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Contents

Finland as a frontrunner in green hydrogen 3
The Finnish hydrogen sector 4
Future visions 9
The Finnish energy sector in a nutshell 13
Useful contacts 15

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Finland as a frontrunner in green hydrogen

Finland is a leader in supporting the energy transition and renewable energy. The national objective is to become carbon neutral by 2035, creating economic growth and an increased carbon handprint through clean solutions in the process. As a central raw material, energy carrier and storage, hydrogen is a key to establishing the envisioned renewables-based economy successfully.

To be on the front foot in the hydrogen market and simultaneously achieve the ambitious carbon neutrality and sustainable growth targets, the Finnish public and private sectors are actively seeking to establish a viable hydrogen-based energy system. The aim is to spearhead sustainable hydrogen development on a European and global level. In express figures, the target is set at an impressive 10% of total European clean hydrogen production and at least a corresponding share of its use. While the sights are set high, the North Ostrobothnia region

along the Bay of Bothnia has – as just one wind power hot-spot of many – indicated the potential to alone meet the national hydrogen production target.

With its innovative and dynamic business environment, cutting-edge research and know-how, as well as a stable political and economic landscape, Finland is well-placed to achieve this goal. The emerging clean hydrogen industry is strongly facilitated by active across-the-board collaboration of stakeholders and opportunities arising from the rapid development of wind power onshore and increasingly also offshore.

The Finnish hydrogen sector

Current status

Finland has a long-standing tradition in the industrial use of hydrogen. The current annual production for industrial purposes is approximately 5 TWh (status 2020), the majority of which is produced through steam methane reforming. Main use-cases are in oil refining and biofuel production, chemical industry, mining and ore refining. Additionally, circa 800 GWh of by-product hydrogen is generated yearly in industrial processes and used in industrial boilers, for district heating, and as process gases. With increased hydrogen demand on the horizon, the available production capacity must be multiplied and the existing capacity transformed to rely on electrolysis or carbon-capture technologies.

Transition to clean hydrogen

The vastly decarbonised electricity production sector and functioning electricity transmission system provide strong foundations for economically feasible hydrogen production via electrolysis. The high-performing grid is developed constantly developed to meet future demands, and the increasingly high zero-carbon ratio in electricity production portfolio already ticks off grid emission intensity demands. While dependent on imports in the preceding fossil-running energy system that is now being phased-out, Finland possesses in abundance the resources needed for the new generation of energy solutions: water, biogenic CO_2, metals, and space for greenfield projects.

With these building blocks, Finland aims to turn its future electricity surplus through hydrogen into industrial investments and the export of derivatives with high value-added. Considerations of energy security and self-sufficiency, together with aspirations to build economic growth on carbon neutrality and domestic green industries, are central incentives for both private and public sector actors, and the general atmosphere is favourable towards clean hydrogen projects.

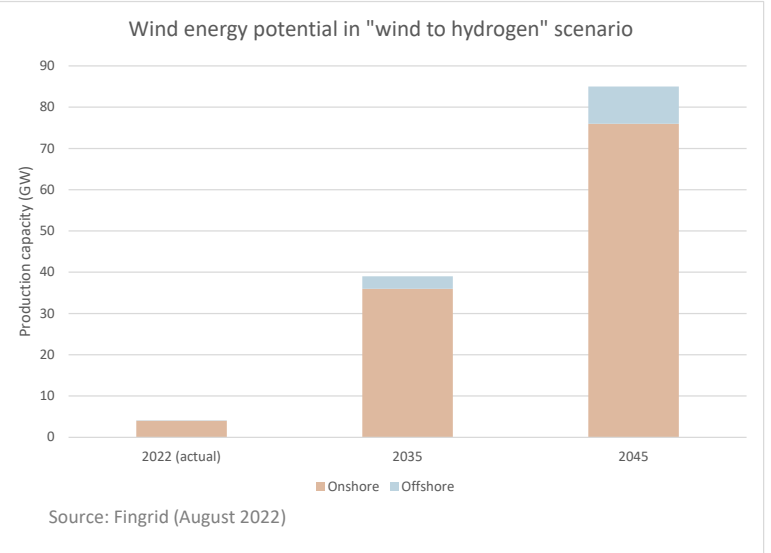
The recent years have witnessed the unveiling of an unprecedented number of clean hydrogen projects in Finland. Substantiated investment plans for upcoming years have reached an aggregate of several billion euros with exponential growth in sight, as more projects receive the green light from authorities and financers. Finland's first industrial-scale green hydrogen and methanation plant is expected to become operational in Harjavalta in 2024. With its ca. 20 MW capacity, the facility will more than triple the country's electrolysis capacity upon commissioning. In its wake, the Finnish hydrogen landscape with

its planned hydrogen valleys in North, Southwest and Southeast Finland has over a short timespan become home to a booming pipeline of GH2 plants, with CODs early in the latter half of the decade and first GW-scale facilities planned to go operational in 2030.

Business cases

Finland's emergent hydrogen projects are characterised by close cooperation between pioneering hydrogen/P2X-focused developers and traditional local energy companies. Hydrogen demonstrations and full-scale installations alike are being developed in urban industrial areas in connection with existing power generation or chemical plants. This sector-coupled approach enhances the competitiveness of the hydrogen value-chain by enabling the harnessing of exhaust gases for on-site CO^2 extraction, the supplying of by-product oxygen to nearby plants, and the use of waste heat for district heating. A local treat is the Finnish forest industry, which as the nation's third largest industry provides a source of biogenic CO2 and a prospective oxygen off-taker.

As no dedicated market for hydrogen has yet been created, the vast majority of projects under development rely on clean hydrogen as feedstock for integrated e-fuel facilities. Further solutions explore the role of hydrogen in steel-making, energy storage and system flexibility services, as well as the production of downstream chemicals and fertilisers such as ammonia. Future prospects in these fields are estimated to be even brighter: although the market development is subject to significant uncertainty, Nordic hydrogen is considered to be well on the road



Source: Fingrid (August 2022)

to being cost-competitive compared to fossil-based solutions by the end of the decade.

The demand-side shows promise as well, and the early-on focus in industrial and transport applications appears a natural continuation playing to the Finnish strengths in heavy industry and ship-building. As these sectors are beginning to decarbonise, the long-standing expertise and supply chains in steel manufacturing, refinery, and maritime solutions create fertile ground for the regional clean hydrogen demand. Indeed, clean hydrogen is visioned as a cornerstone for recasting and creating domestic green industries. Businesses have seized this opportunity to jump on the bandwagon and are engaged in ground-breaking industry-led research into i.a. hydrogen engines and hydrogen-reduced iron.

Project development

Project development in Finland calls for working dialogue with local stakeholders, energy companies, grid operators, municipalities and environmental authorities. Key development activities include environmental assessments, securing of land rights and electricity supply, spatial planning and permitting, as well as the conclusion of project agreements.

Finland has no "one-stop-shop" permit for hydrogen electrolysers. Several individual permits and statements from different state and municipal authorities are required, with limited procedural coordination in place, but the permitting practices are becoming more established as more projects enter the permitting phase.

Clean hydrogen development further enjoys some of the procedural privileges and supportive measures for renewable energy. This includes a recently adopted procedural priority to green transition projects between 2023–2028 in administrative courts and the Regional State Administrative Agency.

Future visions

Wind to hydrogen

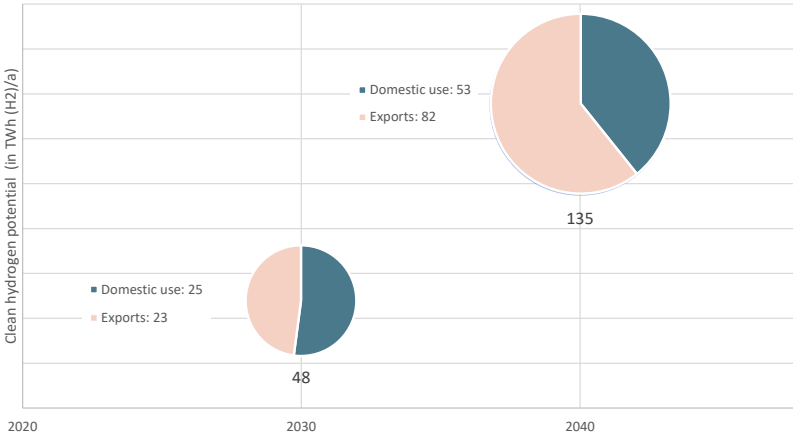
Thanks to advantageous wind conditions and constantly evolving technology, wind power has become the most cost-competitive form of electricity production in Finland, and the industry is booming. Production from the strong wind power pipeline, centred in the geographically favourable coastal and north-western parts of the country, is currently planned to reach over 63 GW onshore and 57 GW offshore in capacity. The production from the farms concretising from this development is expected to surpass the national demand and make cost-competitive feedstock readily available. This makes wind power a key factor in the country's clean hydrogen production and serves as the main enabler of the ambition to become a major hydrogen exporter in Europe. The rapid rise of solar power with its capability to effectively balance seasonal and intra-day profiles in Nordic conditions further strengthens the renewable energy mix.

In hydrogen export-oriented scenarios, the annual wind power production is estimated to be capable of multiplying to circa 130 TWh per annum by 2035 and reaching nearly 300 TWh by 2045. From a market perspective, the interdependence of wind and hydrogen is increasingly perceived as being bidirectional: hydrogen production and other energy-intensive industries can thrive with the support of the affordable wind power, but their rise is also a key prerequisite for the demand keeping pace with supply as Finland continues to grow to a wind superpower. Full utilisation of estimated onshore potential alone is expected to call for up to 27 GW of electrolysis capacity by 2050, equal to over 130 TWh of clean hydrogen production annually. Transport

as molecules is further seen as a cost-effective solution for the expected high volumes of clean hydrogen, and it allows for more expedient growth in areas where temporary local grid bottlenecks could otherwise arise.

Nordic Hydrogen for Europe

Beyond serving Finland's transport sector and the energy intensive steel, chemical and refining industries, much of the hydrogen produced is envisaged to be exported as hydrocarbons or ammonia. At a national level, the scenarios portray electrolyser potential reaching 8 GW in 2030 and multiplying to 35 GW by 2040, with well over half of the total 125 TWh of clean hydrogen produced being available for export, primarily in a further processed form.



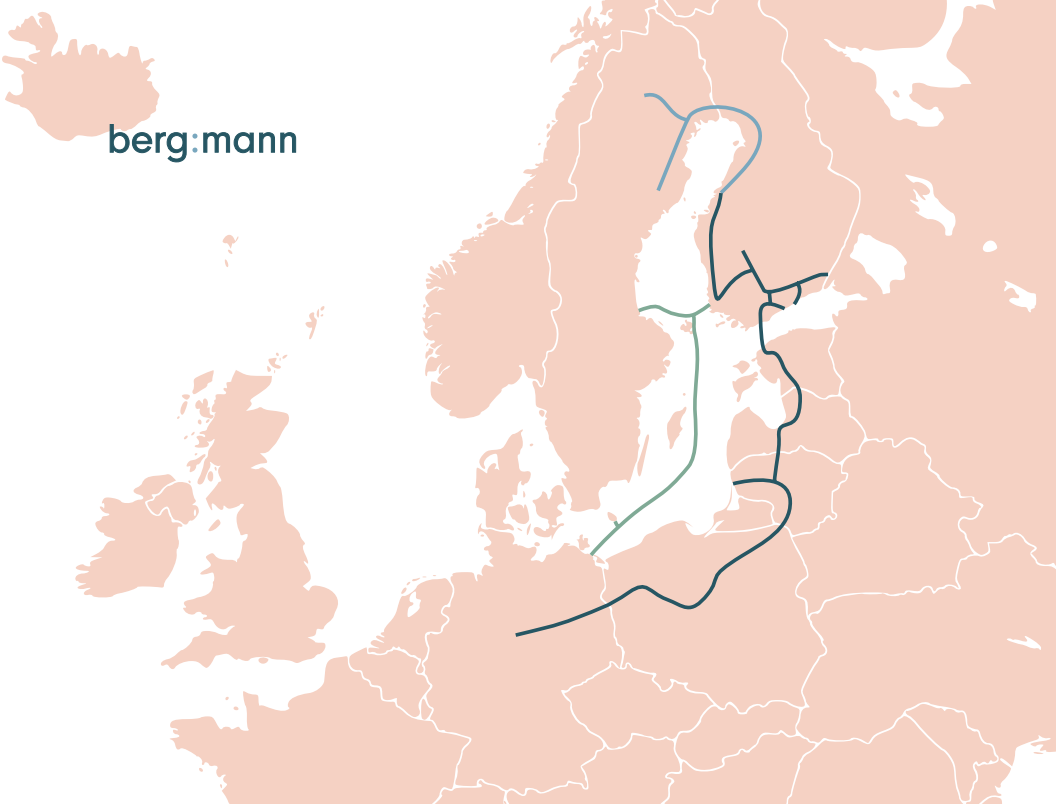
Source: Fingrid and Gasgrid (May 2023)

Regionally, the European Hydrogen Backbone Initiative (EHB) estimates that the supply potential for hydrogen originating in the Nordics and Baltics could reach a total of 185 TWh as early as 2030 and grow to circa 500 TWh by 2040. Most of the supply is expected to be dedicated to clean hydrogen, complemented by grid-based hydrogen powered largely by affordable Scandinavian hydropower.

Hydrogen infrastructure

To realise its hydrogen potential in full, Finland is making significant efforts to create a hydrogen infrastructure. To kickstart pipeline development, the Finnish gas transmission system operator Gasgrid has been given a mandate to establish a national hydrogen network. This includes the construction of a joint pipeline with Sweden (the "Nordic Hydrogen Route"), through which clean hydrogen will be transported on a large scale from areas with high wind power production to industrial customers. The pipeline is planned to be operational by 2030.

Plans to further extend the national network to serve prospective hydrogen valleys in South/Southeast Finland and in Southwest Finland/Satakunta have been published, envisioned to form the Finnish branch of the connection that would reach through the Baltic countries all the way to Poland and Germany (the "Nordic-Baltic Hydrogen Corridor"). On a cross-border level, the TSO-led pre-study for the project is underway with results expected still during 2023.



Concrete steps for another subsea interconnector in the northern Baltic Sea are also underway in the form of a Nordic collaboration between gas TSOs and industry operators that investigates a large-scale, cross-border collection and transportation infrastructure for clean hydrogen (the "Baltic Sea Hydrogen Collector"). This connection from Åland, mainland Finland and Sweden to the German and other Central-European demand markets is planned to be in place by 2030. All three routes are part of the European Hydrogen Backbone Initiative.

The Finnish energy sector in a nutshell

Finland is one of the leading nations in renewable energy. The share of renewables in total energy consumption and electricity supply, both exceeding 40% and growing, is one of the highest in the EU. While hydro and bioenergy are still quantitatively the largest renewable energy sources, the share of wind power is rapidly growing and can amount to over a third of domestic electricity generation in peak hours. Together with the soon phased-out peat, these three major renewables form the country's indigenous energy resources. Peculiar to the national energy portfolio is the strong reliance on nuclear power, solid wood fuels and black liquor.

The Finnish industry sector is the largest individual contributor to total energy consumption. Together, the forest industry, manufacture of basic metals and chemical industry make up as much as 90% of the industry sector's energy consumption. While electricity forms a notable share of it and is mostly CO2-free, due to the processes used approximately one-fourth of energy needed in these industries is still directly derived from fossil fuels – mainly oil, coal and natural gas.

The energy infrastructure is shaped by relatively long transmission distances and dependency on electricity exports from other Nordic countries. The transmission grid covers nearly 15,000 kilometres of high-voltage lines and is operated nation-wide by the TSO *Fingrid Oyj*. To accommodate increasing electrification and geographically segregated production and consumption hot-spots, significant new investments of around EUR 2,1 billion are planned over the next ten years to expand and upgrade the network. The transmission grid is complemented by regional high-voltage and local distribution networks managed

by 9 regional and 77 distribution network companies. The national grid is linked with high-voltage connections to Estonia, Sweden and Norway. While electricity imports have traditionally exceeded exports, the tide is turning with new wind and nuclear power, and in Q2 2023 Finland became an electricity net exporter.

In addition to the electricity transmission grid, the dedicated TSO *Gasgrid Finland Oy* operates a geographically more limited gas transmission network in Southern Finland. Connected to the European gas markets through the *Balticconnector* pipeline, a LNG terminal in Hamina and a FSRU infrastructure in Inkoo, the national gas network serves the Finnish natural gas market, which is open to competition since 2020 and has a yearly demand volume of circa 25 TWh (status 2021). The grid is also used for smaller quantities of domestically produced biogas. Sales volumes are largely attributable to large industrial end-users and energy companies that produce district heating or electricity. Households procure natural gas in small quantities and a vast majority of these only for cooking.

Useful contacts

Networks and advisors

Bergmann Attorneys at Law

Helsinki-based law firm with a strong specialization in industrial projects in construction and engineering, energy, and infrastructure.

Pohjoisesplanadi 21 A
00100 Helsinki
office@bergmann.fi
www.bergmann.fi

Both2nia

Network of collaborators involved in the hydrogen economy with the common goal to establish Europe's largest hydrogen cluster around the Gulf of Bothnia.

www.both2nia.com

Hydrogen Cluster Finland

Network of companies and industrial associations, aiming to facilitate information sharing and collaboration, promote hydrogen economy and create business opportunities.

www.h2cluster.fi

The Finnish Wind Power Association
(Suomen Tuulivoimayhdistys ry)

Association founded in 1988 for promotion of wind energy in Finland with over 160 private individual members and 140 member companies and associations.

Yliopistonkatu 34 B 17
40100 Jyväskylä
tuuli@tuulivoimayhdistys.fi
www.tuulivoimayhdistys.fi

Business Finland

Finnish innovation funding, trade, investment, and travel promotion organization, fully owned by the Finnish Government.

Porkkalankatu 1
00180 Helsinki
https://www.businessfinland.fi/en/do-business-with-finland/home

Finnish Energy Industries
(Energiateollisuus ry)

Sector organisation for the industrial and labour market policy of the energy sector, with about 270 member companies.

Eteläranta 10
00130 Helsinki
info@energia.fi
www.energia.fi

State administration and state-owned companies

Finnish Energy Authority
(Energiavirasto)

Licensing and regulatory authority regulating and promoting operation of the electricity and gas markets, emission reductions, energy efficiency and use of renewable energy

Lintulahdenkuja 2 A
00530 Helsinki
Tel: +358 29 5050 000
kirjaamo@energiavirasto.fi
www.energiavirasto.fi

Gasgrid Oy

State-owned enterprise responsible for the Finnish gas transmission network. Currently involved in early-stage development of hydrogen infrastructure in Finland and the Nordics.

Keilaranta 19 D
02150 Espoo
info@gasgrid.fi
www.gasgrid.fi

Fingrid Oyj

Enterprise in majority state ownership responsible for the Finnish electricity transmission grid.

P. O. Box 530 / Läkkisepäntie 21
00101 Helsinki
Tel. +358 30 395 5000
kirjaamo@fingrid.fi
www.fingrid.fi

Regional State Administrative Agency (AVI)
(Aluehallintovirasto)

6 regional agencies responsible for carrying out executive, steering and supervisory tasks related to, inter alia, environmental protection, environmental sustainability, and public safety. AVIs are involved in environmental permitting of hydrogen projects.

www.avi.fi

Centres for Economic Development, Transport and the Environment (ELY Centres)
(Elinkeino-, liikenenne- ja ympäristökeskus (ELY-keskus))

15 ELY Centres responsible for the regional implementation and development tasks of the central government. ELY Centres are involved in the assessment of environmental impacts of hydrogen projects.

www.ely-keskus.fi
Tel. +358 295 020 900
(service desk for environmental matters)

South Ostrobothnia Centre for Economic Development, Transport and the Environment (ELY Centre for South Ostrobothnia)
(Etelä-Pohjanmaan ELY-keskus)

Dedicated contact point authority for renewable energy projects, offering national permit guidance.

P.O. Box 156 / Alvar Aallon katu 8
60101 Seinäjoki
Tel. +358 295 020 920
(renewable energy permit guidance)

Energy and environment policies

Ministry of Employment and the Economy
(Työ- ja elinkeinoministeriö, TEM)

The ministry responsible for, inter alia, energy policy and integration of the national preparation and implementation of climate policy.

P.O. Box 32
00023 Government
Tel. +358 2951 6001
kirjaamo.tem@gov.fi
www.tem.fi

Ministry of the Environment
(Ympäristöministeriö, YM)

The ministry responsible for the built environment, housing, biodiversity, sustainable use of natural resources and environmental protection.

P. O. Box 35 / Aleksanterinkatu 7
00023 Government
Tel. +358 2951 6001
kirjaamo.ym@gov.fi
www.ym.fi

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November 2023