PORTUGAL

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

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

2

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Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU)
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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.

PORTUGAL

Main results and impacts of hydrogen deployment in Portugal by 2030 in the two scenarios modelled in the present study

Onshore Wind
140 - 1 360 MW
380 - 3 670 GWh/a

Solar Photovoltaic
400 - 3 850 MW
740 - 7 120 GWh/a

Electrolysers
280 - 2 740 MW
770 - 7 450 GWh_{H2}/a

POWER
5 - 900 GWh/a

TRANSPORT
358 - 1 089 GWh/a

BUILDINGS
20 - 1 820 GWh/a

INDUSTRY
390 - 3 643 GWh/a

170 - 350
Buses

1 - 5
Trains

100 - 196
Refuelling Stations

420 - 830
Trucks

54 700 - 109 400
Cars

31 - 2 826 GWh/a
Electricity Produced

33 - 310 GWh/a
into Synthetic Fuels

916 - 34 690
Micro-CHP units
in buildings

3 - 300
Commercial-scale
CHP installations

360 - 610 GWh_{H2}/a
in Refineries

0 - 4.1 kt/a
of Aromatics

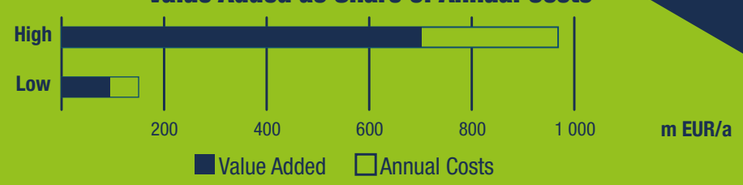
0 - 5.8 kt/a
of Olefins

0 - 5.8 kt_N/a
of Ammonia

92 - 740
m EUR/a

Value Added
in the domestic economy

Value Added as Share of Annual Costs



New Jobs
2 500 - 18 450

Emissions avoided
0.3 - 1.8 Mt CO_2/a

EXECUTIVE SUMMARY

Portugal's commitment for hydrogen deployment according to its NECP

Portugal has the ambition to become *"EU's principal green hydrogen producer"*. According to its NECP, Portugal is committed to *"create a real market for renewable gases[1]"*, to develop an industrial policy with the aim to *"position Portugal as an important European player in the green hydrogen market, leveraging solar energy as a factor for competitiveness"*. In its NECP renewable hydrogen is considered as a key technology to increase the production of renewable electricity and renewable gases in parallel, and to decarbonise sectors with limited low carbon solutions, like the transport and industrial sectors.

According to its NECP, Portugal expects by 2030 a final renewable hydrogen consumption of 65 ktoe (756 GWh) in the transport sector, representing about 7% of the renewable fuels for transport. New regulatory and market measures are announced to pave the way for renewable hydrogen in the industrial, gas and transport sectors addressing the entire value chain from generation, over storage, transport and distribution to end use.

Portugal is in a favourable position for hydrogen deployment given its abundant renewable electricity potential, its 1GW electrolyser's and solar farm flagship project in Sines[2], its involvement in the IPCEI project with the aim to "jumpstart the Portuguese Hydrogen Economy by implementing the necessary infrastructures and economic critical mass", highlighting the great EU interest in deploying renewable hydrogen in Portugal. Portugal was also involved in the **HyLaw**[3] project, that identified and assessed major regulatory barriers, in view of prioritizing measures to address them. The NECP does not provide hydrogen targets for the other sectors than transport.

The scenario assessment shows substantial potential benefits of hydrogen deployment in Portugal 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 Portugal, a strong development of hydrogen demand is assumed in **transport**, especially for passenger cars, buses and trucks. A moderate demand is also expected to develop in aviation (through hydrogen-based liquid fuels or PtL), rail and navigation[4]. A moderate development of hydrogen demand is also assumed in **industry**, especially refining, olefins and aromatics sectors. 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 and is considered as an important opportunity for Portugal.

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 strong demand in the High scenario.

The scenarios assume that Portugal would be one of the early adopters of using hydrogen for power generation (back-up), although the produced electricity volumes will be still low.

Hydrogen production

To cover the estimated hydrogen demand from new uses and from substitution of fossil-based hydrogen, 0.5 - 5.2 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, Portugal estimates an installed capacity in 2030 of 9.3 GW in wind and 9 GW in solar PV, generating almost 43 TWh of renewable electricity in 2030. The technical potential for renewable electricity production in Portugal seems however significantly higher[5]. 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 146 and 970 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[6], the Portuguese GHG emissions should be reduced by 27 Mt CO_2 in 2030, compared to 2015. In the scenarios considered, the deployment of hydrogen could contribute 0.3 - 1.8 Mt CO_2 to this goal, which is equivalent to 1.2% - 6.5% of the required emission reduction.

[1] *Renewable gases comprise biomethane and hydrogen*
[2] *https://www.endseurope.com/article/1670961/portugal-plans-eus-principal-green-hydrogen-producer*
[3] *https://www.hylaw.eu/*
[4] *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.*
[5] *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). The potentials were estimated in 2018 and may meanwhile be slightly different due to technological developments.*
[6] *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 PORTUGAL

According to its NECP, Portugal's strategic vision for 2030 foresees for hydrogen a prominent role as energy carrier. The natural gas infrastructure will be adapted to store, transport, distribute and deliver renewable gases[7], particularly hydrogen, to be consumed in various sectors, allowing to significantly increase the use of renewable energy sources in final energy consumption.

According to its NECP, the Portuguese government is promoting an industrial policy focusing on hydrogen and renewable gases. Policies and measures are planned to coordinate and mobilise public and private investments in renewable hydrogen production, storage, transport and end-use projects. This new focus on hydrogen in Portugal is based on the favourable conditions to deploy a renewable hydrogen market given the possibility to increase significantly the production of renewable electricity at low cost while bringing the required flexibility to the electricity system. Portugal also considers exporting renewable hydrogen.

The development of new applications and the improvement of existing low-carbon technologies require significant efforts in research and innovation. Therefore, Portugal foresees national support for R&D according to its priorities, among which hydrogen and energy storage.

For Portugal, renewable gases have the potential to play an important role in decarbonising sectors that currently have few low carbon alternatives and where electrification in the short and medium-term could remain expensive. Renewable gases can substitute fossil fuels in the industry (as combustion energy carrier or as raw material), in transport of passengers and goods (road, railway and river), and in the maritime and aviation transport. Given its versatility, Portugal also considers the deployment of renewable hydrogen with a territorial perspective, creating of hydrogen valleys or ecosystems (like the project in Sines).

According to its NECP, the Portuguese government is striving to create the necessary conditions and mechanisms to deploy hydrogen at large scale by: (i) regulating the injection of renewable gases into the natural gas network; (ii) implementing a guarantees of origin system for renewable gases; (iii) mobilizing financial resources available in national and European funds to support renewable hydrogen production; (iv) assessing the implementation of binding targets by 2030 to incorporate renewable gases into the natural gas network.

Portugal has the intention to set up a project for renewable hydrogen production at the port of Sines, coupling a 1GW electrolyser with a solar farm. Sines is located on the Atlantic coast, near to natural gas transport and storage infrastructure and an industrial zone with current and potential hydrogen consumers. The project will be developed with European public and private partners.

According to its NECP, Portugal was not able to increase significantly its share of renewable energy sources, as required by the Directive (EU) 2018/2001. Now, the potential conversion of 'excessive' electricity supply into renewable hydrogen changes this paradigm and provides a new opportunity to substantially increase the production of renewable electricity while contributing to decarbonize the gas sector.

According to its NECP, Portugal expects by 2030 a final renewable hydrogen consumption of 65 ktoe (756 GWh) in the transport sector, representing about 7% of the renewable fuels for transport (renewable energy is expected to cover 20% of the final energy consumption in transport by 2030). To this end, Portugal plans to encourage the progressive replacement of bus fleets by 'clean buses', particularly on electricity and hydrogen; to study the conversion of diesel railway equipment to green hydrogen (avoiding the costs of electrifying lines); to promote the use of renewable hydrogen by vessels; to promote the installation of Hydrogen Refuelling Stations (HRS) supplied with renewable hydrogen. The HRS infrastructure will be gradually deployed to ensure a significant territorial coverage, starting with pilots, public transport and logistic fleets.

According to the NECP, energy storage is considered fundamental for security of energy supply and energy system management. Storage capacity in Portugal is expected to increase by 2030, and hydrogen is also considered in this context. Portugal is highly dependent on hydro-pumped storage and intends to develop alternative storage technologies, including of hydrogen. Portugal also plans to promote energy storage on Islands, to reduce the use of fossil fuels, by increasing the production of renewable electricity and gases.

According to its NECP, Portugal plans to assess the conversion of 2 coal-fired power plants to renewable energy sources. The use of renewable hydrogen to substitute coal could avoid the closure of the plants, while reusing existing equipment.

Portugal plans to eliminate the barriers to hydrogen deployment, starting by defining the technical specifications for the injection of hydrogen into the natural gas system.

Given the fact that, in the European panorama, Portugal has one of the most ambitious objectives for the penetration of RES by 2030, the potential for RES adoption, and for hydrogen in particular, is perceived as significant throughout the Economy.

Portugal will encourage RD&I in renewable energies, storage and hydrogen, through national R&D programmes and involvement in the European agendas, as part of the European Strategic Energy Technology Plan (SET Plan). Inter-institutional cooperation is also promoted and research networks are being established in the field of hydrogen.

According to its NECP, Portugal will also promote training for professionals in the field of hydrogen, starting by identifying the training needs based on the expected development of the sector.

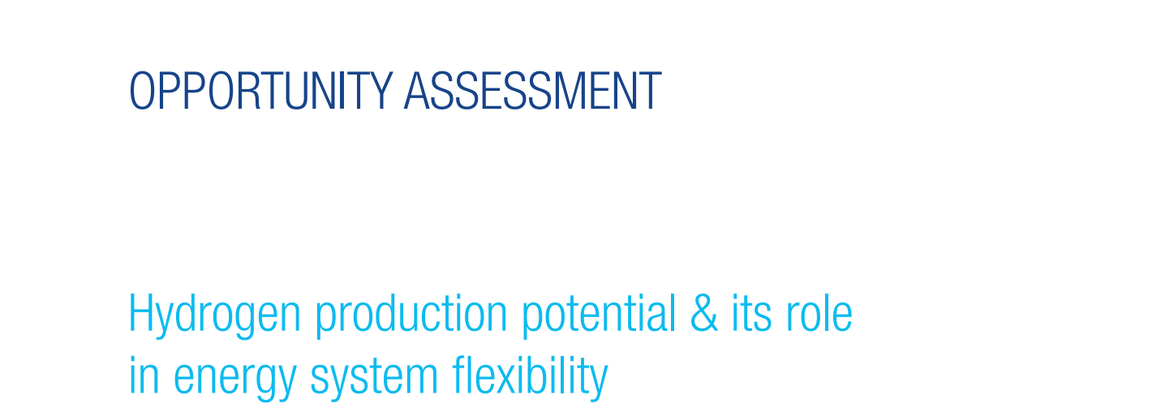
[7] *Renewable gases comprise hydrogen and biomethane*

OPPORTUNITY ASSESSMENT

Hydrogen production potential & its role in energy system flexibility

The technical variable renewable electricity production potential in Portugal is substantially higher than the expected installed renewable electricity generation capacity in 2030, which, according to the assessment, creates a significant opportunity to use this renewable electricity potential to produce hydrogen via electrolysis. According to the NECP, Portugal would by 2030 only use 8% 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.

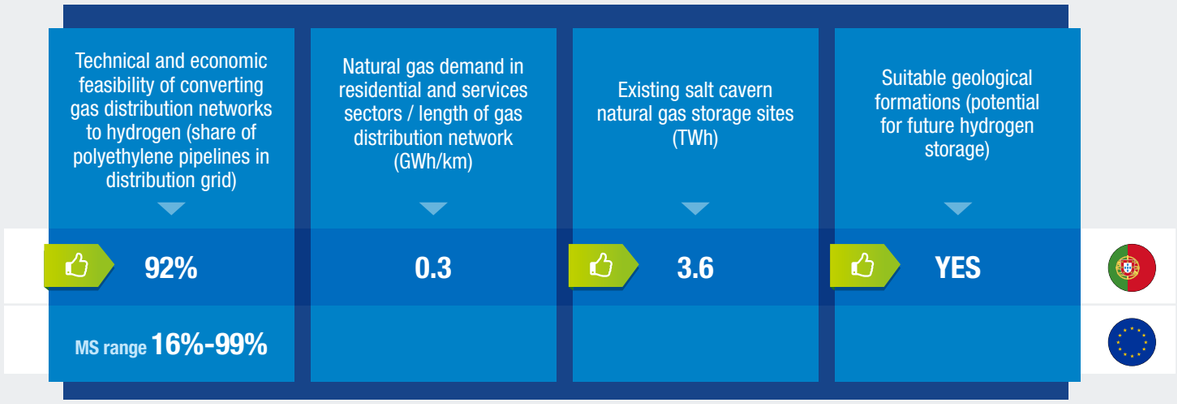
This opportunity is further reinforced by the fact that the Portuguese energy system is forecasted to have in 2030 a higher installed capacity of variable renewable electricity generation than the average load and that the electricity interconnection level of Portugal is expected to remain rather limited, especially when compared to the installed variable renewable generation capacity and taking into account its geographical position on the periphery of the European energy system. This opportunity to use power-to-hydrogen conversion as flexibility provider to the electricity system, is however to a certain extent limited by the availability of a significant capacity of pumped-storage hydroelectricity in Portugal.



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

Energy infrastructure

Portugal can consider using its existing methane infrastructure for hydrogen transport and distribution, by blending hydrogen in the public grid in the short (2025-2030) and medium term (2030-2040) and potentially converting (part of) its network to 100% hydrogen in the long term (>2040). As the share of polyethylene in the distribution network is relatively high, it could be converted to hydrogen at relatively low cost. However, conversion of the distribution networks to dedicated hydrogen pipelines would be a longer-term consideration, as the hydrogen production volumes are expected to be relatively low until 2030. In the short and medium term, hydrogen could hence be blended with methane in the existing grid, without the need for physical adjustments to the transport and end-use infrastructure.



There is some existing salt cavern natural gas storage capacity in Portugal, and large underground salt layers that could provide additional gas storage opportunities across the country. Such natural gas storage sites could on the medium/long term be used for hydrogen storage, in addition to LNG infrastructure.

Current and potential gas & hydrogen demand

In Portugal, opportunities for the deployment of hydrogen seem to be present across the different end-use sectors, with the largest potentials residing in industry and transport. In industry, hydrogen can contribute to the decarbonisation of the gas supply and to replace fossil-derived hydrogen in refineries. In the transport sector, the potential for hydrogen deployment in the short to medium term lies in the road and rail sectors. On the medium to long term, hydrogen and derived fuels can also be deployed to decarbonise the energy use in (international) shipping and aviation. In the built environment, the opportunities for hydrogen deployment seem to be more limited, although it can contribute to the decarbonisation of the existing use of natural gas and oil for heating purposes. Furthermore, hydrogen is one of the low-carbon energy carriers that can be deployed to fulfil the growing demand for space cooling.

Opportunities for hydrogen demand in industry

The assessment shows that Portugal has a significant potential for hydrogen use in industry. First of all, natural gas accounts for more than a quarter of the industrial energy demand and this natural gas can be replaced relatively easily with renewable hydrogen. Apart from this, the country has some refineries with existing use of fossil-derived hydrogen. Although the production capacities of the Portuguese refineries are relatively low, there is an opportunity for this industry to deploy renewable or low carbon hydrogen to replace the fossil-derived hydrogen. Furthermore, 32% of the energy demand in industry is used to generate heat for high-temperature processes. Hydrogen is one of the few low-emission energy carriers that is well-suited for the generation of high-temperature heat.

Presence of ammonia industry / share of ammonia production capacity in EU28 total	Presence of refineries / Share of Portuguese refineries in total captive hydrogen production by refineries in the EU28	Share of Portugal 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)
0%	4%	0%	27%	32%
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 share of gas in the energy mix of households and services in Portugal is rather limited (11%). However, when it comes to the demand for heating, which accounts for roughly 40% of the energy demand in the built environment, natural gas represents over 30% of the energy mix. Renewable or low-carbon hydrogen can be deployed to decarbonise this part of the heating demand. Next to natural gas, around 15% of the heating demand is satisfied through the use of oil-fired boilers. On the medium to long term, hydrogen can be used as one of the solutions to replace this form of heating. Portugal also has a significant demand for cooling, which accounted for 6% of the total final energy demand in households and services in 2015, but is expected to increase. On the medium to long term hydrogen-based technologies could be used to satisfy the growing demand for cooling.

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)
11%	41%	6%
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 Portuguese transport sector, the largest opportunities for the deployment of hydrogen on the short to medium term reside in road and rail transport, but in the medium to long term hydrogen and derived fuels could also play a role in aviation and (international) shipping. Like in all EU countries, the Portuguese road transport sector is heavily reliant on fossil fuels. Together with electrification, hydrogen can contribute to the decarbonisation of the energy use in this sector, especially in heavy-duty transport. Hydrogen can also play a role in the decarbonisation of passenger car transport, especially in the larger car segment and for users who need cars with large driving ranges. In Portugal's rail sector, one fifth of the energy consumption is still dependent on fossil fuels. Next to further electrification, deployment of hydrogen trains is one of the solutions to reduce GHG emissions from the Portuguese rail sector. The aviation sector and international shipping are also responsible for a significant share of the energy use in the transport sector in Portugal. Although these sectors are currently not yet covered by European or international climate legislation, EU countries will need to make a collective effort to support the decarbonisation of these sectors.

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
18% (11 304 GWh)	20% (118 GWh)	1.4% (961 GWh)	13.4% (9 039 GWh)	18% (15 853 GWh)	96% (60 951 GWh)
Average 32% MS range 18%-48%	Average 30% MS range 0%-95%	Average 2% MS range 0%-9.8%	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

Portugal has the ambition to become "EU's principal green hydrogen producer", and has effectively a positive enabling environment for hydrogen deployment in the coming decade and beyond, despite the existence of some regulatory and non-regulatory barriers. The government's commitment is clearly shown in its NECP, its Roadmap for Hydrogen in Portugal[8] and its industrial policy, comprising important measures to pave the way for a wide renewable hydrogen deployment in the transport, gas, power and industrial sectors. Portugal is investing in the deployment of infrastructure, is planning to invest in large production assets (e.g. in the Sines port) and is funding fundamental research and demonstration projects.

Taking into account its large potential for hydrogen production based on renewable electricity, Portugal could further consider hydrogen within its energy policy to address the decarbonisation challenges across all energy end-use sectors, preferably in coordination with Spain and other EU partners (e.g. potential consumers), and taking into account the initiatives and policies at EU level. The national association for hydrogen (AP2H2[9]) could provide support in the implementation of the roadmap.

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

The Portuguese Direction General of Energy and Geology (DGEG) prepared a Roadmap for Hydrogen[10] that was submitted to the Secretary of State of Energy in December 2018. An Action Plan is being finalized, based on the energy and environmental performance of hydrogen in the Portuguese energy system, and focusing on the following strategic priorities for 2030: Power-to-Gas, Power-to-Mobility & Power-to-Power. The plan emphasizes the need to implement pilot and demonstration projects.

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

Portugal is expected to meet the non-ETS GHG reduction target (-17%) and probably to overachieve it with the planned policies and measures.

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 Decree-Law 60/2017 which establishes the framework for the implementation of an alternative fuel infrastructure (QAN), explicitly refers to hydrogen.

Inclusion of hydrogen in national plans for the deployment of alternative fuels infrastructure (2014/94/EU)	Existence of hydrogen refuelling stations (2019)
YES	0
	Total 156

Existence of (investment on) hydrogen-related projects

There are currently no hydrogen-related industrial projects in Portugal[11]

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)
NO	0.6	NO	0

[8] *https://www.sciencedirect.com/science/article/abs/pii/S0360319919339436*
[9] *http://www.ap2h2.pt/*
[10] *https://www.portugalenergia.pt/events/roteiro-para-o-hidrogenio-em-portugal/*
[11] *This assessment is based on the NECP2030.*

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

Portugal has set up a CO_2 pricing mechanism in 2015 and has introduced carbon related taxation for vehicles, which are key incentives to shift progressively to the use of low carbon vehicles (including on hydrogen).

Positive environment

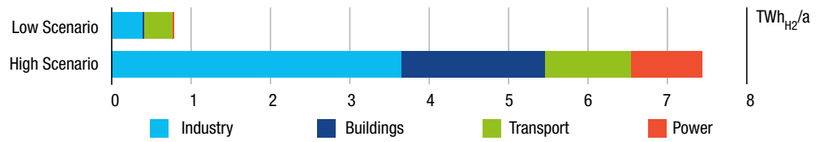
Fossil energy import bill

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

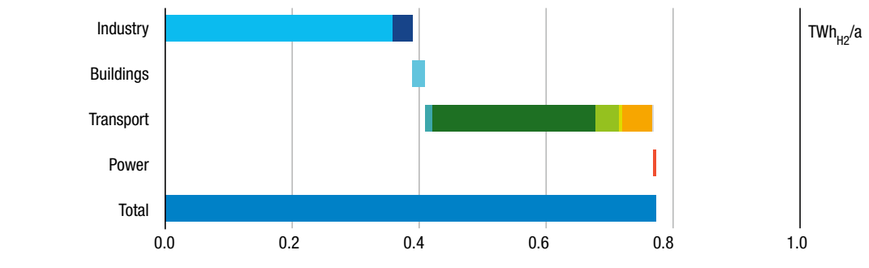
Import bill for natural gas as share of national Gross Value Added	Import bill for all fossil fuels
0.7%	**2.5%**
Average: **0.6%** MS range: 0% - 1.5%	Average: **2%** MS range: 0% - 7%

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

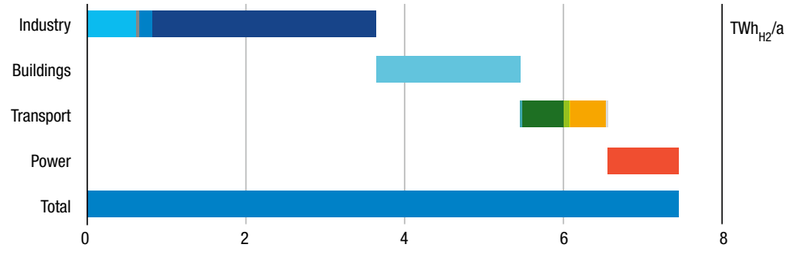


Low scenario



In the low scenario, renewable hydrogen accounts for 0.5% of final total energy demand (i.e. 0.8 out of 168 TWh/a) or 5.0% of final gas demand (15 TWh/a) according to EUCO3232.5.

High scenario

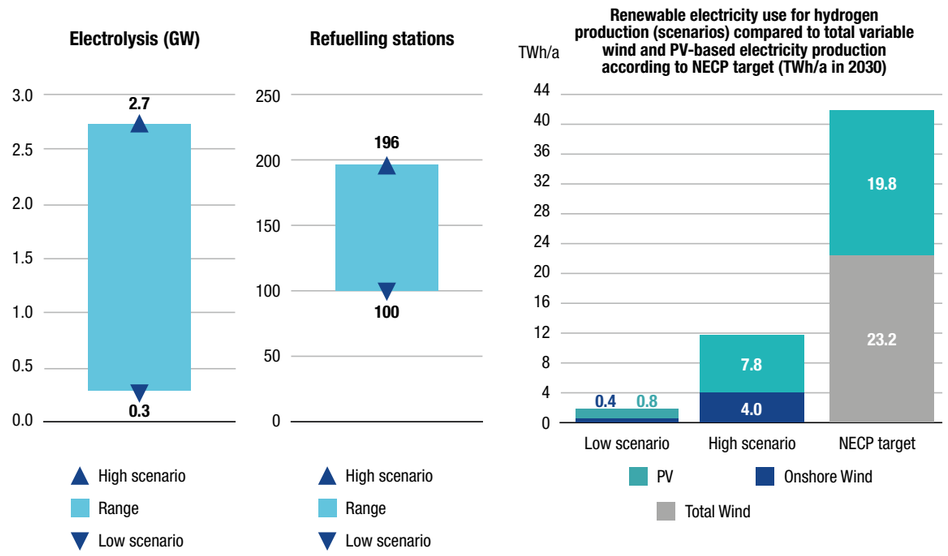


In the high scenario, renewable hydrogen accounts for 4.4% of final total energy demand (i.e. 7.4 out of 168 TWh/a) or 48.5% of final gas demand (15 TWh/a) according to EUCO3232.5.

Hydrogen generation, infrastructure and end users in Portugal 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 1.2% of the overall technical renewable power potential in the low scenario and for 11.4% in the high scenario.

End users

End user	Unit	Low scenario	High scenario
Passenger cars	Nº	54 700	109 400
Buses	Nº	170	350
Lorries	Nº	200	400
Heavy duty vehicles	Nº	220	430
Trains	Nº	1	5
Substituted fuel in aviation	GWh/a	32	301
Substituted fuel in navigation	GWh/a	1.0	9.5
Micro CHP	Nº	920	34 690
Large CHP	Nº	0	300
Iron&Steel	% of prod.	0%	0%
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 55 000- 111 000 fuel cell vehicles on the road.

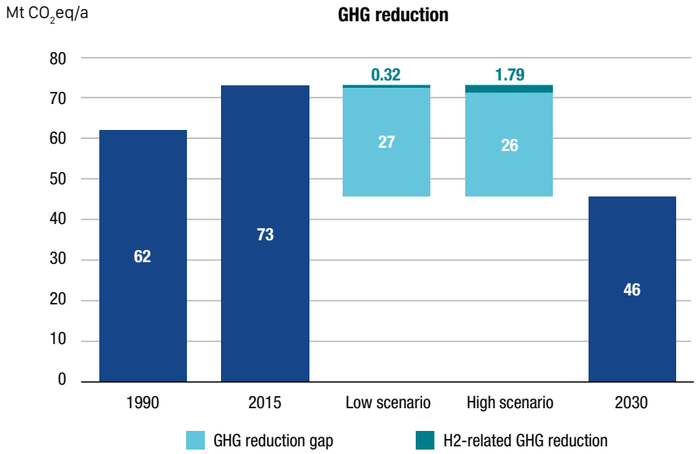
Futher use of renewable hydrogen is foreseen in ammonia production (up to 5%).

Finally, the introduction of 920 - 34 990 stationary fuel cells for combined power and heat production is estimated.

Environmental and financial impact in Portugal 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.

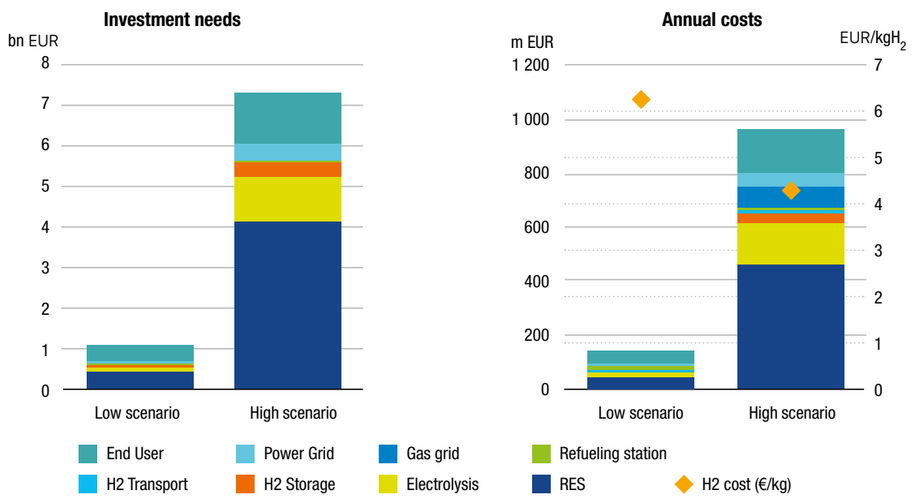
Environmental impact



An additional GHG emission reduction of 0.3-1.8 Mt CO_2 is estimated in 2030 corresponding to 1.2%-6.5% 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 1.1-7.3 billion EUR until 2030, while annual expenditure would amount to 150-970 million EUR (including end user appliances as well as power and gas grids).

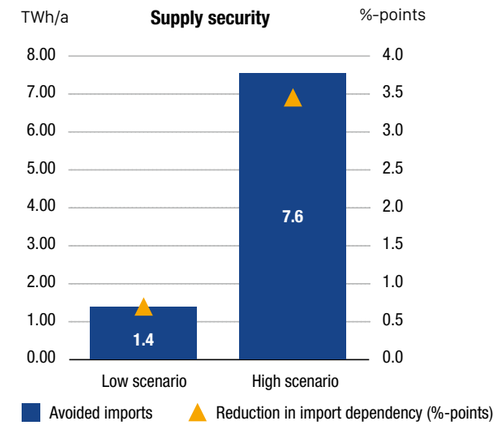


Impact on security of supply, jobs and economy in Portugal by 2030

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

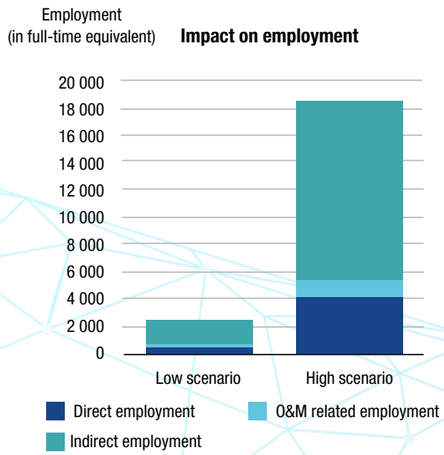
Deployment of renewable hydrogen would lead to 1.4-7.6 TWh/a of avoided imports, and thus reduce import dependency by 0.6-3.5% (in volume terms) in 2030, depending on the scenario.

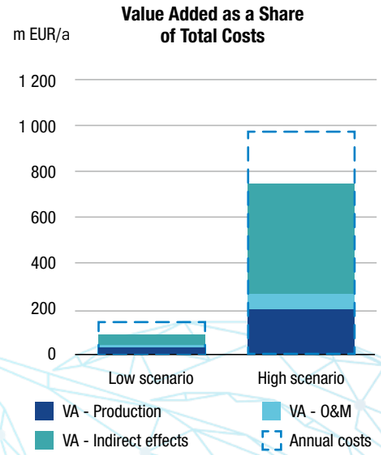


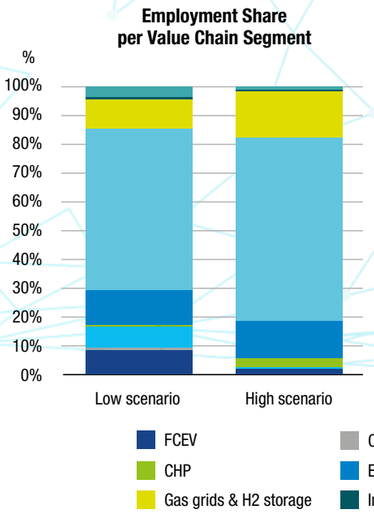
Impact on employment and value added

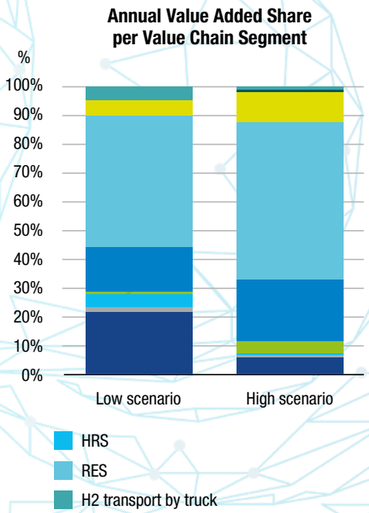
This analysis shows that in the years 2020-2030 around 38 million EUR can be retained annually in the domestic economy as value added in the low scenario, and almost 262 million EUR in the high scenario (value added is defined here as sum of wages for employees, margins for companies and taxes). If the indirect effects induced by the investment in and operation of hydrogen technologies are also taken into account, around 92 million EUR (low scenario) and almost 740 million EUR (high scenario) of value added can be created in the Portuguese economy annually, which is equivalent to more than two thirds of annual investment needed. Most of this value added is expected to be created by building and operating dedicated renewable electricity sources and electrolysers for hydrogen production, and by building and operating hydrogen transport networks and storage facilities.

The hydrogen-related expenditures in 2020-2030 are estimated to generate employment of 630 – 5 340 direct jobs (in production and operations & maintenance) and contribute to a further 1 870 – 13 100 indirectly related jobs, depending on the scenario. Most of these jobs are expected to be created in the by building and operating renewable electricity sources, electrolysers and hydrogen transport infrastructure (in the low scenario, a significant amount of employment is also generated by investment and operation of fuel cell vehicles).









PORTUGAL

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

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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