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

H2

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
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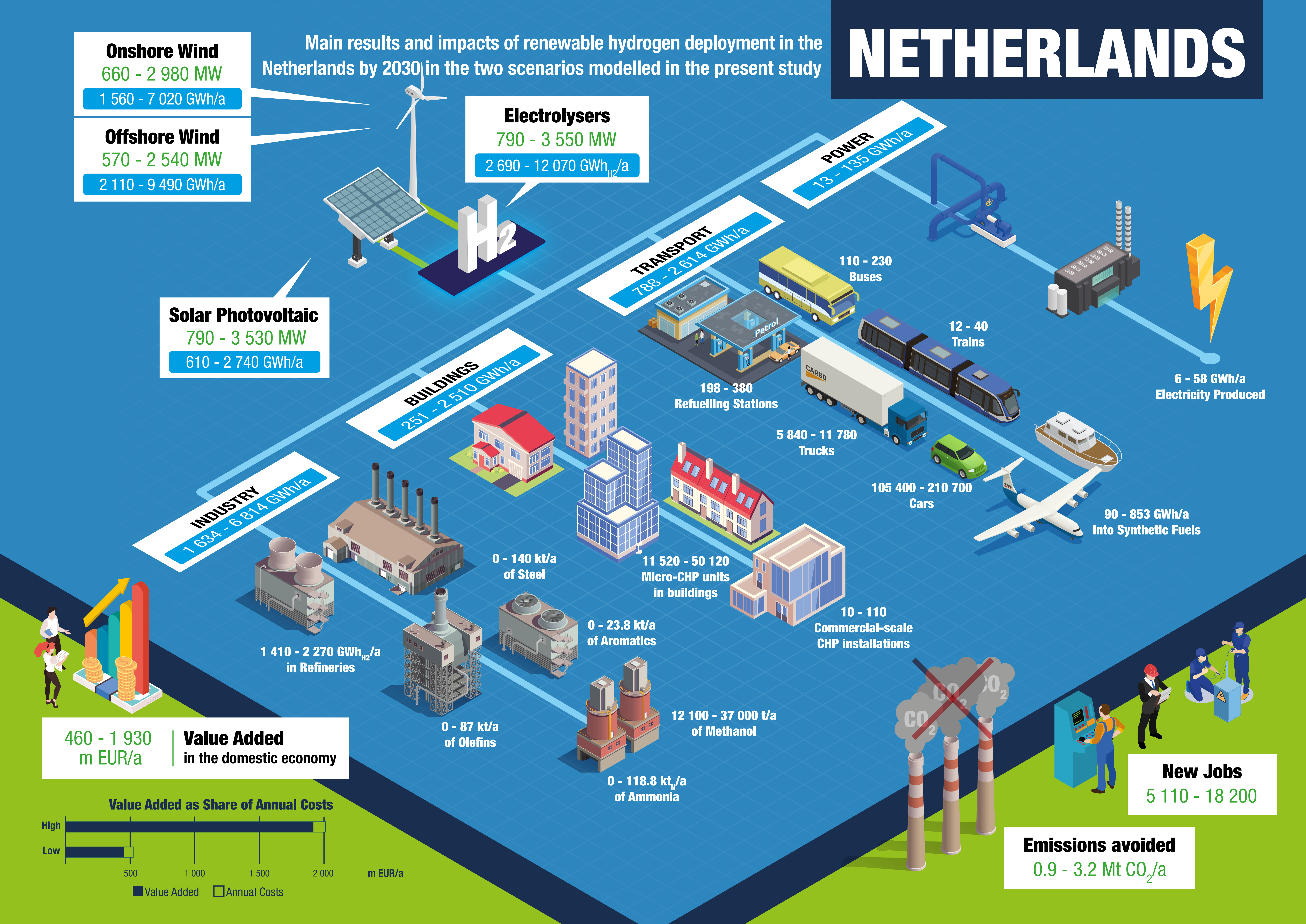
Introduction

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.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Main results and impacts of renewable hydrogen deployment in the Netherlands by 2030 in the two scenarios modelled in the present study
Onshore Wind
660 - 2 980 MW
1 560 - 7 020 GWh/a
Offshore Wind
570 - 2 540 MW
2 110 - 9 490 GWh/a
Electrolysers
790 - 3 550 MW
2 690 - 12 070 GWh$_{H2}$/a
Solar Photovoltaic
790 - 3 530 MW
610 - 2 740 GWh/a
H_2
POWER
13 - 135 GWh/a
6 - 58 GWh/a
Electricity Produced
TRANSPORT
788 - 2 614 GWh/a
110 - 230
Buses
12 - 40
Trains
198 - 380
Refuelling Stations
5 840 - 11 780
Trucks
105 400 - 210 700
Cars
90 - 853 GWh/a
into Synthetic Fuels
BUILDINGS
251 - 2 510 GWh/a
11 520 - 50 120
Micro-CHP units
in buildings
10 - 110
Commercial-scale
CHP installations
INDUSTRY
1 634 - 6 814 GWh/a
0 - 140 kt/a
of Steel
1 410 - 2 270 GWh$_{H2}$/a
in Refineries
0 - 23.8 kt/a
of Aromatics
0 - 87 kt/a
of Olefins
12 100 - 37 000 t/a
of Methanol
0 - 118.8 kt$_N$/a
of Ammonia
460 - 1 930
m EUR/a
Value Added
in the domestic economy
Value Added as Share of Annual Costs
High
Low
500
1 000
1 500
2 000
m EUR/a
Value Added
Annual Costs
New Jobs
5 110 - 18 200
Emissions avoided
0.9 - 3.2 Mt CO_2/a
CO_2

EXECUTIVE SUMMARY

The Netherlands's commitment for hydrogen deployment according to its NECP

The Netherlands has the ambition to become a European leader in the deployment of hydrogen, as *"hydrogen is considered to play an essential role in the transition, to achieve the 2050 climate goals"*[1]. In its NECP and National Strategy to achieve the 2030 GHG emission reduction targets, the Netherlands is committed to launch a hydrogen programme, which would support the ambition to have an installed electrolyser capacity of 3-4 GW in 2030.

Dutch industrial players have conducted a feasibility study for building hydrogen plants coupled to large offshore wind parks[2]. Low-carbon and green hydrogen will have a role to play in industry, buildings and the transport sector. The Netherlands foresees to address the entire value chain from generation, over storage, transport and distribution to end-use.

The Netherlands is in a favourable starting position given its extensive gas transport and distribution infrastructure as well as its current investments in hydrogen research and in pilot & demonstration projects and the possible use of the Rotterdam harbour for hydrogen trade. The Dutch gas TSO intends to convert and deploy its methane infrastructure for hydrogen transport, and some provinces are planning to deploy a hydrogen Valley[3]. The Netherlands is involved in the Green Flamingo[4] and Green Octopus[5] IPCEI projects, and was also involved in the HyLaw[6] project, which identified and assessed major regulatory barriers in view of prioritizing measures to address them. The Dutch participation in Mission Innovation, especially in the Innovation Challenge no 8 on renewable and clean hydrogen[7], will support the development of a global hydrogen market by identifying and overcoming key technology barriers.

The Dutch NECP does not provide hydrogen use targets per sector nor specific hydrogen-related measures, but the Government is committed to cooperate on policy instruments and practical measures with other European countries. Furthermore, the Dutch government has recently published a Hydrogen Vision[8], which describes the role that the cabinet sees for hydrogen in the future energy system of the Netherlands and the measures that will be taken to promote hydrogen development on the short term as well as potential measures to promote hydrogen development in the long term. The vision also emphasises the importance of bilateral and EU-wide cooperation on hydrogen development.

The scenario assessment shows substantial potential benefits of hydrogen deployment in the Netherlands 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 the Netherlands, 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[9]. A significant development of hydrogen demand is also assumed in the scenarios in **industry**, especially in methanol production 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 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, 2 to 9 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, the Netherlands estimates an installed capacity of 16.6 GW in wind and 26.1 GW in solar PV, generating over 91 TWh of renewable electricity in 2030. The technical potential for renewable electricity production in the Netherlands seems however significantly higher[10]. 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 520 and 2 000 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. According to the European EUCO3232.5 scenario[11], the Dutch GHG emissions should be reduced by 60 Mt CO_2 in 2030, compared to 2015. In the scenarios considered, the deployment of hydrogen could contribute 0.9 – 3.2 Mt CO2 to this goal, which is equivalent to 2% - 5% of the required emission reduction.

[1] *https://www.volkskrant.nl/columns-opinie/nederland-wordt-het-land-van-wind-water-en-waterstof~b0f3b37b/*
[2] *https://www.reuters.com/article/us-shell-gasunie-hydrogen/shell-and-gasunie-plan-to-build-massive-dutch-green-hydrogen-plant-idUSKCN20L1AV*
[3] *https://foresightdk.com/hydrogen-northern-netherlands-is-ready/*
[4] *https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5e208b85ba1b7664a1933b7d/1579191174296/Green%2BHH2%2BGreen%2BFlamingo%2Bposter_print.pdf*
[5] *https://www.hydrogen4climateaction.eu/s/Green-Octopus.png*
[6] *https://www.hylaw.eu/sites/default/files/2018-10/National%20Policy%20Paper%20-%20Denmark%20%28EN%29.pdf*
[7] *http://mission-innovation.net/our-work/innovation-challenges/renewable-and-clean-hydrogen/*
[8] *Kamerbrief DGKE / 20087869 Kabinetsvisie waterstof.*
[9] *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*
[10] *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).*
[11] *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 DUTCH NECP

The Dutch NECP refers to the National Strategy to achieve the long-term reduction targets set in the Climate Agreement. The strategy is a comprehensive policy document addressing five sectors, namely electricity, industry, mobility, agriculture and land use, and built environment, and several cross-sectoral topics, namely electrification, hydrogen, biomass, innovation, employment, financing, civil participation, spatial integration and regional energy strategy.

In its Climate Agreement, the Netherlands announces a hydrogen programme, which will focus on unlocking the supply potential of green hydrogen (3 to 4 GW of electrolysers by 2030), developing the necessary infrastructure (roll-out of a hydrogen infrastructure in the industrial clusters), cooperating with end-use sectors, and facilitating ongoing initiatives and projects. This programme will also promote synergies between infrastructure and use of low-carbon and renewable hydrogen.

This programme should ensure a step by step scaling up of renewable hydrogen production:

- By enabling a decrease of the cost of electrolysis. According to market operators, a reduction of 65% of the capex for electrolysers can be expected by 2030, from around EUR 100 million per 100 MW now to EUR 35 million per 100 MW when up-scaling to 3-4 GW of electrolysis capacity installed.

- By defining how the capacity, deployment and location of electrolysers can contribute to the integration of renewable electricity (coming mainly from offshore wind parks) into the energy system.

- By providing the necessary storage and transport infrastructure for hydrogen, mainly by adapting existing natural gas infrastructure, which will allow to create a basic national infrastructure for renewable hydrogen (transport and storage).

Up to 2030, this programme includes the following steps:

- 2019-2021: finalisation of the preparatory programme for the deployment of renewable hydrogen based on ongoing initiatives and projects and an assessment of the goals and next phases of implementation;

- 2022-2025: if the cost reduction for renewable hydrogen is considered sufficient and involved parties confirm their commitment, start scaling up to 500 MW of electrolysis capacity, combined with the development of hydrogen demand and regional infrastructure;

- 2026-2030: scaling-up to 3-4 GW of electrolyser capacity, connected to storage sites and dedicated transport infrastructure

The Netherlands intends to cooperate with other European countries on policy instruments and practical measures, including for the development of renewable hydrogen. In this context, the Pentalateral Energy Forum has organised a workshop to define possible cooperation topics on hydrogen. The five concerned countries will also examine possible common approaches for guarantees of origin, cross-border infrastructure, the respective role of TSOs and DSOs and standards for hydrogen injection. They also intend to exchange information and best practices on support schemes for hydrogen and innovation projects and the future role of hydrogen in general.

To realise the shift to a decarbonised mobility system, the availability of sustainable energy carriers, such as electricity, biofuels and renewable hydrogen is essential. As all necessary technologies are not yet readily available, road freight transport will use sustainable biofuels in a transitory period and would shift to electricity or renewable hydrogen thereafter. Hydrogen will play an important role in heavy transport, for example trucks, buses and potentially to replace the use of diesel for trains. The Dutch government has also announced its intention to develop Hydrogen Refuelling Stations infrastructure.

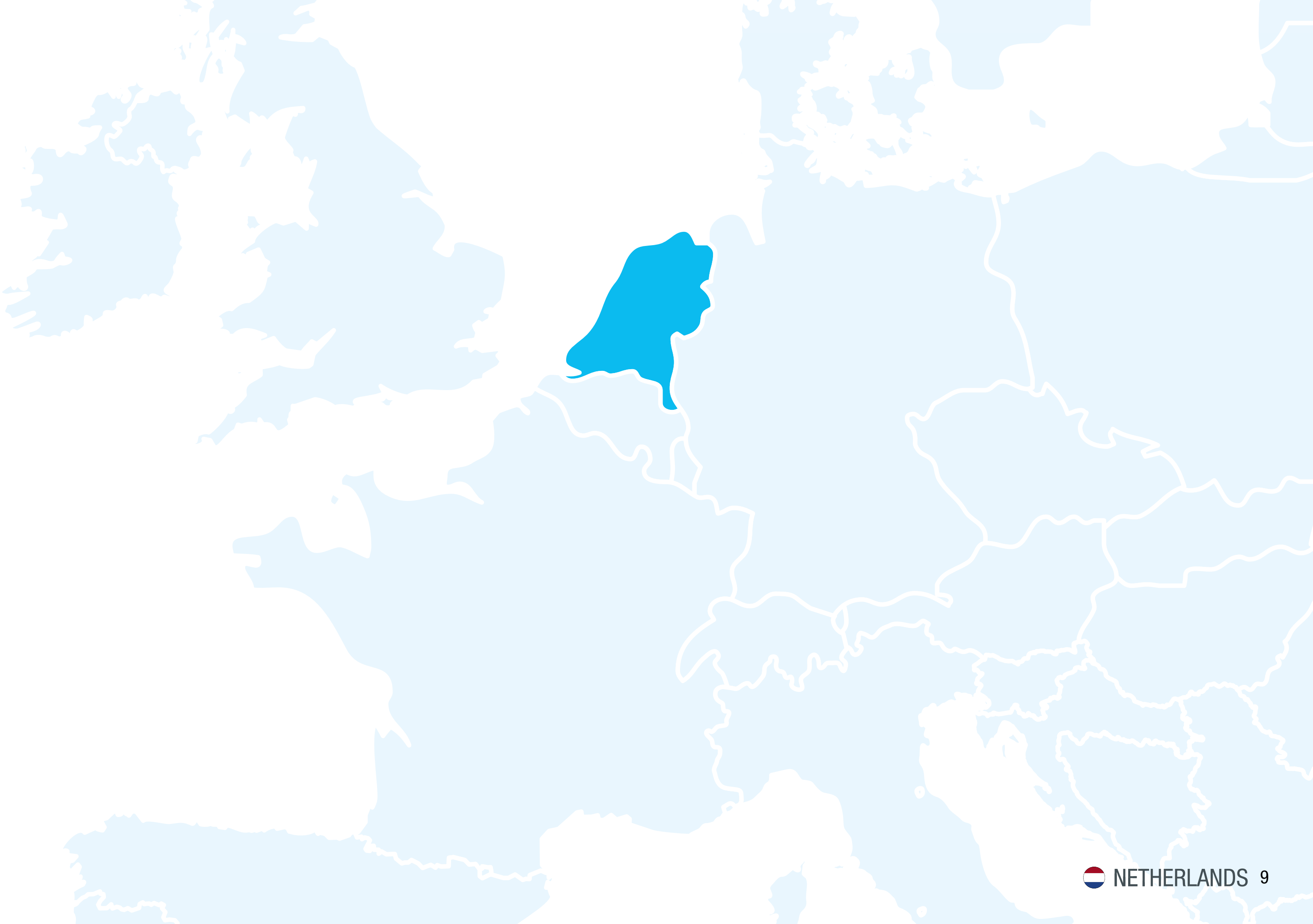
As the share of variable renewable electricity production is growing, ensuring system stability and security of supply will require more flexible options, including large-scale conversion of electricity to hydrogen, that can be stored at lower cost and for longer periods than electricity.

The Dutch government considers CCS as a necessary transition technology to reduce CO_2 emissions in sectors where no cost-effective alternative options are available in the short term. CCS can play a useful role in achieving negative emissions and can pave the way for the development of hydrogen and CCU.

The Netherlands participates in the Mission Innovation and its innovation challenge in the field of hydrogen, offering to research institutions and companies the opportunity to attract additional private resources for energy innovation. The Netherlands is also active in the IEA activities related to hydrogen and in the technology network and participates in several Hydrogen Technology Collaboration Programs (TCP).

Energy research related to hydrogen and fuel cells has been growing for several years, while research on fossil fuels is limited and focuses particularly on CCUS.

By 2050, raw materials, products and processes in industry should be net climate neutral and at least 80% circular. Hydrogen is considered among the solutions to contribute to this target.



OPPORTUNITY ASSESSMENT

Hydrogen production potential & its role in energy system flexibility

The estimated technical variable renewable electricity production potential in the Netherlands is more than twice as high as its expected electricity demand in 2030, which represents an opportunity to build additional dedicated renewable electricity plants coupled with electrolysers. As the variable renewable electricity capacity will be higher than the average load in 2030, using the potential 'surplus' in renewable electricity generation to produce hydrogen via electrolysis is another interesting option. This opportunity is further reinforced by the fact that the electricity interconnection capacity of the Netherlands is expected to remain rather limited, especially when compared to the forecasted installed variable renewable electricity generation capacity in 2030. According to the NECP, the Netherlands would use only 31% of its technical potential in variable renewable electricity generation by 2030, so there is a great margin for building up dedicated renewable electricity capacities for hydrogen production via electrolysis.

There is also an opportunity to use power-to-hydrogen conversion (and storage) as a flexibility provider, as the Dutch energy system is expected to have increasing flexibility needs, and does not have large scale pumped hydro storage on its territory.

The production of low-carbon hydrogen via steam reforming of natural gas combined with CCUS can be considered as an opportunity, as the Netherlands is one of the most advanced countries in the European Union in this domain.

	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
Netherlands	299	269%	91.44	31%	328%	High

The Netherlands has a high readiness for deployment of CCS, with a high geological potential for CO2 storage and well-advanced research programme for CCUS.

Energy infrastructure

The Netherlands could consider using its existing methane infrastructure for hydrogen transport and distribution, by blending hydrogen in the public grid in the short term (2025-2030) and by converting (part of) its network to hydrogen in the medium (2030-2040) and long term (>2040). A study published in 2018 (Kiwa and Netbeheer Nederland) concludes that the Dutch methane distribution infrastructure can be made fit for hydrogen transport at relatively low cost[12].

The TSO Gasunie has plans to set up a hydrogen backbone infrastructure by 2030, using existing methane pipelines for 100% hydrogen transport. The major technical changes lie in adapting the compressor stations and metering equipment, not the pipelines as such[13]. The TSO has already adapted 12 km of existing pipelines for hydrogen transport[14].

As transporting hydrogen is in general less expensive than transporting electricity (HV), 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 the Netherlands.

	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)
Netherlands	16%	0.9	0	YES
EU	MS range 16%-99%			

To date, there are no salt cavern gas storage sites in the Netherlands, that could be used for hydrogen storage. However, there is a Palaeozoic salt deposit which might be suitable for hydrogen storage. The availability of suitable formations to develop storage sites for seasonal or short-term hydrogen storage represents an opportunity for the Netherlands and offers it a competitive advantage compared to other Member States.

[12] https://www.netbeheernederland.nl/_upload/Files/Toekomstbestendige_gasdistributienetten_133.pdf
[13] https://www.gasunie.nl/nieuws/waterstof-coalitie-concrete-plannen-voor-een-vliegende-start-van-de-waterstofeconomie
[14] https://www.gasunie.nl/en/news/gasunie-hydrogen-pipeline-from-dow-to-yara-brought-into-operation

Current and potential gas & hydrogen demand

The Netherlands has considerable opportunities for the deployment of hydrogen across sectors. In industry and the built environment, renewable or low-carbon hydrogen can gradually replace the use of natural gas. In the Dutch ammonia and methanol industry and refineries, existing fossil-derived hydrogen can be replaced by low-carbon or renewable hydrogen and on the medium to long term, hydrogen-based processes could replace coal-based production processes in the Dutch steel factory in IJmuiden. Next to this, hydrogen is expected to become a competitive fuel for the generation of high-temperature process heat, on the medium to long term. In the transport sector, there is also significant potential for the deployment of hydrogen and derived fuels, especially in road transport, and on the medium and long term also for the decarbonisation of the vast energy demand related to the bunkering of international ships. Lastly, hydrogen is one of the solutions to decarbonise the remaining fossil-dependent part of rail transport.

Opportunities for hydrogen demand in industry

In the Netherlands, the opportunities for the deployment of hydrogen in industry are considerable. First of all, the Dutch industry has a substantial market share in Europe's ammonia production and refinery capacity. These industries already use fossil-based hydrogen, which could be replaced by renewable or low-carbon hydrogen. The Netherlands is also home to MCN, a large methanol production company, where the largest part of the methanol is produced from fossil resources. However, MCN has shown interest to produce methanol from renewable hydrogen and waste-CO_2 from other industrial processes. Next to this, natural gas accounts for almost two fifths of the industrial energy mix and the deployment of renewable or low-carbon hydrogen is a suitable option to replace the fossil gas supply. Furthermore, a large share (38%) of the industrial energy consumption in the Netherlands 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 the generation of high-temperature heat. Lastly, the Dutch steel sector, which is responsible for 7% of the primary steel production in the EU can be decarbonised through the switch from conventional fossil-based steelmaking processes to a process where direct reduction iron is produced using renewable or low-carbon hydrogen.

	Presence of ammonia industry / share of ammonia production capacity in EU28 total	Presence of refineries / Share of Dutch refineries in total captive hydrogen production by refineries in the EU28	Share of the Netherlands 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)
Netherlands	15%	9%	7%	38%	45%
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 the Dutch built environment, natural gas accounts for 60% of the final energy demand and over 70% of the demand for heating. Therefore, hydrogen could play a substantial role in the decarbonisation of heating in the Dutch built environment, even more now the Netherlands is strongly reducing its domestic natural gas production. Although electrification is a suitable technology to decarbonise heating in new neighbourhoods, low-carbon or renewable hydrogen can be a cost-effective strategy to decarbonise the older part of the Dutch building stock, with houses already being connected to the gas distribution grid.

	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)
Netherlands	60%	76%	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

When looking at the transport sector in the Netherlands, the potential for the deployment of hydrogen lies primarily in road transport, the rail sector and also in the shipping sector. Like in most EU countries, the Dutch road transport sector is still heavily dependent on fossil fuels. Hydrogen is a suitable solution to decarbonise this sector, especially in segments where electrification is difficult, as is the case for heavy-duty road transport. Diesel trains still account for 17% of the energy consumption in the Dutch rail sector, and hydrogen is one of the low-carbon solutions that can be deployed to decarbonise this part of the rail sector. In 2020, there will be pilots with hydrogen trains as well as battery-electric trains in the north of the Netherlands, which should enable the rail company to choose the technology that will be used to replace the diesel trains. Furthermore, the energy use for fuelling international ships in the Netherlands is 9% higher than that used for all domestic transport (road, rail, domestic air transport and inland shipping) combined. Although international shipping is 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 decarbonisation of 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
Netherlands	30% (35 006 GWh)	17% (312 GWh)	3% (3 541 GWh)	109% (135 518 GWh)	15% (50 219 GWh)	97% (114 661 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 Netherlands has a favourable enabling environment for hydrogen deployment given its supporting policies, its current investments in hydrogen research and in pilot and demonstration projects as well as in gas transport and distribution infrastructure. The Netherlands is currently involved in the Green Flamingo[15] and Green Octopus[16] IPCEI projects[17]. The Dutch gas TSO intends to convert and deploy its methane infrastructure for hydrogen transport, and some provinces are planning to deploy a hydrogen Valley[18].

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

The Netherlands aims to phase out its natural gas use, and renewable and low-carbon hydrogen are expected to play a major role in this transition.

The Energy Top Sector tender scheme (TSE) stimulates and subsidises innovations in energy, including hydrogen technologies. In this context, a specific Hydrogen Roadmap[19] was prepared in 2018, aiming at stimulating the roll-out of hydrogen for mobility, energy production, transport and storage, and as feedstock in the industry. There is a National Agenda for refuelling station infrastructure deployment. Innovation targets for CCS and CCU may pave the way for the development of low carbon hydrogen production using natural gas and CCUS.

In its Climate Agreement presented in June 2019, the Netherlands announced a hydrogen programme which will focus primarily on unlocking the supply potential of green hydrogen (3 to 4 GW of electrolysers by 2030). Recently, the cabinet published a Hydrogen Vision describing the roles that hydrogen could play in the Dutch energy system and industry[20]. It describes the measures in place to promote hydrogen development, including the stimulation of hydrogen through the SDE++ subsidy, which is expected to lead to low-carbon hydrogen (H2+CCS) projects and a green hydrogen exploitation study. The Vision also mentions measures that could be taken to further stimulate hydrogen roll-out, such as coupling of off-shore wind tenders with green hydrogen production and an admixture obligation for synthetic fuels in aviation fuel (preferably EU-wide from 2023) and admixture of hydrogen in the gas grid.

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

The Netherlands' 2030 target for greenhouse gas (GHG) emissions not covered by the EU Emissions Trading System (non-ETS) is -36% compared to 2005, as set in the Effort Sharing Regulation (ESR, 2018/842/EU). The NECP also recalls the national total GHG emission target of - 49% by 2030 compared to 1990. This high ambition in the national climate policy creates opportunities for the deployment and use of renewable or low-carbon hydrogen.

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 Dutch National Policy Framework (or NPF set in the context of the alternative fuel infrastructure directive (2014/94/EU)) includes a strong commitment towards hydrogen. The deployment of 20 publicly accessible hydrogen refuelling points is planned by 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
YES	4	2 093 311

Existence of (investment on) hydrogen-related projects

There are at present several hydrogen refuelling stations in the Netherlands (20 would be operational by end 2020[21]), a large power-to-gas project coupled with a solar plant (HyStock[22]), as well as several projects under development. In addition, 12 km of natural gas pipeline have been converted to 100% hydrogen (between Dow and Yara).

The Dutch provinces of Groningen and Drenthe have drawn up a plan to turn their region into a "hydrogen valley" in view of becoming a springboard for the hydrogen economy globally[23]. Several other projects have been launched in the transport, industry and building sectors (see opwegmetwaterstof.nl[24]).

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	1.2	YES	2

[15] https://static1.squarespace.com/static/5d3f0387728026000121b2a2/t/5e208b85ba1b7664a1933b7d/1579191174296/Green%2BHH2%2BGreen%2BFlamingo%2Bposter_print.pdf
[16] https://www.hydrogen4climateaction.eu/s/Green-Octopus.png
[17] https://www.hydrogen4climateaction.eu/projects
[18] https://foresightdk.com/hydrogen-northern-netherlands-is-ready/
[19] https://www.topsectorenergie.nl/sites/default/files/uploads/TKI%20Gas/publicaties/20180514%20Roadmap%20Hydrogen%20TKI%20Nieuw%20Gas%20May%202018.pdf
[20] Kamerbrief DGKE / 20087869 Kabinetsvisie waterstof.
[21] https://opwegmetwaterstof.nl/tanklocaties/
[22] https://www.energystock.com/about-energystock/the-hydrogen-project-hystock
[23] https://foresightdk.com/hydrogen-northern-netherlands-is-ready/
[24] https://opwegmetwaterstof.nl/

Existence of national tax incentives (CO_2 pricing mechanisms & car taxation)	Positive environment
The Netherlands plans to set up a CO_2 pricing mechanism and has introduced carbon related taxation for vehicles, which is key to progressively shift towards the use of low carbon vehicles (including on hydrogen).	Planned

Fossil energy import bill

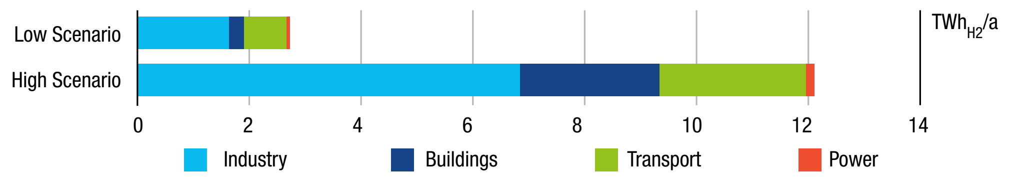
The Netherlands could consider the hydrogen deployment potential from a security of gas supply and energy import (trade balance) perspective, because its natural gas production is drastically decreasing and its oil consumption is heavily dependent on imports. Switching from imported fossil fuel to nationally produced hydrogen for industrial processes, heating and transport applications could contribute to reducing the energy import dependence and bill.

	Import bill for natural gas as share of national Gross Value Added	Import bill for all fossil fuels
Netherlands	0%	1.4%
EU	Average: 0.6% MS range: 0% - 1.5%	Average: 2% MS range: 0% - 7%

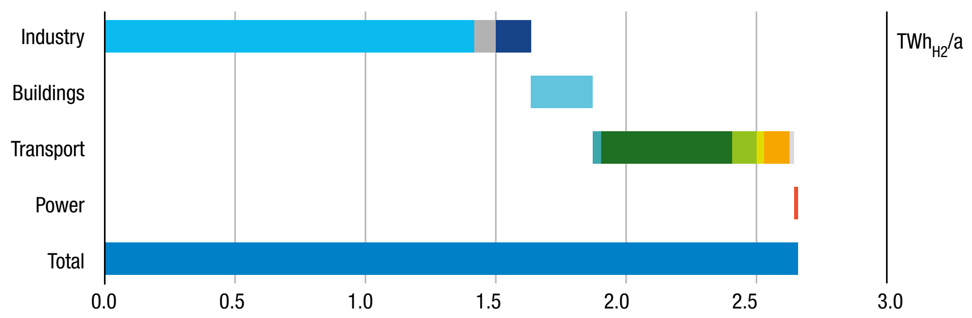
SCENARIO ASSESSMENT

Estimated renewable/low carbon hydrogen demand for the Netherlands 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).

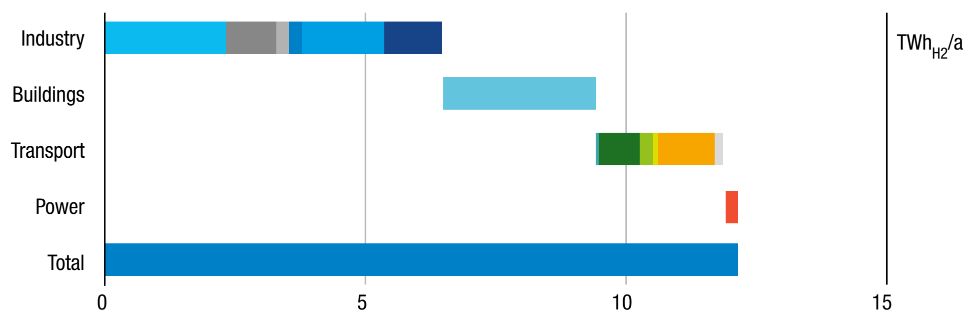


Low scenario



In the low scenario, renewable hydrogen accounts for 0.6% of final total energy demand (i.e. 2.7 out of 481 TWh/a) or 1.7% of final gas demand (157 TWh/a) according to EUCO3232.5.

High scenario

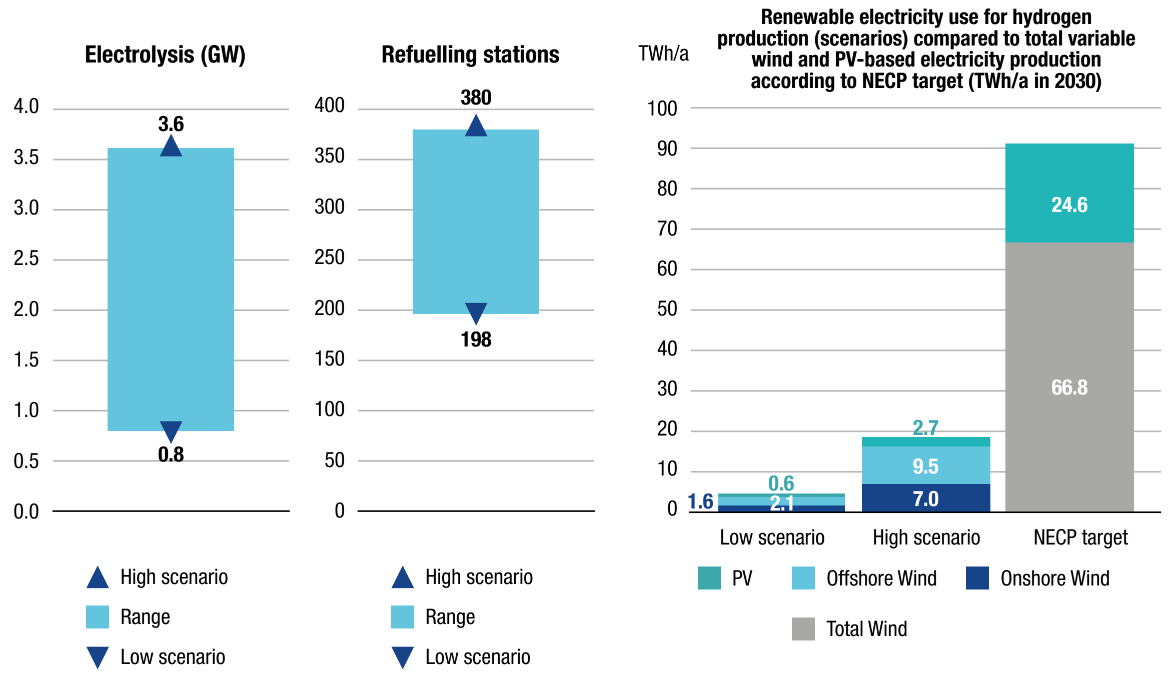


In the high scenario, renewable hydrogen accounts for 2.5% of final total energy demand (i.e. 12.1 out of 481 TWh/a) or 7.7% of final gas demand (15 TWh/a) according to EUCO3232.5.

Hydrogen generation, infrastructure and end users in the Netherlands 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 2.2% of the overall technical renewable power potential in the low scenario and for 9.7% in the high scenario. Alternatively hydrogen produced from SMR + CCS would require 3.9 -17.5 TWh/a of natural gas at a SMR+CCS capacity of 0.3 -1.5 GW for the low and high scenarios, respectively.

End users

End user	Unit	Low scenario	High scenario
Passenger cars	Nº	105 400	210 700
Buses	Nº	110	230
Lorries	Nº	5 400	10 900
Heavy duty vehicles	Nº	440	880
Trains	Nº	12	37
Substituted fuel in aviation	GWh/a	83	789
Substituted fuel in navigation	GWh/a	6.8	64.3
Micro CHP	Nº	11 520	50 120
Large CHP	Nº	10	110
Iron&Steel	% of prod.	0%	2%
Methanol	% of prod.	2%	7%
Ammonia	% of prod.	0%	5%

According to the estimations, the hydrogen refuelling station network will by 2030 encompass between 200-380 stations for 111 000-223 000 fuel cell vehicles on the road.

In addition, the analysis estimates substitution of up to 2% of the conventional steel production by renewable hydrogen-based steelmaking.

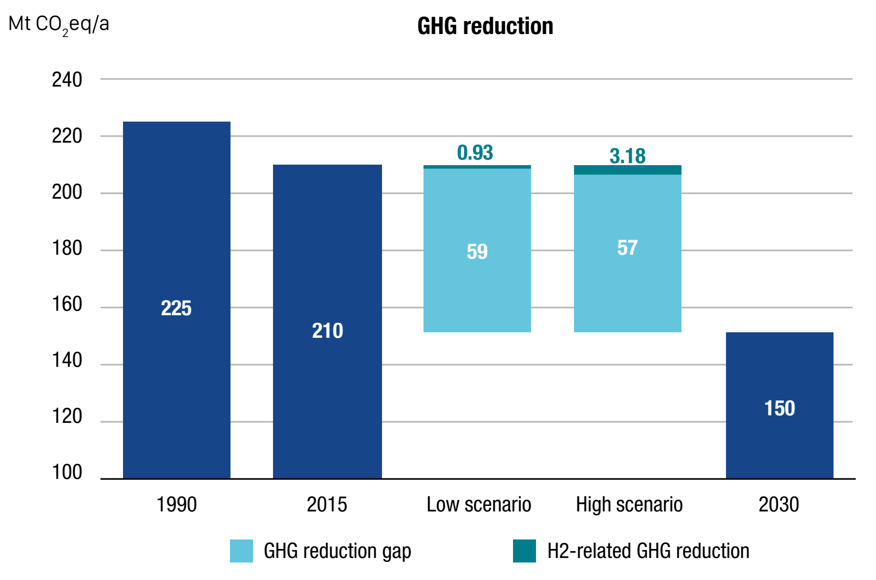
Futher use of renewable hydrogen is foreseen in methanol production (up to 7%) and in ammonia production (up to 5%).

Finally, the introduction of 11 530-50 230 stationary fuel cells for combined power and heat production is estimated.

Environmental and financial impact in the Netherlands 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.

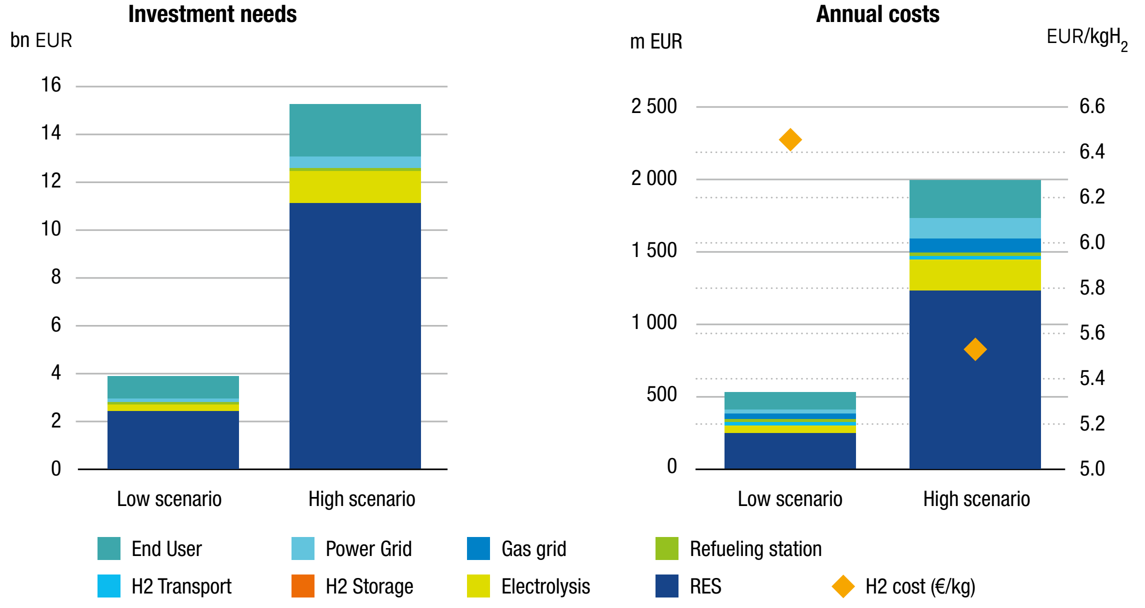
Environmental impact



An additional GHG emission reduction of 0.9-3.2 Mt CO_2 is estimated in 2030 corresponding to 1.6%-5.3% 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 3.9-15.2 billion EUR until 2030, while annual expenditure would amount to 520-2000 million EUR (including end user appliances as well as power and gas grids).

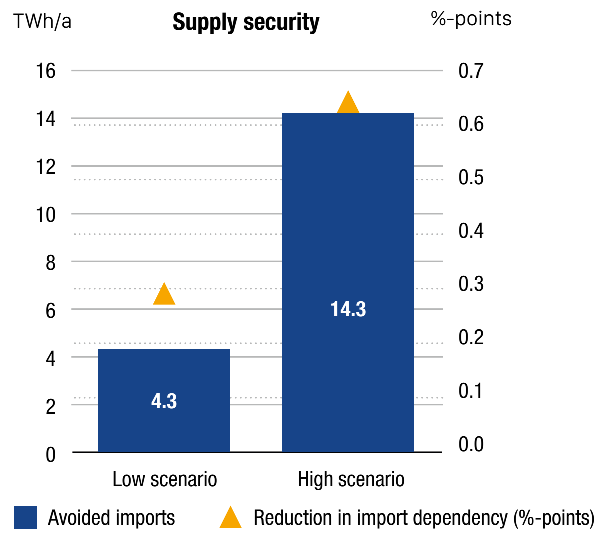


Impact on security of supply, jobs and economy in the Netherlands by 2030

Hydrogen contributes to the 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

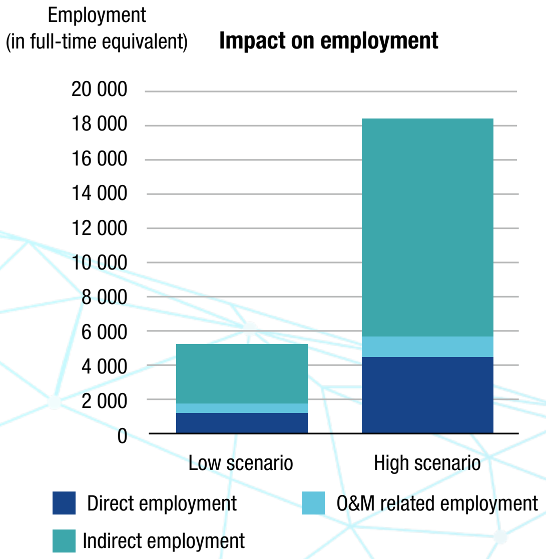
Deployment of renewable hydrogen would lead to 4.3-14.3 TWh/a of avoided imports, and thus reduce import dependency by 0.3-0.7% (in volume terms) in 2030, depending on the scenario.

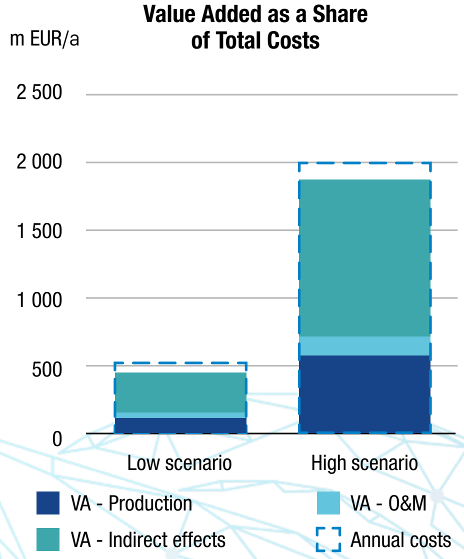


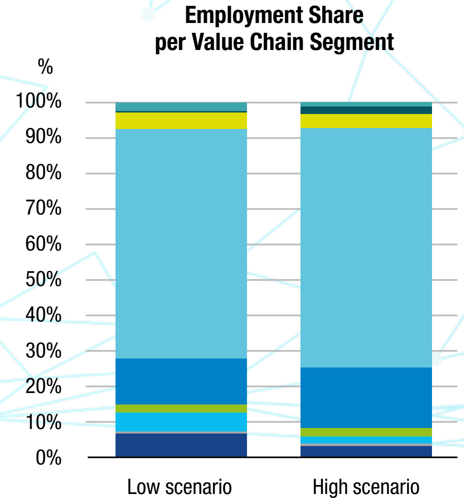
Impact on employment and value added

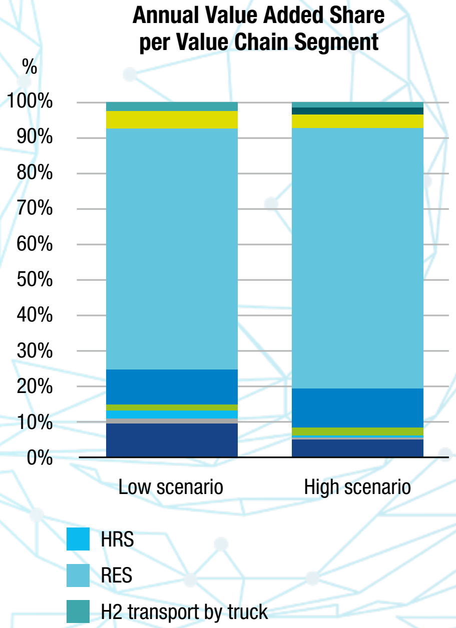
This analysis shows that in the years 2020-2030 almost 170 million EUR can be retained annually in the domestic economy as value added in the low scenario, and over 670 million EUR in the high scenario (value added is defined here as sum of wages for employees, margins for companies and taxes). If the indirect effects induced by the investment in and operation of hydrogen technologies are also taken into account, around 460 million EUR (low scenario) and over 1 900 million EUR (high scenario) of value added can be created in the Dutch economy annually, which is almost equivalent to the amount of annual investment needed. Two-thirds to three quarters of this value added is expected to be related to the production, installation and operation of dedicated renewable electricity generation capacity, followed by investments in and operation of electrolysers.

The hydrogen-related expenditures in 2020-2030 are estimated to generate employment of 1 700 – 5 800 direct jobs (in production and operations & maintenance) and contribute to a further 3 400 – 12 400 indirectly related jobs, depending on the scenario. The split of jobs per component of the hydrogen value chain is very comparable to the picture for the value added, with renewable energy generation and electrolysis representing the major share of the employment that is expected to be created.









NETHERLANDS

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

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING