focus of research into novel hydrogen production technologies appears to be the use of chemoorganotrophic bacteria to transform biomass and waste into hydrogen. Finland is participating in this part of the Nordic Biohydrogen research project, together with Norway, Iceland, Sweden, Denmark, Estonia and Latvia.[15]

- ***Carbon capture and storage (CCS***)

  There is limited capacity for carbon capture and storage in Finland at present. No geological formations exist for the sequestration of CO_2 in Finland – the nearest suitable locations are offshore oil and gas fields in the North Sea and Barents Sea. Use of these sites would entail transporting captured CO_2 500 to 1000 km, however. There are large domestic resources of silicates suitable for the sequestration of CO_2 as a mineral carbonate, but the technology for this process is still at the early stages of development and its energy intensity remains uncertain. Finland has industrial experience of CO_2 capture, as significant quantities of the gas are used in the pulp and paper industry, as well as for beverage production. In Finland, most of the industrial utilisation of CO_2 is covered by captured CO_2. The biggest capture plants produce CO_2 as a by-product from hydrogen, alcohol and calcium chloride production. In paper industry, CO_2 needed in paper pigment (PCC, $CaCO_3$) production is usually captured from flue gases of the pulp and paper integrate. The major barriers to the use of CCS are the distance that the gas would have to be transported to geological sequestration sites abroad and the high costs

associated with this process, and the lack of maturity of mineral carbonate sequestration technology.[16]

Conversion

- ***Compression***

  The Finnish lab gas company Woikoski has long experience (since 1913) of refining and distributing hydrogen for commercial users. The gas is generally transported in the form of compressed gas, so it is reasonable to assume that the company has considerable expertise in compression technology.[14]

- ***Liquefaction***

  No information was available on the use of liquefaction of hydrogen in Finland. This may indicate that this technology is not an area of expertise. Woikoski is producing liquid helium, so it is expected to be able to produce liquid hydrogen if so needed.

- ***Rechargeable metal hydrides***

  Hydrogen fuel cell products with metal hydride storage systems are already commercially available in Finland. For example, the company Oy Hydrocell Ltd has two metal hydride storage units available with capacities of 200 and 1200 litres of hydrogen. The company produces portable alkaline fuel cells and metal hydride canisters for hydrogen storage. At present this remains a relatively small-scale hydrogen storage technology, however.[17]

- ***Carbon-based materials***

  The use of carbon-based materials such as nanotubes for hydrogen storage does not appear to be a research priority in Finland.

- ***Novel technologies***

  Other hydrogen conversion technologies such as glass microspheres, rechargeable organic liquids and chemical hydrides do not appear to be a research priority in Finland.

H_2 transport

- ***Hydrogen pipelines***

  No information was available regarding the existence of hydrogen pipelines in Finland. However, small scale pipelines are used to transport hydrogen from the production plant to end use locations in refineries such as Fortum's Porvoo refinery.

- ***Road transport***

  The Finnish special gas company Woikoski has a wide delivery network for gaseous hydrogen based on compressed gas trucks. This is a mature technology in Finland, which should be relatively easy to expand to cope with increased demand.[14]

Distribution

- ***Refuelling infrastructure***

  At present the hydrogen refuelling infrastructure in Finland is nonexistent, although there is a refuelling site at the 'Hydrogen Village' experimental site for hydrogen applications in Äetsä, South-West Finland,[14] where hydrogen produced in a chemical plant is used as by-product, and can be used for small light-weight local transport vehicles.

End use

- ***Fuel cells***

  Finland has a well-developed fuel cell sector. Fuel cells are a focus of considerable public and private research, and some applications are being commercialised. The ClimBus and DENSY programmes of the National technology Agency (Tekes) fund a number of research projects on hydrogen fuel cells. These include: the FINSOFC project, which aims to support the development of industrial SOFC for CHP (50 kW to 5 MW) and auxiliary power unit (5 – 200 kW) applications; participation in the EU REAL SOFC project – in particular on the standardisation and quality assurance of SOFCs and test methods; the POWERPEM project that aims to construct a 1 kW PEMFC power pack suitable for light vehicles; development of disposable micro fuel cell power sources; and development and optimization of catalysts.

  In the private sector, Wärtsilä Corporation develops SOFC systems for stationary and APU use. At present they are assembling a 20 kW prototype and intend to be on the market with a 50 kW product in 2007 and a 250 kW product in 2010. The company also aims to develop and commercialise SOFC-based CHP units with (50kW) commercial demonstration units planned for 2007. While SOFC technology is not directly related to the development of hydrogen, some fuel cell expertise may be transferable to hydrogen-based systems.

  Hydrocell Ltd has two PEMFC power packs suitable for small portable power or battery charging already commercially available. VTT has technical speciality in both PEM and SOFC technology. Enfucell in collaboration with Helsinki University of Technology is

developing direct methanol biocatalytic fuel cells for low power portable electrical devices.

The focus of Finnish research and development to date has been on stationary and portable fuel cell applications – transport applications have not been a priority. This may be partly to do with the lack of a light vehicle manufacturing industry in Finland – Finnish vehicle manufacturers produce heavy goods vehicles rather than passenger cars. The Finnish car fleet also has a longer than average renewal time due to high taxes on new cars – 18 years compared with an EU average of 12. However, Finland has a number of off-road vehicle and mobile machinery producers acting on the global market. Such are Sandvik Mining and Construction, Patria Vehicles and Kalmar Industries. They are interested in future development of fuel cell powered machines and have therefore been involved in feasibility studies in cooperation with VTT and Helsinki University of Technology.

- ***ICE***

  Finland has an extensive CHP network – in 2001 31% of all electricity consumed was generated from CHP. A fraction of these CHP plants are currently based on natural gas ICE (mostly gas turbines, a few piston engines as well) for power production.[2] Although there are no hydrogen-fuelled ICE plants in operation, the industrial experience gained through the application of natural gas plants is transferable to hydrogen ICE plants. Wärtsilä Corporation is a major producer of ICE gas engines for CHP use. Currently, there is no use of hydrogen ICEs for transport in Finland.

Conclusions

An analysis of the possible hydrogen production feedstocks in Finland shows that natural gas, nuclear power, biomass, coal and biogas are most readily available. The use of natural gas is potentially limited by a lack of diversity in supply options, while the use of coal is likely to be limited by the strict targets to reduce CO_2 emissions. Coal (and gas) might however become more attractive politically if carbon capture and storage technologies could be used to sequester the emissions produced in conjunction with their use. Lack of suitable sequestration sites in Finland is likely to make this an expensive option, unless mineral carbonate sequestration technologies can be further developed.

Biomass and biogas are the most abundant renewable domestic fuel sources, but the lack of technology for their conversion to hydrogen represents a significant barrier to their use. Conversely, technology for the conversion of natural gas (via steam methane reforming) and nuclear power (via electrolysis of water) is already used commercially in the country.

Although Finland benefits from a long industrial experience of hydrogen conversion technologies, especially compression and metal hydride systems, there is a lack of experience in distribution systems – the refuelling or mini-grid infrastructure is very limited, and there are few if any hydrogen pipelines.

Stationary and portable fuel cell applications are a technological strength in Finland – a few companies have commercial or near-commercial products and there is a large amount of research being conducted on these systems. ICE hydrogen systems are less well known, although the country's considerable natural gas ICE experience may be transferable to hydrogen.

Transport applications of hydrogen technology remain relatively unexplored in Finland – demonstration projects could generate valuable experience.

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