SWEDEN

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

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

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
(Ref. FCH / OP / Contract 234)
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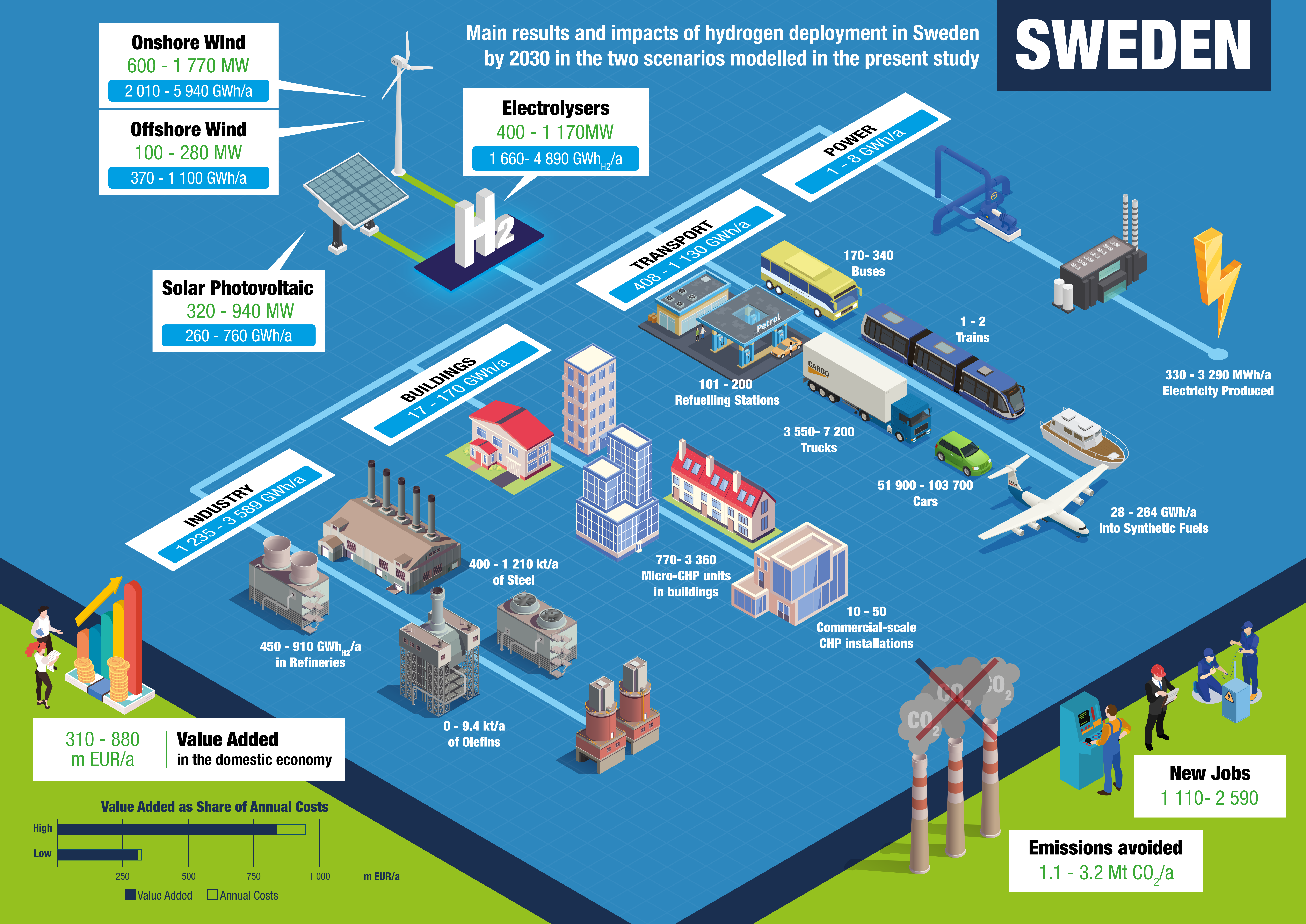
Introduction

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.



SWEDEN
Main results and impacts of hydrogen deployment in Sweden by 2030 in the two scenarios modelled in the present study
Onshore Wind
600 - 1 770 MW
2 010 - 5 940 GWh/a
Offshore Wind
100 - 280 MW
370 - 1 100 GWh/a
Solar Photovoltaic
320 - 940 MW
260 - 760 GWh/a
Electrolysers
400 - 1 170MW
1 660- 4 890 GWh_{H2}/a
H_2
POWER
1 - 8 GWh/a
TRANSPORT
408 - 1 130 GWh/a
BUILDINGS
17 - 170 GWh/a
INDUSTRY
1 235 - 3 589 GWh/a
170- 340
Buses
1 - 2
Trains
101 - 200
Refuelling Stations
Petrol
CARGO
3 550- 7 200
Trucks
51 900 - 103 700
Cars
28 - 264 GWh/a
into Synthetic Fuels
330 - 3 290 MWh/a
Electricity Produced
400 - 1 210 kt/a
of Steel
770- 3 360
Micro-CHP units
in buildings
10 - 50
Commercial-scale
CHP installations
450 - 910 GWh_{H2}/a
in Refineries
0 - 9.4 kt/a
of Olefins
CO_2
CO_2
CO_2
310 - 880
m EUR/a
Value Added
in the domestic economy
Value Added as Share of Annual Costs
High
Low
250
500
750
1 000
m EUR/a
Value Added
Annual Costs
New Jobs
1 110- 2 590
Emissions avoided
1.1 - 3.2 Mt CO_2/a

EXECUTIVE SUMMARY

Sweden's commitment for hydrogen deployment according to its NECP

Already in 2012, Hydrogen Sweden[1], the Hydrogen Association founded in 2007, published "The Hydrogen and Fuel Cell Guide"[2], highlighting the interest to deploy hydrogen and fuel cells in Sweden, for both climate goals and economic growth. In 2017 Sweden adopted a long-term target to reach net-zero greenhouse gas emissions by 2045 at the latest.[3] Sweden was also one of the first EU Members States to implement a carbon tax scheme in 1991. These are probably the main drivers paving the way to low-carbon applications, including those based on hydrogen.

The Swedish NECP does not comprise specific hydrogen related measures or objectives, but some concrete hydrogen initiatives or projects are mentioned, for instance "In 2016, SSAB, LKAB and Vattenfall joined forces to create HYBRIT with the aim to replace coking coal with hydrogen. The result will be the world's first fossil-free steel-making technology"[4]. Further, "Nilsson Energy will build the world's first fully off-grid energy sufficient housing complex in Sweden's Vårgårda Municipality, which will operate solely on solar energy and compressed hydrogen."[5]; in 2019 the Swedish Patent and Registration Office issued two new patents for Swedish fuel cell company myFC for its green hydrogen liquid fuel[6]; Statkraft and Everfuel joined Hyundai, Toyota and Hydrogen Sweden in an EU-supported initiative to explore hydrogen road transport in Sweden[7] as part of the "Greener transport in the Nordic region with hydrogen" initiative.

Sweden is in a prime position to further transform its energy system using hydrogen fuel cells[8], given its high share of electricity obtained from low carbon and renewable sources and the important commitment of actors along the whole value chain, like those involved in the Scandinavian Hydrogen Highway Partnership[9], which aims to make Scandinavia "one of the first regions in Europe where hydrogen is available and used in a network of refuelling stations" (the project Baltic Sea Hydrogen Network[10] is financed by the Swedish Institute).

The scenario assessment shows substantial potential benefits of hydrogen deployment in Sweden 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 Sweden, a significant development of hydrogen demand is assumed in the considered scenarios in **transport**, especially for passenger cars, buses, trucks and trains, and to a limited extent in aviation (through hydrogen-based liquid fuels or PtL) and navigation[11]. A significant development of hydrogen demand is also assumed in the scenarios in **industry**, especially in the iron and steel sector and refining. Some 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 use of hydrogen for electricity generation by 2030, mainly in combined heat and power installations.

Hydrogen production

To cover the estimated hydrogen demand from new uses and from substitution of fossil-based hydrogen, 1 to 3 GW of dedicated renewable electricity sources 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, Sweden presents an estimate of installed renewable electricity capacity in 2030, reaching 12.1 GW in onshore wind and 2.7 GW in solar PV, generating over 37 TWh of renewable electricity in 2030. The technical potential for variable renewable electricity production in Sweden seems however significantly higher[12]. 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 340 and 940 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[13], the Swedish GHG emissions should be reduced by 17 Mt CO2 in 2030, compared to 2015. In the scenarios considered, the deployment of hydrogen could contribute 1.1–3.2 Mt CO_2 to this goal, which is equivalent to 7% - 19% of the required emission reduction.

[1] *http://www.vatgas.se/in-english/*
[2] *http://www.vatgas.se/wp-content/uploads/2016/02/VatgasSverigeBranchkatalog_lagupplost.pdf*
[3] *http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedish-environmental-work/Work-areas/Climate/Climate-Act-and-Climate-policy-framework-/*
[4] *http://www.hybritdevelopment.com/*
[5] *https://www.pv-magazine.com/2019/01/04/off-grid-swedish-housing-block-to-be-supplied-100-by-pv-hydrogen/*
[6] *https://news.cision.com/myfc/r/two-new-swedish-patents-for-myfc-s-liquid-hydrogen-fuel,c2474474*
[7] *http://www.scandinavianhydrogen.org/nhc/*
[8] *http://www.fchea.org/in-transition/2019/5/6/scandinavia-fuel-cell-industry-developments*
[9] *http://www.scandinavianhydrogen.org/*
[10] *http://www.scandinavianhydrogen.org/bsr-hydrogen-network-%20conference/*
[11] *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.*
[12] *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).*
[13] *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*

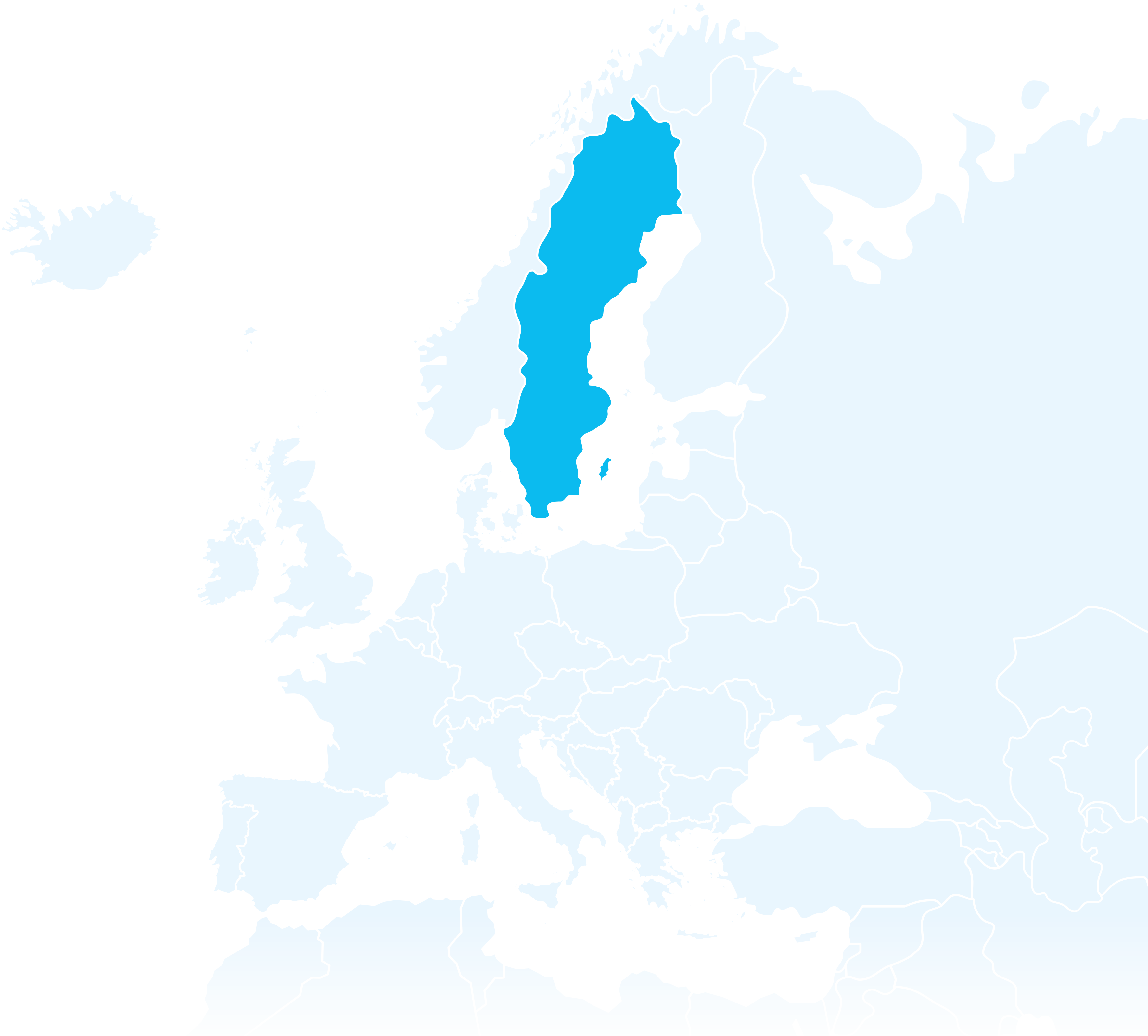
HYDROGEN IN THE NECP OF SWEDEN

The Swedish Energy Agency coordinates the deployment of infrastructure for alternative fuels including hydrogen and supports the County Administrative Boards in developing regional plans for alternative fuels infrastructure.

The Swedish Energy Agency and the Norwegian state-owned company Gassnova are providing financial support for a carbon capture and storage (CCS) demonstration project at the Preem refinery in Lysekil, investigating the possibility to install an industrial-size CCS plant next to the refinery's hydrogen unit. This CCS plant, which would reduce the CO_2 emissions by up to 500 000 tonnes a year, should be commissioned by 2025.

Within the framework of the HYBRIT project (HYdrogen BReakthrough Ironmaking Technology[14]), which is co-financed by the 'Industrial Evolution' (Industriklivet) programme and the industry, several research and pilot studies are being undertaken in Sweden. Those studies may result in breakthroughs for fossil-free production of steel from iron ore. In 2017, the decision was taken to support a four-year research project within the framework of the National energy research and innovation programme. These studies are carried out on industrial processes for hydrogen direct reduction, for the production of renewable electricity and for the production and storage of renewable hydrogen (the Swedish Energy Agency is providing about half of the research budget, the remaining coming from the private sector). During 2018, the feasibility study focused on identifying the conditions for a pilot plant, its basic design, location, and technology choices for further development. Later in 2018, the construction of two pilot plants started. In one of these pilot plants, studies will be conducted to develop a process in which hydrogen gas is used to produce Direct Reduced Iron (DRI) from iron ore pellets, to be melted in an electric arc furnace to produce steel.

The Swedish Gas Association believes that the role of renewable gas should be given greater prominence and notes the lack of information concerning the use of hydrogen within the energy system.



[14] http://www.hybritdevelopment.com/

OPPORTUNITY ASSESSMENT

Hydrogen production potential & its role in energy system flexibility

The estimated technical variable renewable electricity production potential in Sweden is almost ten times higher than the expected Swedish electricity demand in 2030, which, according to the assessment, creates a significant opportunity to use this abundant renewable electricity potential to produce hydrogen via electrolysis. According to the NECP, Sweden would by 2030 only use 3% of its technical potential in renewable electricity generation, so there is a great margin for building up additional dedicated renewable electricity sources for hydrogen production.
The existence of nuclear power generation capacity in Sweden may represent a specific opportunity for deploying hydrogen; as the variable cost of nuclear power plants is very low, they could be used at full load while converting 'excess' output into hydrogen. This approach would also enhance the load factor of power-to-hydrogen installations and improve their economic feasibility.

The opportunity to use power-to-hydrogen conversion as a flexibility provider to the electricity system is rather limited, as the installed variable renewable generation capacity is expected to be lower than the average load in 2030, which means that the flexibility needs can in principle be covered by other means, including flexible supply, demand response and cross-border trade.

	Technical variable renewable electricity potential (TWh/yr)	Technical renewable electricity generation potential compared to forecasted gross electricity consumption in 2030 (EUCO)	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
Sweden	1 419	939%	37.35	3%	88%	Low

Sweden has limited readiness for wide-scale deployment of CCS. Even though there are plans in place to use CCS technologies by 2030, there is only limited indication of progress towards using captured CO_2 in industrial processes and/or utilizing the potential storage capacities.

Energy infrastructure

Even though natural gas consumption (and related infrastructure) in Sweden is limited, the country can consider using its existing methane infrastructure for hydrogen transport and distribution, either by blending hydrogen with natural gas or by converting (part of) its network to dedicated hydrogen delivery from renewable electricity production areas to hydrogen use locations. As the distribution network is mostly made of polyethylene, it could be converted to hydrogen at a relatively low cost. However, the existing network only covers a small part of the country. Moreover, as the expected hydrogen production volumes will be low in the short and medium term, they can be injected into the gas grid without any adaptation to the transport, distribution or end-user infrastructure. Converting existing natural gas infrastructure to dedicated hydrogen networks would hence probably not be needed before 2030.

	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)
Sweden	N.A	0.4	0	NO
EU	MS range 16%-99%			

There are no salt cavern natural gas storage sites in Sweden that could be used for hydrogen, nor underground salt layers that could provide suitable storage opportunities for hydrogen.

Current and potential gas & hydrogen demand

According to the assessment, there are opportunities for the deployment of hydrogen in Sweden, predominantly related to the transport sector. Hydrogen can be one of the solutions to decarbonise the remaining fossil energy use in road transport, which can start on the short term. On the medium to long term, hydrogen and derived fuels can be deployed to decarbonise international shipping and the aviation sector. In the built environment, the use of fossil fuels is very minimal, but still hydrogen could be one of the solutions to decarbonise the energy use for heating fully. In industry, the opportunities for hydrogen relate to several niche applications such as the decarbonisation of hydrogen use in refineries and the replacement of conventional fossil-based steelmaking. Lastly, hydrogen can be deployed for the generation of high-temperature process heat.

Opportunities for hydrogen demand in industry

In Sweden, there is some potential for the deployment of hydrogen in industry, although on the short term the opportunities are relatively limited. Sweden does have some refinery capacity, where fossil-derived hydrogen is already being used, so there is an opportunity on the short to medium term to switch to the use of low-carbon or renewable hydrogen in these facilities. Sweden also has a steel production plant, which is still using a conventional fossil-based steelmaking process. The steel plant is already running the demonstration project HYBRITT, through which the company will gain experience in hydrogen-based steelmaking. In the future, these activities can be scaled up and eventually replace the entire conventional steelmaking process. In Sweden, the use of natural gas is very limited, which is also the case in industry. Still, together with biogas, hydrogen is one of the solutions that can be deployed to decarbonise the gas supply. Lastly, almost one fifth of the industrial energy use is used for the generation of high-temperature process heat. Hydrogen is one of the few low-emission energy carriers that is well-suited for this purpose.

	Presence of ammonia industry / share of ammonia production capacity in EU28 total	Presence of refineries / Share of Swedish refineries in total captive hydrogen production by refineries in the EU28	Share of Sweden 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)
Sweden	0%	1.4%	3%	3%	18%
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

In Sweden, the opportunities for the deployment of hydrogen for heating applications in the built environment seem rather limited. Although 66% of the energy use in households and services in Sweden is dedicated to heating, fossil fuels account for only 8% of the fuel mix for heating and natural gas for only 2%. Still hydrogen can be deployed as one of solutions to decarbonise this small remaining share of fossil fuel use.

	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)
Sweden	1%	66%	3%
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

In the transport sector, a significant potential for the deployment of hydrogen exists in Sweden. In comparison to other countries, the Swedish road transport sector has a high share of non-fossil energy carriers in the fuel mix of road transport, but still almost 80% of the energy use in road transport is fossil-based. Next to electrification, hydrogen is one of the solutions that can decarbonise the road transport sector, especially for heavy-duty transport and vans, hydrogen is a suitable technology as electrification is more challenging in these market segments. Still, hydrogen could also be one of the routes via which passenger car transport can be decarbonised, especially in a country like Sweden where long driving ranges are often required. Apart from road transport, hydrogen and derived fuels can be deployed to decarbonise the energy use for international shipping, which consumes an equivalent of almost 30% of Sweden's domestic energy use. Although international shipping is currently not yet covered by European or international climate legislation, EU countries with large shipping activities need to make a collective effort to support the decarbonisation of this sector. Hydrogen and derivatives thereof, are amongst the few solutions for (near) full decarbonisation of energy use in shipping on the long term. The same holds for the aviation sector, which uses an equivalent of 10% of the total energy use in Sweden's domestic transport.

	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 consump-tion) 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
Sweden	33% (24 795 GWh)	1% (23 GWh)	0.5% (457 GWh)	28.5% (27 702 GWh)	9% (10 861 GWh)	79% (73 157 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 assessment shows that Sweden has no comprehensive framework for the deployment and use of hydrogen. The NECP does not comprise concrete objectives or supporting measures specifically related to hydrogen.

In 2017, Sweden adopted a new climate policy framework[15], consisting of a climate act, climate targets and the setting up of a climate policy council. Sweden aims to reach net-zero greenhouse gas emissions by 2045 at the latest.

In Sweden, there are no technology-specific policies to promote hydrogen fuel cell vehicles and refuelling stations infrastructure. Given the ambitious climate targets, the deployment of low carbon solutions and technologies is expected to be driven by the market. Hydrogen, as well as all other low carbon options, is addressed and incentivized through various policy instruments (like car taxation, carbon pricing).

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

Sweden could also identify and address specific regulatory barriers to the deployment of hydrogen applications, taking into account the initiatives and policies at EU level.

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

Sweden has an overarching climate policy framework that encompasses hydrogen and fuel cells.

[15] http://www.swedishepa.se/Environmental-objectives-and-cooperation/Swedish-environmental-work/Work-areas/Climate/Climate-Act-and-Climate-policy-framework-/

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

Existing and additional policies and measures developed in Sweden’s NECP may be sufficient to achieve the non-Emission Trading Scheme (non-ETS) GHG emissions reduction target. Sweden has also set a national 2030 target which is more ambitious than its Effort Sharing Regulation (Regulation (EU) 2018/842) target. In this context, hydrogen applications are expected to emerge and be deployed next to other low carbon solutions in all the concerned sectors (building, transport, agriculture and industry).

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)

The Swedish action program within the EU 2014/94/EU Directive for alternative fuels aimed to have 13 operational hydrogen refuelling stations in 2020.

	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
Sweden	YES	5	1 211 206
EU		Total 156	Average 1 677 543

Existence of (investment on) hydrogen-related projects

The statistics indicate that 5 refuelling stations were in 2019 operational in Sweden, while the objective was to have by 2020 13 refuelling stations. There is also 1 industrial project in operation, 2 under construction, and various research activities running, meaning that Sweden is effectively acquiring experience in the production, delivery and use of renewable hydrogen.

The different measures and initiatives could contribute to allow progressively the shift to low carbon vehicles (including hydrogen).

	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)
Sweden	NO	1.7	NO	3

Positive environment ✓

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

The NECP recalls that Sweden has implemented carbon taxes in 1991. Sweden applies different annual vehicle tax rates based on the vehicle's carbon emissions (or bonus-malus), to provide buyers an incentive to select low carbon cars, light-duty trucks, light-duty buses and mobilhomes.

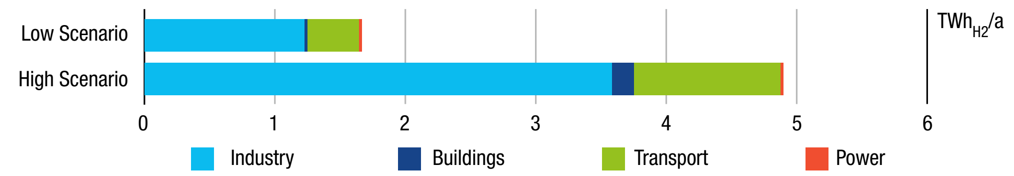
Fossil energy import bill

Like many EU Member States, Sweden is strongly dependent on imports for its natural gas as well as its oil consumption. Switching from imported fossil fuel to nationally produced hydrogen for industrial processes, heating and transport applications could contribute to reducing the import dependence and bill.

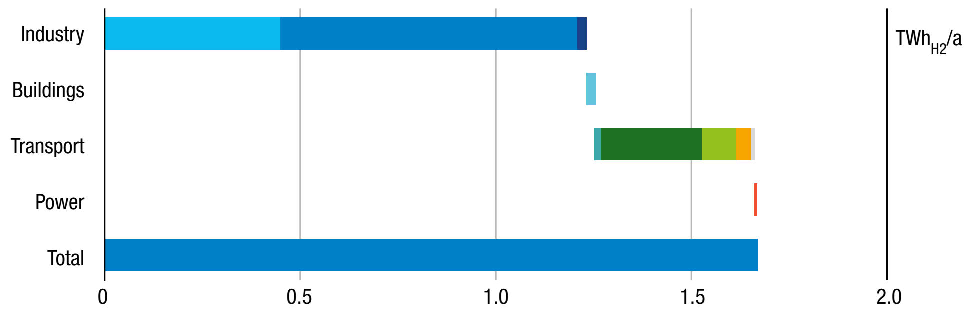
	Import bill for natural gas as share of national Gross Value Added	Import bill for all fossil fuels
Sweden	0.1%	1.1%
EU	Average: 0.6% MS range: 0% - 1.5%	Average: 2% MS range: 0% - 7%

SCENARIO ASSESSMENT
Estimated renewable/low carbon hydrogen demand for Sweden 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).

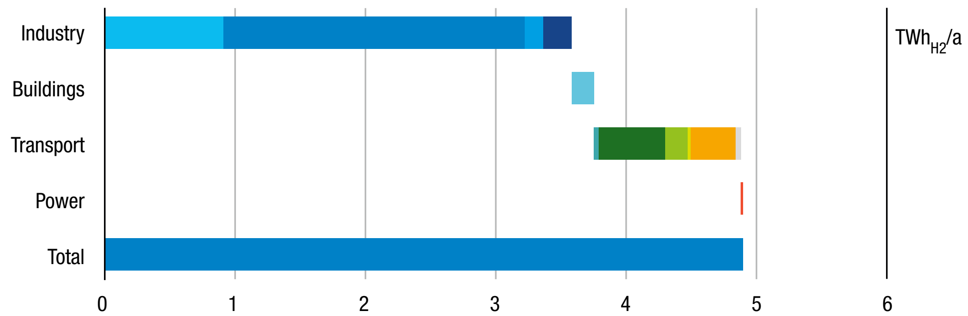


Low scenario

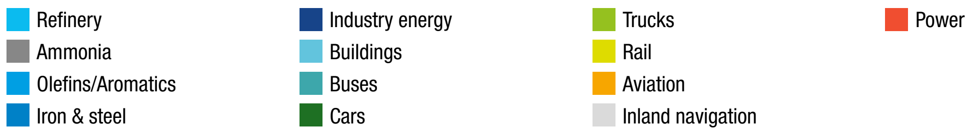


In the low scenario, renewable hydrogen accounts for 0.5% of final total energy demand (i.e. 1.7 out of 330 TWh/a) or 16.2% of final gas demand (10 TWh/a) according to EUCO3232.5.

High scenario



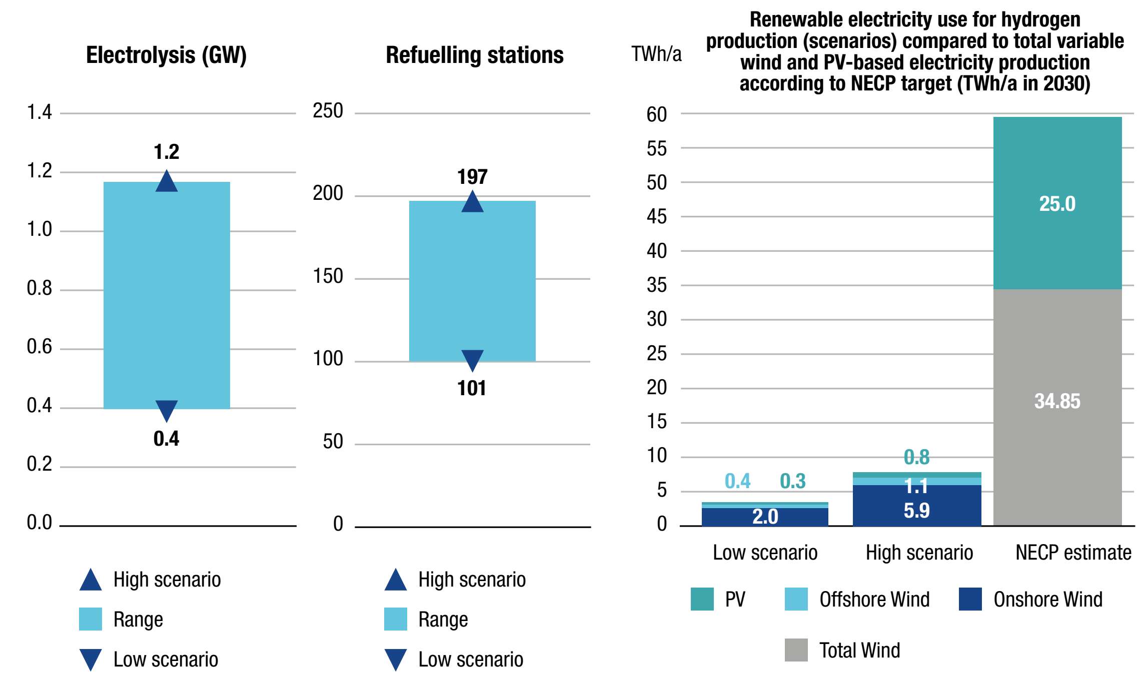
In the high scenario, renewable hydrogen accounts for 1.5% of final total energy demand (i.e. 4.9 out of 330 TWh/a) or 47.8% of final gas demand (10 TWh/a) according to EUCO3232.5.



Hydrogen generation, infrastructure and end users in Sweden 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 0.5% of the overall technical renewable power potential in the low scenario and for 1.4% in the high scenario.

End users

End user	Unit	Low scenario	High scenario
Passenger cars	Nº	51 900	103 700
Buses	Nº	170	340
Lorries	Nº	3 500	7 100
Heavy duty vehicles	Nº	50	100
Trains	Nº	1	2
Substituted fuel in aviation	GWh/a	25	238
Substituted fuel in navigation	GWh/a	2.7	25.4
Micro CHP	Nº	770	3 360
Large CHP	Nº	10	50
Iron&Steel	% of prod.	8%	25%
Methanol	% of prod.	0%	0%
Ammonia	% of prod.	0%	5%

According to the estimations, the hydrogen refuelling station network will by 2030 encompass between 100-200 stations for 56 000-111 000 fuel cell vehicles on the road.

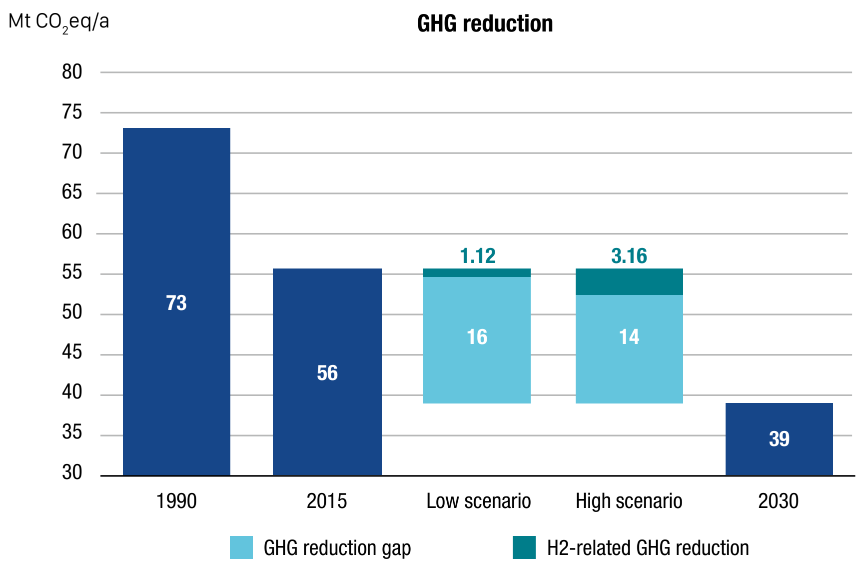
In addition, the analysis estimates substitutions of up to 25% of the conventional steel production by renewable hydrogen-based steelmaking.

Finally, the introduction of 780-3 410 stationary fuel cells for combined power and heat production is estimated.

Environmental and financial impact in Sweden by 2030

Greenhouse gas (GHG) emission reductions were 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.

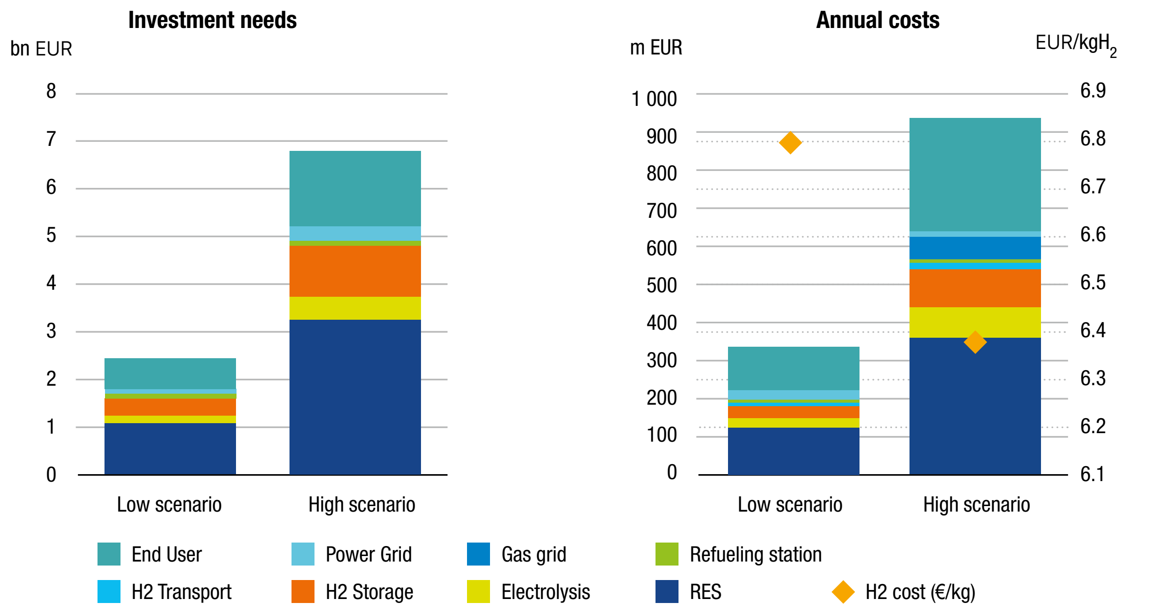
Environmental impact



An additional GHG emission reduction of 1.1-3.2 Mt CO_2 is estimated in 2030 corresponding to 6.7%-18.8% 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 2.5-6.8 billion EUR until 2030, while annual expenditure would amount to 340-940 million EUR (including end user appliances as well as power and gas grids).

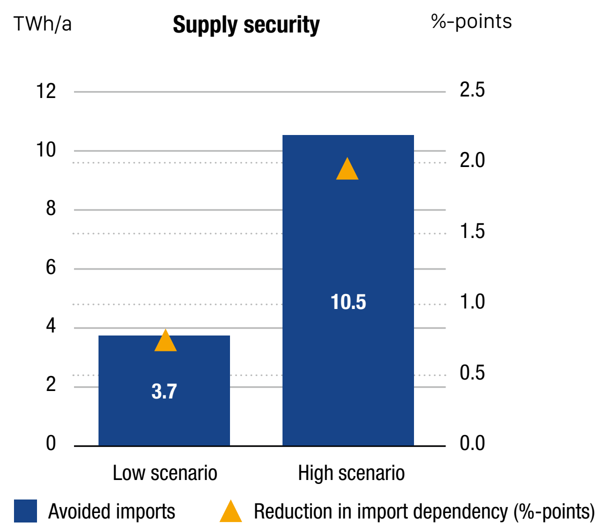


Impact on security of supply, jobs and economy in Sweden by 2030

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

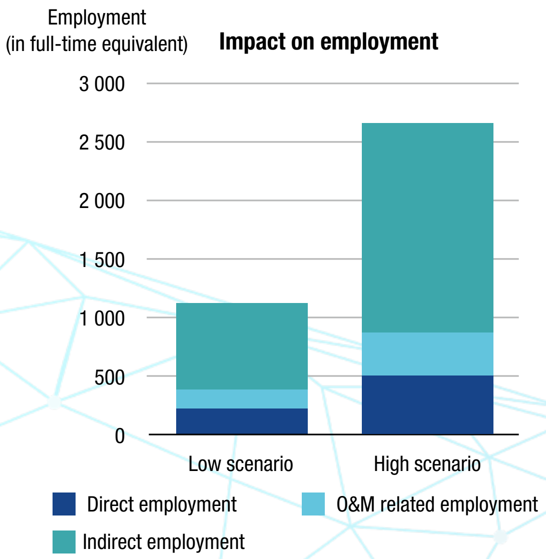
Deployment of renewable hydrogen would lead to 3.7-10.5 TWh/a of avoided imports, and thus reduce import dependency by 0.7-2.0% (in volume terms) in 2030, depending on the scenario.

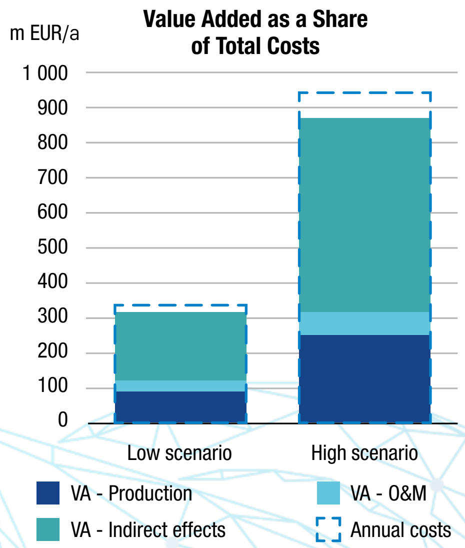


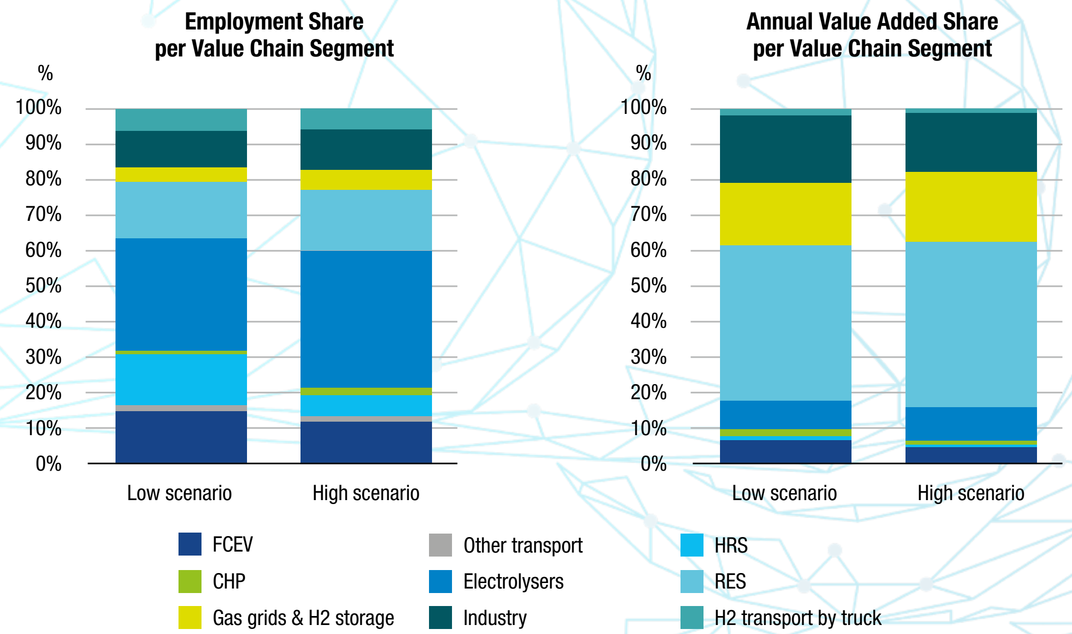
Impact on employment and value added

This analysis shows that in the years 2020-2030 around 120 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 310 million EUR (low scenario) and almost 880 million EUR (high scenario) of value added can be created in the Swedish 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 and operating hydrogen transport networks and storage facilities, and by investment in industrial application, in particular in the steel industry.

The hydrogen-related expenditures in 2020-2030 are estimated to generate employment of 360 - 900 direct jobs (in production and operations & maintenance) and contribute to a further 740 – 1 700 indirectly related jobs, depending on the scenario. Most of these jobs are expected to be created in by building and operating electrolysers and renewable electricity sources for hydrogen production, in industry and by investing in passenger fuel cell vehicles.







SWEDEN

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

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING