FINLAND

Opportunities for **Hydrogen Energy Technologies** Considering the National Energy & Climate Plans

FCH

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

H2

Contract details
Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU)
Study on Opportunities arising from the inclusion of Hydrogen
Energy Technologies in the National Energy & Climate Plans
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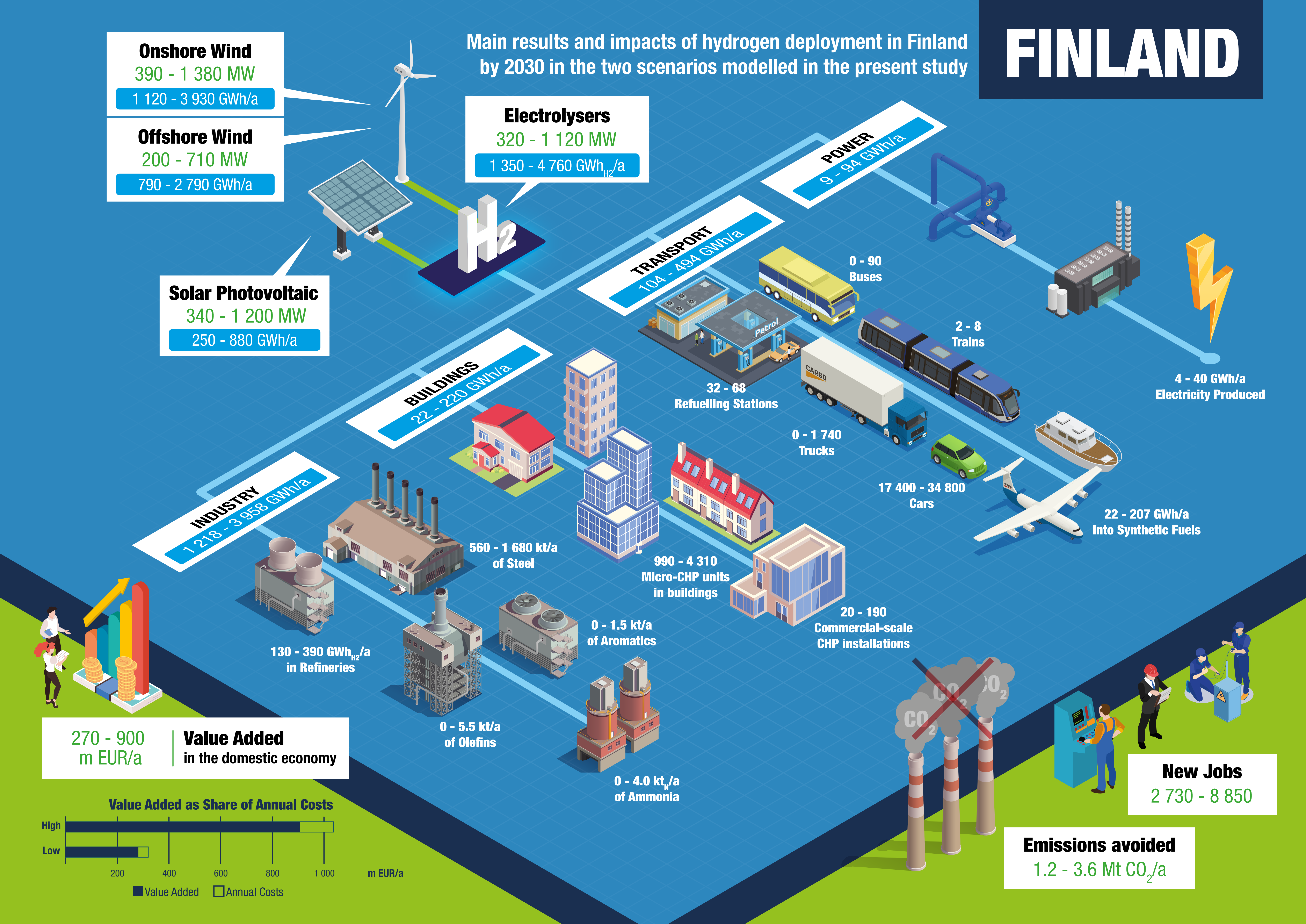
Introduction

The **Fuel Cells and Hydrogen Joint Undertaking** (FCH JU), in close cooperation with the **European Commission - DG Energy**, has commissioned a study on the "Role of Hydrogen in the National Energy and Climate Plans". This study is being conducted by the consultancies **Trinomics and LBST**.

This fiche represents one of the outputs of the study; it comprises two major parts:
- Analysis of **national opportunities for hydrogen deployment**, based on the national hydrogen production and demand potential, the gas infrastructure and the enabling environment. In this context, the role of hydrogen in the current National Energy and Climate Plan is in particular analysed.
- Assessment of **national economic, environmental and technical impacts of hydrogen deployment** under a high and a low scenario.

This information is expected to provide useful information to EU Member States that are considering to include renewable or low-carbon hydrogen deployment in their decarbonisation policies or roadmaps.



FINLAND
Main results and impacts of hydrogen deployment in Finland by 2030 in the two scenarios modelled in the present study
Onshore Wind
390 - 1 380 MW
1 120 - 3 930 GWh/a
Offshore Wind
200 - 710 MW
790 - 2 790 GWh/a
Solar Photovoltaic
340 - 1 200 MW
250 - 880 GWh/a
Electrolysers
320 - 1 120 MW
1 350 - 4 760 GWh_{H2}/a
H_2
POWER
9 - 94 GWh/a
TRANSPORT
104 - 494 GWh/a
BUILDINGS
22 - 220 GWh/a
INDUSTRY
1 218 - 3 958 GWh/a
0 - 90
Buses
2 - 8
Trains
32 - 68
Refuelling Stations
Petrol
CARGO
0 - 1 740
Trucks
17 400 - 34 800
Cars
4 - 40 GWh/a
Electricity Produced
22 - 207 GWh/a
into Synthetic Fuels
560 - 1 680 kt/a
of Steel
990 - 4 310
Micro-CHP units
in buildings
20 - 190
Commercial-scale
CHP installations
130 - 390 GWh_{H2}/a
in Refineries
0 - 1.5 kt/a
of Aromatics
0 - 5.5 kt/a
of Olefins
0 - 4.0 kt_N/a
of Ammonia
CO_2
270 - 900
m EUR/a
Value Added
in the domestic economy
Value Added as Share of Annual Costs
High
Low
200
400
600
800
1 000
m EUR/a
Value Added
Annual Costs
New Jobs
2 730 - 8 850
Emissions avoided
1.2 - 3.6 Mt CO_2/a

EXECUTIVE SUMMARY

Finland's commitment for hydrogen deployment according to its NECP

Already in 2013, a Finnish hydrogen roadmap[1] was prepared by VTT Technical Research Centre of Finland and partly funded by the Finnish Funding Agency for Technology and Innovation. The report highlighted the opportunities for Finland from a widespread adoption of hydrogen and presented recommendations. Finland was one of the first EU Members States that set more ambitious national climate targets than the EU levels and that implemented a carbon tax scheme. These are the main drivers paving the way to low-carbon applications, including those based on hydrogen.

The Finnish NECP does not comprise specific hydrogen related measures or objectives, but some concrete hydrogen initiatives or projects are being carried out, for instance *"the steel company SSAB has announced to produce fossil-free steel in 2026. The most effective ways of reducing direct GHG emissions in the industry are new innovations, such as SSAB's hydrogen reduction and the electrification of machinery and equipment"*[2]. Further, the Finnish city of Kerava has announced that it will use around 20 Fuel Cell buses for public transport[3], *"a three-hectares solar park will be built to produce the electricity needed for the hydrogen production"*.

Hydrogen for use in the transport sector will be produced with electrolysers using renewable electricity. Concrete plans have been included in the National Energy and Climate Strategy[4], the Medium-term Climate Change Policy Plan[5] (projections foresee a limited number of fuel-cell cars) and in Finland's plan on the deployment of alternative fuels infrastructure (according to Directive 2014/94/EU).

The scenario assessment shows substantial potential benefits of hydrogen deployment in Finland by 2030

Hydrogen demand

Two (high and low) scenarios of hydrogen demand in 2020-2030 were developed, based on different levels of ambition linked to the national context. The resulting values are summarised in the scheme in the previous page. For Finland, a limited development of hydrogen demand is assumed in **transport**, especially for passenger cars and trains, and to a limited extent in aviation (through hydrogen-based liquid fuels or PtL) and navigation[6]. A significant development of hydrogen demand is also assumed in the considered scenarios in **industry**, especially in the iron and steel sector and to a more limited extent in refining. These industries use fossil-based hydrogen as feedstock or reducing agent, which could be replaced by renewable hydrogen. Switching high temperature heat processes fuels to renewable hydrogen could represent another important potential use in the considered scenarios.

In the **building** sector, hydrogen can replace part of the current use of natural gas and can be distributed via existing gas grids through admixture to natural gas. The building sector is expected to have in the Low scenario a limited demand of hydrogen by 2030 but would have a stronger demand in the High scenario.

The scenarios assume only a marginal share of electricity generation from hydrogen by 2030, coming from combined heat and power installations.

Hydrogen production

To cover the estimated hydrogen demand from new uses and from substitution of fossil-based hydrogen, 0.9 to 3.3 GW of dedicated renewable electricity capacity would have to be installed to produce green hydrogen via electrolysis. While "surplus" electricity might be available in times of high renewable electricity production, the main share will have to be covered by dedicated sources. In the two scenarios, part of the 2030 hydrogen demand would still be covered by fossil-based hydrogen produced via steam-methane reforming of fossil fuels.

In its NECP, Finland estimates the production of more than 18 TWh of renewable electricity from variable renewable sources in 2030. The technical potential for renewable electricity production in Finland seems however significantly higher[7]. Building additional renewable electricity capacity dedicated for hydrogen production thus could be a feasible scenario.

Estimated socio-economic and environmental impacts

The annual costs to produce green hydrogen (including the cost of dedicated renewable electricity sources), to develop the transport infrastructure (or adapt the existing one) and end-user applications would in the considered scenarios reach respectively 310 and 1 000 million EUR. These activities will generate value added in the domestic economy, amongst others by creating jobs in manufacturing, construction and operation of hydrogen technologies, and will contribute to greenhouse gas emission reductions. This is in particular important in hard-to-decarbonize industries, such as steel production. According to the European EUCO3232.5 scenario[8], the Finnish GHG emissions should be reduced by 18 Mt CO_2 in 2030, compared to 2015. In the scenarios considered, the deployment of hydrogen could contribute 1.2 – 3.6 Mt CO_2 to this goal, which is equivalent to 6% - 20% of the required emission reduction.

[1] http://www.fuelcelltoday.com/news-archive/2013/may/the-finnish-hydrogen-roadmap-hydrogen-to-join-electricity-in-ending-traffic-pollution
[2] https://teknologiateollisuus.fi/en/ajankohtaista/article/giant-investment-reduces-7-finlands-carbon-dioxide-emissions-fast-track
[3] https://fuelcellsworks.com/news/testing-fuel-cell-buses-in-finland/
[4] The National Energy and Climate Strategy does not address hydrogen but it has been addressed in the Government report on the National Energy and Climate Strategy for 2030
[5] See the Government Report on Medium-term Climate Change Policy Plan for 2030: https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/80769/YMre_21en_2017.pdf?sequence=1
[6] Detailed assumptions are available in the methodology annex of the report, that can be consulted via the following link: http://trinomics.eu/project/opportunities-for-hydrogen-in-necps
[7] The technical potential for renewable electricity production is based on the study commissioned by DG ENER Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure (Trinomics, LBST, E3M; 2019).
[8] EC, 2019. Technical Note on Results of the EUCO3232.5 scenario on Member States. Available at https://ec.europa.eu/energy/sites/ener/files/technical_note_on_the_euco3232_final_14062019.pdf

HYDROGEN IN THE NECP OF FINLAND

Finland is not directly addressing hydrogen in its NECP, but several generic targets and measures mentioned are expected to indirectly stimulate the deployment and use of renewable hydrogen.

Hydrogen is indirectly addressed through renewable energy measures in the transport sector: *"The objectives and measures for promoting the use of transport biofuels and other renewable energy sources in transport have been included in the National Energy and Climate Strategy, the Medium-term Climate Change Policy Plan and in Finland's plan implementing the Directive on the deployment of alternative fuels infrastructure (2014/94/EU)."* The aim is to increase the share of biofuels in the overall transport fuels consumption in Finland to 30 % by 2030. Another objective is to increase the number of gas-powered cars to 50 000 by 2030.

Finland has fixed *national targets related to energy self-sufficiency that also include the decision to ban the use of coal for energy production by 2030 and to halve the domestic use of mineral oil by 2030 compared to 2005 levels;* all competitive alternatives to fossil fuel would be promoted, including hydrogen.

Finland does not consider hydrogen production as a potential flexibility provider for the electricity system to facilitate the deployment of variable renewable electricity, but rather focuses on other flexibility means, in particular interconnection capacity: *"Higher [inter]connection capacity with Central Europe and the increasing share of variable renewable energy, particularly wind energy, requires strengthening the interconnector capacity also within the Nordic market area"*.

Hydrogen is considered as one of the options to decarbonise the industry: *"industry is developing its processes towards carbon neutrality, which often means electrification of the energy use and increased renewable energy use. This transition is also driven by the Government Programme that sets the national target of carbon neutrality by 2035."*

Next to the NECP, the Medium-term Climate Change Policy Plan foresees that "The purchases of electric, hydrogen-powered and gas-powered vehicles will be promoted so that the share of new technologies in the vehicle fleet can be brought up to a level that is adequate for creating a well-functioning market".

The Government's report on the National Energy and Climate Strategy for 2030 (2017) also explicitly refers to hydrogen:

- Hydrogen produced from renewable energy source would be included in the definition of renewable transport fuels as stated in the Act on the promotion of the use of biofuels for transport (446/2007). This report also announced that the share of renewable transport fuels would be raised to 40% by 2030.

- "The distribution station network for alternative fuels (including gas and hydrogen) and the network of recharging points needed for electric vehicles will mainly be built on market terms in Finland. In addition, cost-effective ways of promoting the expansion of the network of recharging points for electric vehicles and refuelling points for gas-powered vehicles. will be assessed, taking into consideration the recommendations of the working group on distribution infrastructure that examined this question. The goal for Finland is to have a minimum of 250 000 electric vehicles (fully electric vehicles, hydrogen-powered vehicles and rechargeable hybrids) and a minimum of 50 000 gas-fuelled vehicles in 2030."

- "In addition to electricity, hydrogen is the only energy carrier that enables completely carbon free transport, provided that no fossil energy has been used to produce the hydrogen"

- "While advanced biofuels will be the most important energy form to replace fossil fuels in the next decade, it is obvious and over the long term essential that other new power sources, including electricity and hydrogen, will also gain a foothold"

OPPORTUNITY ASSESSMENT

Hydrogen production potential & its role in energy system flexibility

There is a strong opportunity for Finland to utilize renewable electricity for hydrogen production, as its estimated technical potential of variable renewable electricity production is about seven times higher than its forecasted electricity demand in 2030. According to the NECP, Finland would only effectively use 3% of its technical potential in variable renewable electricity generation by 2030, so there is a great margin for building dedicated renewable electricity capacity for hydrogen production via electrolysis.

Projections indicate there would be a limited opportunity to use power-to-hydrogen technologies to provide additional flexibility services to the Finnish energy system. Most of the renewable electrical energy production is expected to be delivered by dispatchable sources, especially biomass, and the installed variable renewable electricity generation capacity in 2030 is projected to be relatively low compared to average load. The flexibility needs of the system will therefore be rather low and it will be possible to mostly cover them with the aforementioned dispatchable renewable energy sources, demand response and trade with neighbouring countries, since the electricity interconnection capacity is expected to be of similar magnitude as the variable renewable electricity generation capacity.

	Technical variable renewable electricity potential (TWh/yr)	Technical renewable electricity generation potential compared to forecasted gross electricity consumption in 2030 (NECP)	NECP estimate of variable renewable electricity production in 2030 (TWh/yr)	NECP estimate of variable renewable electricity production in 2030 compared to its technical potential	Ratio between variable power generation capacity in 2030 and average load (based on NECP)	Readiness for CO_2 storage
Finland	664	702%	18.27	3%	55%	Very Low

With respect to the production of low-carbon hydrogen via steam reforming of natural gas combined with CCS, the potential is very limited due to lack of suitable geological CO_2 storage sites.

Energy infrastructure

The methane distribution network in Finland is to a large extent made of polyethylene, which means that it could be converted to hydrogen use at a relatively low cost. However, as the total length of the network is limited compared to the size of the country, this option would only allow to decarbonise a small share of the building sector. However, converting (part of) the transport network for dedicated hydrogen transport could be an interesting option to transport large volumes of renewable electricity, after conversion to hydrogen from the North to the locations of consumption, in particular the industry.

As transporting hydrogen is in general less expensive than transporting electricity, it might be appropriate to assess coupling large renewable power plants remotely located (like large off-shore or onshore wind/PV parks) with electrolysers and transporting the energy output to high energy demand areas via hydrogen pipelines. This could be an opportunity to consider in Finland.

	Technical and economic feasibility of converting gas distribution networks to hydrogen (share of polyethylene pipelines in distribution grid)	Natural gas demand in residential and services sectors / length of gas distribution network (GWh/km)	Existing salt cavern natural gas storage sites (TWh)	Suitable geological formations (potential for future hydrogen storage)
Finland	95%	0.3	0	NO
EU	MS range 16%-99%			

To date, there are no salt cavern natural gas storage sites in Finland that could be used for hydrogen storage, nor underground salt layers that could provide suitable storage opportunities for hydrogen.

Current and potential gas & hydrogen demand

The most significant opportunities for the deployment of hydrogen in Finland, especially on the short term, are in the transport sector. Hydrogen can play a role in the decarbonisation of road and rail transport and on the medium to long term, hydrogen and derived fuels might also play a role in the decarbonisation of domestic and international shipping. In industry, the role for hydrogen deployment is limited on the short term, due to the low share of natural gas in the industrial energy mix and the low demand for high temperature process heat. However, there are opportunities for the deployment of decarbonised hydrogen in refineries and in the long term also in the steel industry. In the built environment, the potential role for hydrogen deployment is rather limited, although it could play a role in decarbonising the remaining fossil fuel use in district heating plants.

Opportunities for hydrogen demand in industry

In Finland, the opportunities for hydrogen use in industry are, on the basis of the assessed indicators, rather limited. Natural gas only plays a marginal role in the country's industrial energy mix and the energy demand related to the use of high-temperature process heat is rather low. Still, hydrogen is one of the technologies that can contribute to the decarbonisation of the energy demand in industry, together with other technologies including electrification options. Niche applications where renewable or low-carbon hydrogen can play a role are in the refinery sector, where fossil-based hydrogen is already used in several processes. Additionally, hydrogen could also provide a suitable solution for the decarbonisation of primary steel production in Finland.

	Presence of ammonia industry / share of ammonia production capacity in EU28 total	Presence of refineries / Share of Finnish refineries in total captive hydrogen production by refineries in the EU28	Share of Finland in total primary steel production in the EU28	Share of natural gas in industrial energy demand (2017)	Share of high-temperature (>200°C) process heat in industrial energy demand (2015)
Finland	0%	4%	3%	5%	15%
EU	MS range 0%-16%	MS range 0%-26%	MS range 0%-30%	Average 32% MS range 0%-43%	Average 38% MS range 9%-60%

Opportunities for hydrogen demand for heating and cooling in the built environment

The opportunities for the deployment of hydrogen for the decarbonisation of heating in Finland's built environment are limited. A combination of biomass, district heating and electric heating account for the lion's share (>90%) of the country's heat demand in households and services. In district heating, biomass is the most dominant fuel accounting for over 70% of the fuel inputs. Hydrogen could be one of the low-carbon energy carriers that can replace the remaining fossil fuel inputs in Finland's district heating sector. The demand for cooling in Finland is rather minimal.

	Share of natural gas in the household and service sector energy demand (2017)	Share of heating in the household and service sector energy demand (2015)	Share of cooling in the household and service sector energy demand (2015)
Finland	1%	81%	2%
EU	Average: 34% MS range: 0% - 60%	Average: 74% MS range: 41% - 82%	Average: 3% MS range: 0% - 46%

Opportunities for hydrogen demand in transport

Like most EU countries, Finland has a large potential for hydrogen use in road transport. More than a third of the energy use in this sector is consumed by trucks, buses and light commercial vehicles (e.g. vans). Since electrification of this segment remains challenging, there is a significant opportunity for hydrogen to decarbonise this part of Finland's road transport. Next to this, diesel trains still account for around a quarter of the energy use in Finland's rail sector. A switch to hydrogen trains is one of the solutions to reduce the GHG emissions from rail transport in Finland. Furthermore, hydrogen could also play a role in the decarbonisation of the energy mix in the shipping sector. Domestic shipping accounts for 3% of the total transport demand, so in order to fully decarbonise Finland's transport sector, a switch to low-carbon fuels in the shipping sector is needed. Hydrogen and derived fuels are amongst the most feasible solutions to do this. On the medium to long term, these energy carriers can also be used to decarbonise the fuel used by international ships and in the aviation sector.

	Share of heavy transport (trucks, buses & vans) in total energy demand in road transport in 2020	Share of fossil fuels in energy use of rail transport (and absolute consumption) in 2017	Share of inland shipping in overall energy demand for transport in 2017	Energy use by international shipping relative to total (domestic) final energy use in transport in 2017	Share of domestic and international aviation in overall energy demand for transport (incl. energy use int. aviation) in 2017	Share of fossil fuels in energy use of road transport in 2017
Finland	35% (14 933 GWh)	24% (239 GWh)	3% (1 476 GWh)	8% (4 121 GWh)	14% (9 390 GWh)	90% (40 946 GWh)
EU	Average 32% MS range 18%-48%	Average 30% MS range 0%-95%	Average 2% MS range 0%-10%	Average 14% MS range 0%-1011%	Average 14% MS range 1%-25%	Average 95% MS range 79%-100%

Enabling environment: national hydrogen policies and plans, projects and industry

The assessed indicators show that Finland has no comprehensive framework for the deployment and use of hydrogen. The NECP has not set any objectives or supporting measures specifically related to hydrogen. In Finland, there are no technology-specific policies to promote fuel cell vehicles and hydrogen refuelling stations infrastructure. Driven by ambitious climate targets, the deployment of low carbon solutions and technologies will be fully driven by the market.

Hydrogen, as all other low carbon options, is addressed and incentivized through various policy instruments (like car taxation, carbon pricing).

However, to facilitate hydrogen development, it is deemed appropriate that Finland further invests in hydrogen related research, further implements pilot and demonstration projects and continues the deployment of hydrogen refuelling stations in the frame of regional cooperation. Finland is already at the forefront of research on "Hydrogen Breakthrough Ironmaking Technology".

Finland could also address the regulatory barriers to the deployment of hydrogen applications and take into account the initiatives and policies at EU level.

Existence of (or concrete plans for) national hydrogen roadmaps or strategies — Positive environment: ✕

Finland has an overarching national Energy and Climate Strategy that encompasses hydrogen and fuel cells.

GHG mitigation gap in non-ETS sectors (need for additional GHG reduction measures) — Positive environment

In its NECP, Finland acknowledges that "According to the Effort Sharing Regulation (ESR), it should by 2030 reduce its greenhouse gas emissions in the effort sharing sector by 39% compared to 2005 levels. However, if flexibility measures are used, the emissions may be higher". Additional measures could hence be needed. Therefore, a higher use of low carbon hydrogen in the non-ETS sectors (transport and building H&C) could become an adequate option.

Existence of (active) hydrogen national association — Positive environment: ✕

Current and planned hydrogen refuelling infrastructure for the transport sector

Alternative fuels infrastructure directive (2014/94/EU)

Next to its commitment to biofuels, electric vehicles and CNG/LNG for heavy transport, the Finnish National Policy Framework (or NPF set in the context of the alternative fuel infrastructure Directive (2014/94/EU)) reflects a strong commitment towards hydrogen. The NPF contains a comprehensive list of support measures to promote the deployment of alternative fuel infrastructure, including hydrogen refuelling stations.

Inclusion of hydrogen in national plans for the deployment of alternative fuels infrastructure (2014/94/EU)	Existence of hydrogen refuelling stations (2019)	which is equivalent to 1 refuelling station per … cars
YES	2	Not Applicable

Existence of (investment on) hydrogen-related projects

The deployment of 19 publicly accessible hydrogen refuelling points in addition to the two existing ones is planned, ensuring a distance of maximum 300 km between any two refuelling points. There are currently also two other hydrogen projects under operation. The steel company plans to produce fossil-free steel as of 2026 and considers that the most effective way is through hydrogen reduction[9]. The Finnish city of Kerava intends to use around 20 FC buses, with hydrogen produced with a nearby solar PV plant[10].

Existing R&D and pilot projects directly related to hydrogen	RD&D annual expenditure on hydrogen & fuel cells (m EUR) (average 2013-2017)	Activities and projects in industry to use hydrogen as feedstock	Number of power-to-gas projects (existing and planned)
YES	0	YES	2

[9] https://teknologiateollisuus.fi/en/ajankohtaista/article/giant-investment-reduces-7-finlands-carbon-dioxide-emissions-fast-track
[10] https://fuelcellsworks.com/news/testing-fuel-cell-buses-in-finland/

Positive environment

Existence of national tax incentives (CO_2 pricing mechanisms & car taxation)

Finland has already set up a CO_2 pricing mechanism in 1990 and has introduced a carbon related taxation for vehicles. Both measures are key to facilitate the progressive switch to low carbon vehicles (including hydrogen).

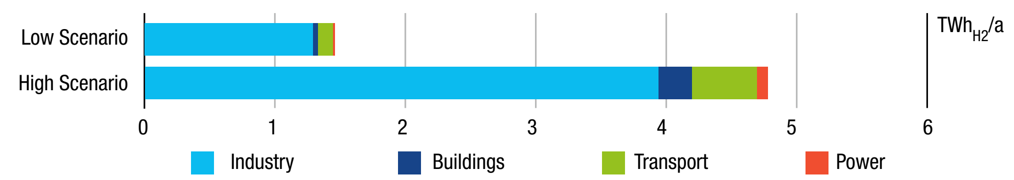
Fossil energy import bill

Like many other EU Member States, Finland is strongly dependent on imports for its oil consumption. Switching from imported fossil oil to nationally produced hydrogen to complement its biofuel ambitions for heating applications and the transport sector will contribute to reducing its energy import dependence and bill.

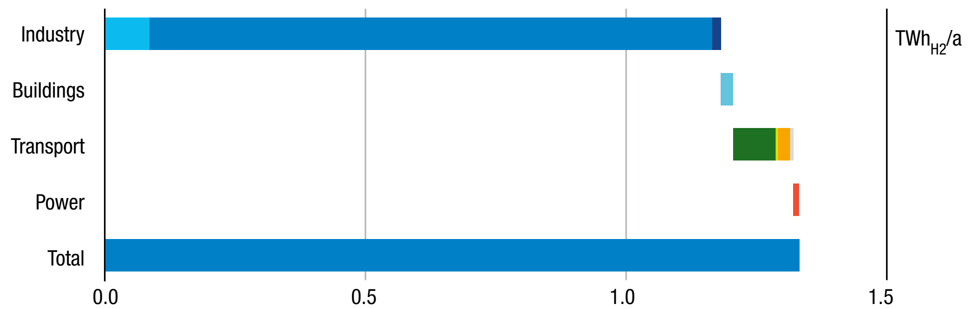
	Import bill for natural gas as share of national Gross Value Added	Import bill for all fossil fuels
Finland	0.01%	1.2%
EU	Average: 0.6% MS range: 0% - 1.5%	Average: 2% MS range: 0% - 7%

SCENARIO ASSESSMENT
Estimated renewable/low carbon hydrogen demand for Finland by 2030

Hydrogen demand in the year 2030 has been estimated in a low and a high scenario covering the range of uncertainty. Today, conventional hydrogen mainly used in industry is produced from fossil fuels (e.g. through steam methane reforming) or is a by-product from other chemical processes. Both scenarios assume that in 2030 renewable hydrogen will be provided to partially substitute current conventional production and to cover additional demand (e.g. from transport sector).

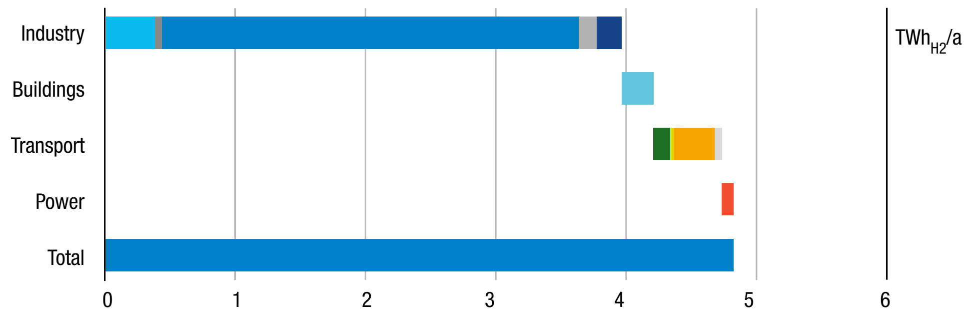


Low scenario

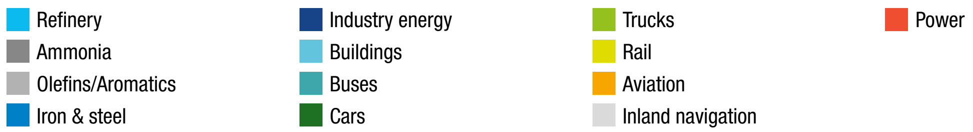


In the low scenario, renewable hydrogen accounts for 0.6% of final total energy demand (i.e. 1.4 out of 273 TWh/a) or 10.3% of final gas demand (13 TWh/a) according to EUCO3232.5.

High scenario



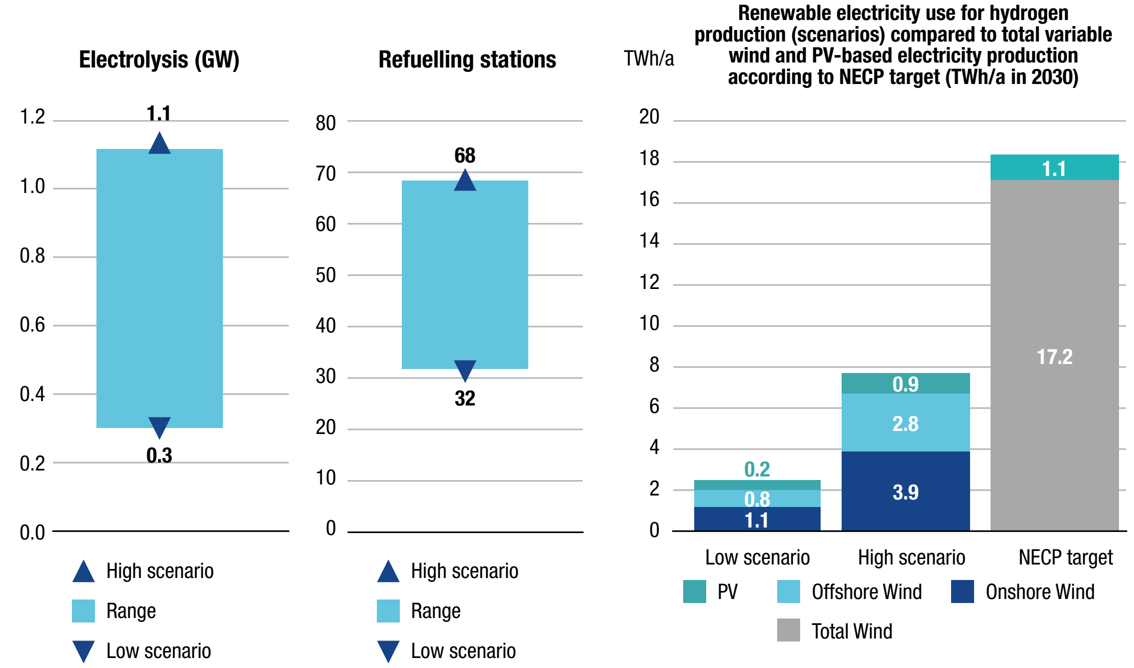
In the high scenario, renewable hydrogen accounts for 2.0% of final total energy demand (i.e. 4.8 out of 237 TWh/a) or 36.4% of final gas demand (13 TWh/a) according to EUCO3232.5.



Hydrogen generation, infrastructure and end users in Finland by 2030

The analysis of renewable hydrogen generation, infrastructure and end use is based on the demand estimates presented above. Renewable hydrogen is generated from variable renewable power using electrolysis. The analysis covers only national hydrogen production to satisfy domestic demand and does not take into account any cross-border trade of hydrogen (i.e. hydrogen imports and exports are not included in this analysis).

Renewable hydrogen generation and infrastructure



The required renewable power production accounts for 1.1% of the overall technical renewable power potential in the low scenario and 4.0% in the high scenario.

End users

End user	Unit	Low scenario	High scenario
Passenger cars	Nº	17 400	34 800
Buses	Nº	0	90
Lorries	Nº	0	1 700
Heavy duty vehicles	Nº	0	40
Trains	Nº	2	8
Substituted fuel in aviation	GWh/a	18	168
Substituted fuel in navigation	GWh/a	4.1	39.3
Micro CHP	Nº	990	4 310
Large CHP	Nº	20	190
Iron&Steel	% of prod.	13%	40%
Methanol	% of prod.	0%	0%
Ammonia	% of prod.	0%	5%

According to the estimations, the hydrogen refuelling station network will by 2030 encompass between 30-70 stations for 17 000-37 000 fuel cell vehicles on the road.

In addition, the analysis estimates substitutions of up to 40% of the conventional steel production by renewable hydrogen-based steelmaking.

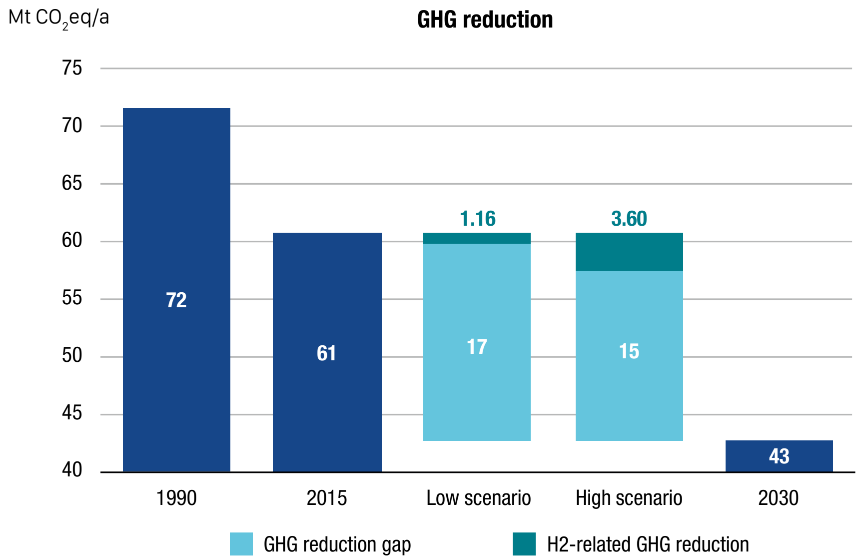
Further use of renewable hydrogen is foreseen in ammonia production (up to 5%).

Finally, the introduction of 1 010-4 500 stationary fuel cells for combined power and heat production is estimated.

Environmental and financial impact in Finland by 2030

Greenhouse gas (GHG) emission reductions have been calculated by estimating the fuels replaced by hydrogen, and their respective greenhouse gas footprint. Comparing these to the 2030 GHG reduction targets results in the contribution of hydrogen to achieving these targets.

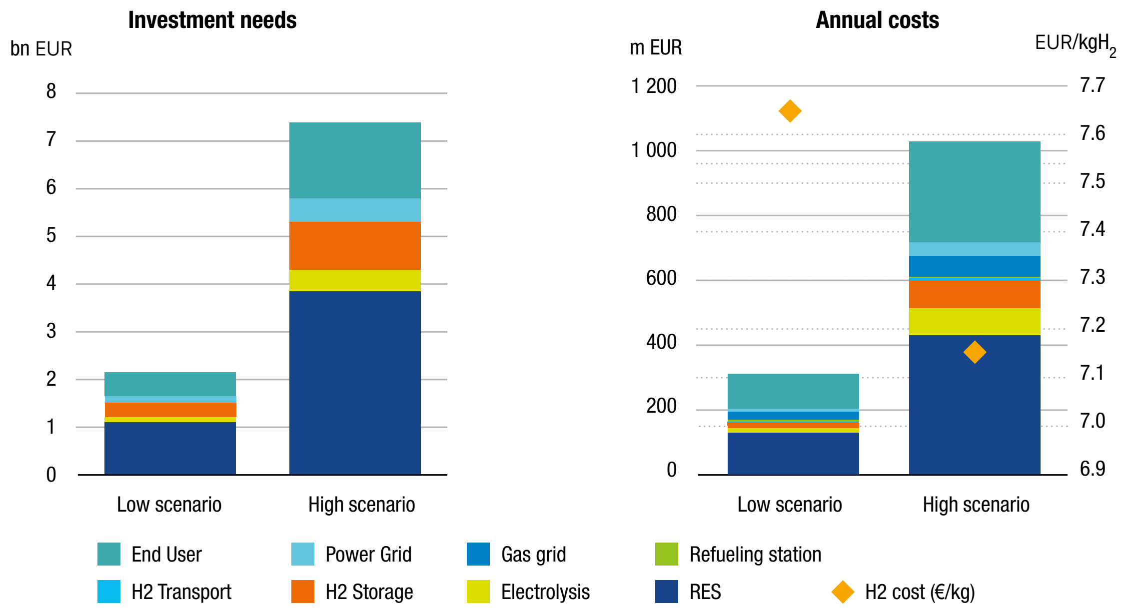
Environmental impact



An additional GHG emission reduction of 1.2-3.6 Mt CO_2 is estimated in 2030 corresponding to 6.3%-19.7% of the overall GHG emission reduction gap towards 2030 target (based on EUCO3232.5).

Financial impact

The financial scenario assessment includes investments (CAPEX) until 2030 and operating expenses (OPEX) per year in 2030. Cumulative investments in hydrogen technologies are estimated at 2.1-7.1 billion EUR until 2030, while annual expenditure would amount to 310-1 020 million EUR (including end user appliances as well as power and gas grids).

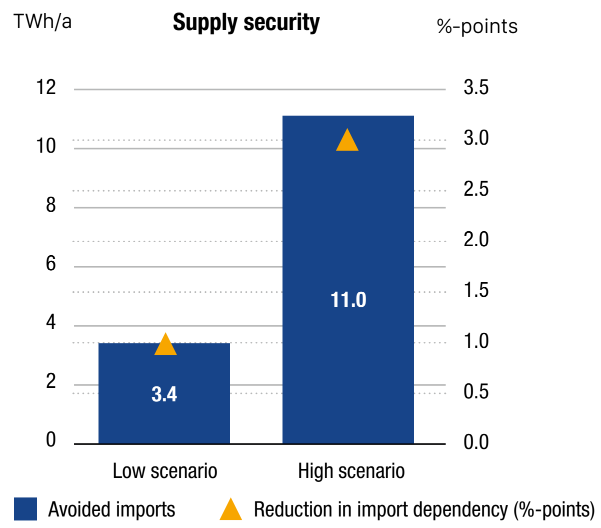


Impact on security of supply, jobs and economy in Finland by 2030

Hydrogen contributes to the security of energy supply security objective by reducing fossil energy import dependence and enhances energy supply diversification by facilitating deployment of renewable energy sources. This is assessed by estimating imported fossil fuels that will be replaced by hydrogen based on domestic renewable sources.

Security of energy supply

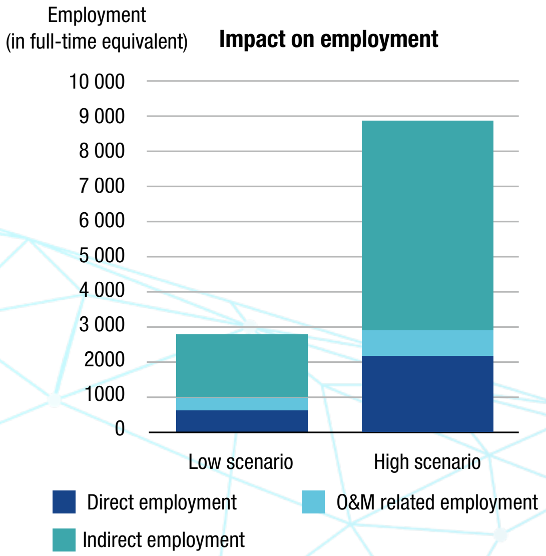
Deployment of renewable hydrogen would lead to 3.4-11.0 TWh/a of avoided imports, and thus reduce import dependency by 0.9-3.0% (in volume terms) in 2030, depending on the scenario.

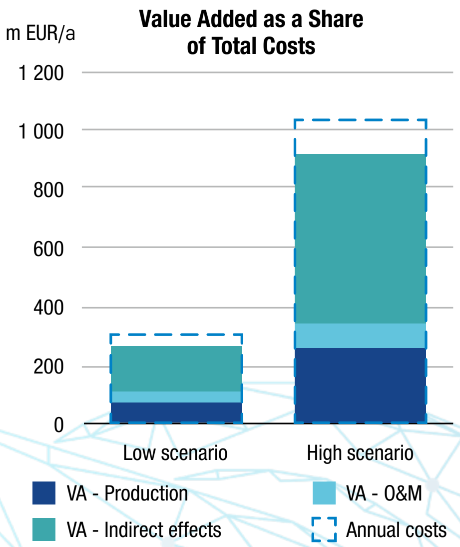


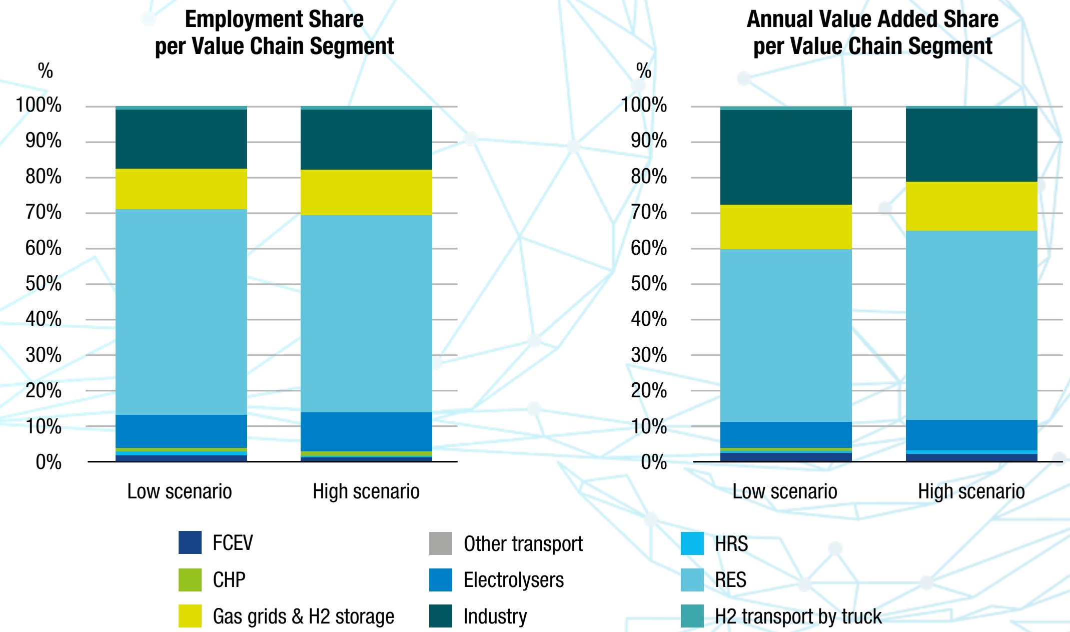
Impact on employment and value added

This analysis shows that in the years 2020-2030 more than 100 million EUR can be retained annually in the domestic economy as value added in the low scenario, and almost 320 million EUR in the high scenario (value added is defined here as sum of wages for employees, margins for companies and taxes). If the indirect effects induced by the investment in and operation of hydrogen technologies are also taken into account, around 270 million EUR (low scenario) and almost 900 million EUR (high scenario) of value added can be created in the Finnish economy annually, which is almost equivalent to the amount of annual investment needed. Most of this value added is expected to be created by building dedicated renewable electricity sources for hydrogen production, by building the infrastructure for hydrogen transport and storage, and in industry applications, in particular in the steel industry.

The hydrogen-related expenditures in 2020-2030 are estimated to generate employment of 950 - 2900 direct jobs (in production and operations & maintenance), and contribute to a further 1800 - 6000 indirectly related jobs, depending on the scenario. Most of these jobs are expected to be related to building and operation of renewable electricity sources and to activities in industry.







FINLAND

Opportunities arising from the inclusion of **Hydrogen Energy Technologies** in the National Energy & Climate Plans

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING