Market Update Hydrogen

Updated January 2023

Norwegian Energy Partners

Introduction

The green shift and utilization of hydrogen as an energy carrier is now discussed worldwide. Governments, organizations, finance institutions/investors, companies, and individuals have defined their own targets and obligations for reducing emissions, and Hydrogen is a major part of the solution. It has nearly become a competition to have the best ambitions and at the same time see opportunities and create jobs for their countries.

NORWEP has skilled energy advisors around the world, and they have provided input on local opportunities within Hydrogen and other energy carriers based on Hydrogen such as ammonia.

This report is meant to give an overall view of what is happening in the most important markets, how to get access and understand opportunities. The report will be updated regularly.

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Content:

Useful information – Norway and internationally

- Hydrogen project visualisation platform – ENTSOG
- https://www.tu.no/artikler/her-er-det-mest-gunstig-a-produsere-hydrogen/513436
- Geopolitics of the Energy Transformation: The Hydrogen Factor
- Hydrogen Economy Hints at New Global Power Dynamics (irena.org)
- Global Energy Review 2021 – Analysis – IEA
- The Future of Hydrogen 2019 – Analysis – IEA
- World Energy Outlook 2022 - IEA
- Norway 2022 Energy Policy Review - IEA

Hydrogen - Market Update

Australia

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Current market situation for hydrogen

- The drivers for developing the hydrogen business and green shift is an abundance of cheap renewable energy - onshore wind & solar. Australia has invested over A$35 billion in renewables since 2017, and in 2020 deployed new wind and solar PV at 8.5 times the global per capita average.
- Huge potential to become a hydrogen export nation to energy hungry Asia. Australia is currently largest global LNG exporter – want to become the largest H2 exporter, part of national strategy.
- Hydrogen strategies developed both at Federal and state levels; strong focus on both decarbonize industry sectors and export.
- Federal (and state) governments have developed strong collaborative relationships with governments and research institutions in Korea, Japan, Singapore and Germany – identified as future key strategic export markets.
- A$275MM federal funding announced for 2021-22 budget.
- Government policy is to largely rely on private investment in the sector.
- No ESG (environment, social and governance) drivers including taxonomy.
- Strong interest from bank, finance and investors due to the perceived huge export potential, several international players like Intercontinental Energy developing a presence.
- There has been a major shift in attitude towards climate change in recent years due to several severe natural disasters in Australia; fires, floods, droughts etc. that have been blamed on climate change.

Projects & prospects

Currently there are (May 2022):

- 20 projects operating or under construction (all in Australia)
- 10 projects at an advanced stage of development planning (10 in Australia and 3 in New Zealand)
- ~100 projects announced / under development

A few key projects listed below – for more details on all, visit HyResource

Operator/owner	Name of project/place	Capacity (MW)	Capacity	Operational	Remarks/links to project
Yara / Engie	Pilbara	10	625 ktpa	2023	Demonstration Project – advanced stage
Origin	Bell Bay	500	420 ktpa	2025+	Currently conducting feasibility study
FFI	Bell Bay	250	250 ktpa	FID 2022/23	Domestic and export
Consortium	AREH	26,000	TBA	2028	Developed in stages, domestic and export
Woodside	H2Perth	10	4.5 tpd	TBA	Domestic use; transport and gas grid dilution
J-Power	HESC		100,000+ tpa	2030+	Blue H2 from brown coal, pilot operating
Consortium	WGEH	50,000	20 mtpa	2030+	Developed in stages, domestic and export

General comments / strategic headlines

- Little exists locally, so most technologies will need to be imported across entire value chain; production, transportation, storage and utilization.
- Main focus is on green hydrogen from cheap renewable energy.
- Utilisation includes; power gen, heat/power for steel production, mobility – both road, maritime and train (mining sector) and domestic use for power storage, heating and appliances.
- The most important technologies going forward in the market is electrolysers, a lot of focus on reducing the cost of these and transportation, large volume export to Asia, focus is LH2, Ammonia and compressed.
- The main players/drivers in the market is mining/resource companies, utility/power companies, gas transmission companies and local governments.
- Traditional energy companies are involved (both blue and green H2). However, several new players including major mining companies (e.g. FMG) and infrastructure owners (gas transmission lines).
- Most important technology providers: mostly international players, e.g. NEL, Haskel, Siemens, Hyon, Huyndai etc
- Most important operators: many players – most important would be Fortescue Future Industries; wants to become largest clean energy provider in the world.
- Opportunities for Norwegian companies across the entire hydrogen value chain; production, transportation (land and sea), storage (small and large scale) and utilization – owner/operator of H2 plants also an opportunity.

Useful information

- Hydrogen strategy – aims to position Australia as a major global Hydrogen player by 2030
  - supports the creation of 5-6 ‘hydrogen hubs’ – regions where hydrogen users and exporters are co-located
- Hydrogen roadmap – developed by CSIRO, national research body
- First Low Emissions Technology Statement 2020 – identified Hydrogen as one of 5 key technology areas
- HyResource – database with up to date info on hydrogen projects and research initiatives in Australia
- CSIRO Hydrogen Industry Mission – research focused on building Australia’s clean hydrogen industry
- Hydrogen Technology Cluster Australia (H2TCA)
- HyCapability – searchable dB of Australia’s hydrogen equipment, technology and services industry

Hydrogen - Market Update

Brazil

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Current market situation for hydrogen

Drivers for developing the hydrogen business and green shift:

- Multinationals from different sectors are trying to enable to setting up zero carbon fuel production units in Brazil
- Studies indicates the production of low-carbon steel, e-fuels and liquid ammonia are the best bets
- Brazil is starting down the route of green hydrogen based on its high potential for producing clean energy from wind farms, solar and biomass production
- Fundamental guidelines for the National Hydrogen Program: I - Interest in developing and consolidating the hydrogen market in Brazil and the country's international insertion on economically competitive bases; II - The inclusion of hydrogen as one of the priority themes for investments in research, development and innovation, pursuant to CNPE Resolution No. 2, of February 10, 2021, approved by the National Energy Policy Council; III - The importance of hydrogen as an energy vector that, combined with other solutions, has the potential to globally contribute to a low-carbon energy matrix; IV - Interest in international cooperation for technological and market development for the production and energy use of hydrogen; V - The diversity of energy sources available in the country for the production of hydrogen; VI - Technologies associated with this energy vector already developed and under development in the country; VII - The diversity of applications of hydrogen in the economy; VIII - The potential for domestic demand and for the export of hydrogen in the context of energy transition; and IX - Brazil's leadership on the theme "Energy Transition" at the United Nations High Level Dialogue on Energy.

Leading regulatory, policy and strategy space for the hydrogen:

- The National Energy Policy Council (CNPE) approved in April this year the elaboration of the National Hydrogen Program.
- Country is still at a very early stage in terms of regulation to make this market viable.

Public fundings and incentives:

- The Ministry of Mines and Energy (MME) will launch R&D program aiming the use of strategic R&D resources for the development of hydrogen technologies. First project applications is planned from 2023.
- The government is being chased by multilateral organizations and development agencies from other countries, who say they really want to help Brazil with green hydrogen or other colors. One of the ideas (already in discussions with the agencies) is that in this strategic call Brazil has part of the funding for projects coming from these organizations that have non-refundable resources for demonstration projects.

ESG (environment, social and governance) drivers including taxonomy:

- The great challenge facing the country today regarding the ESG agenda is taxonomy, which is already being addressed by the Central Bank, especially around governance, but which needs to evolve. There is no global taxonomy. The European Union moved forward, generating its own taxonomy. It is important to discuss how to measure to avoid asymmetries and different views.
- Brazil is still slipping on the use of ESG practices in granting credit to companies. However, the model has evolved over time with the creation of “Bureau Verde”, by the Central Bank, which disseminates the culture of evaluating some risks; and the BNDEs (National Brazilian Development Bank) program, which encourages investments linked to sectors such as reforestation, sustainable energy sources, mining and steel.
- It is part of the proposed guidelines for the National Hydrogen Program to participate, in a sovereign way, in international discussions related to the definition of the production chain and use of hydrogen, as well as the conformation of the global hydrogen market (ESG taxonomies and criteria, certifications, standards, among others), with a view to the international competitiveness of the Brazilian hydrogen sector in its different routes.

Influences from the bank, finance and investors:

- A growing number of investors are seeking to align their portfolios with the purposes of the Paris agreement.
- In September 2020, the Brazilian Central Bank included in its agenda the pillar of sustainability, with the objective of seeking better management of social, environmental and climate risks in the national financial system.
- In Brazil, the possible investments announced so far are from companies in the renewable energy, industrial gases and iron ore sectors, but the oil companies are also looking into the matter, under penalty of being left out of the energy transition.

Interest in hydrogen/green shift in general – ups and downs:

- Several MoU have been signed with the 4 states in Brazil. Investments being considered are forecasted to be at least US$ 23 billion.
- It is a legal issue in defining who has the regulatory authority on H2. There is a potential competence dispute between Aneel (National Electric Energy Agency), ANP (National Petroleum Agency) and ANA (National Water Agency). Everything is still undefined. This uncertainty generates investor caution to develop a market here in Brazil, which is still at a very early stage.
- Despite the lack of regulation, the production of green hydrogen in Brazil already attracts multinationals.
- The projects seek to take advantage of wind and solar generation and port infrastructure to bring hydrogen to European market.
- The government has stated that the Brazilian strategy will not focus only on green hydrogen and will incorporate all colors.

Projects & prospects

- Multinationals are trying to make possible the installation of production units for zero carbon fuel in Brazil. Since February 21, six memorandums of understanding were signed with the states of Ceará, Pernambuco and Rio de Janeiro. Investments under study totaled at least US$ 22.2 billion (around R$ 116 billion).
- Projects are still under study and one of the projects is estimated to be one of the biggest hydrogen producers in the world.

General comments / strategic headlines

- Brazil has a variety of existing bases for production, since onshore renewable sources (Hydropower, wind and solar) to biomass, biofuels and natural gas.
- The production and industrial uses of hydrogen in Brazil are relatively consolidated. However, the broader use of energy projects based on hydrogen will require a more continued investment in RD&I so that the country can be a relevant player in the Hydrogen Economy.
- International cooperation is being agreed, in special with Germany.
- Brazilian strategy will not focus all colors, but project perspectives are foreseeing green hydrogen and ammonia.
- End-users can be process industry, power production, heavy transportation. Not exactly defined, it will depend on how competitive it will be.
- The most important technologies going forward in the market:
  - Electrolysis, to reduce the production costs
  - Green Ammonia production to export to Europe
- Main players/drivers in the market: Ministry of Mines and Energy and Energy Research Office – EPE
- Shift in the most important players (newcomers, companies changing business etc.) is not clear yet.
- Most important clients/stakeholders in the market: Fortescue Future Industries, Qair Brasil, White Martins, Enegix Energy, PECEM Port complex, Açu Port complex, Siemens, Eletrobras, BNDES
- Digitalization will play an important role in the hydrogen industry development, as it should be digital from the start.

General comments / strategic headlines

What should Norwegian companies focus on in the market? Where are the opportunities for Norwegian companies?

- Cooperation with Brazilian institutions, universities, Federal and State government
- Diffusion of new technologies, the development of an infrastructure for the production, storage, transport, and distribution of hydrogen
- Norwegian project companies could take advantage of the proximity to Europe and Wind and Solar potential of Brazilian NE region , as other companies are already doing.
- Main challenge for the development and use of green hydrogen is to reach the levels of competitiveness with other sources (blue, gray) by reducing its costs
- Combine and offer the experience in Solar and Wind power technologies for hydrogen production.
- Australia, Germany and France are getting the front.

Useful information

- Baseline to support the Brazilian Hydrogen Strategy
  https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-569/NT_Hidroge%cc%82nio_EN_revMAE%20(1).pdf#search=hidrogenio
- National Hydrogen Program
  https://www.gov.br/mme/pt-br/assuntos/noticias/mme-apresenta-ao-cnpe-proposta-de-diretrizes-para-o-programa-nacional-do-hidrogenio-pnh2/HidrognioRelatriodiretrizes.pdf
- Brazilian Hydrogen Association
  https://www.facebook.com/abhidrogenio/
  https://www.linkedin.com/company/abhidrogenio/?originalSubdomain=br
- Brazilian Hydrogen Energy Compact Side Event - UN High Level Dialogue on Energy
  https://www.youtube.com/watch?v=y9SIaNGI344
- Unicamp
  https://en.inova.unicamp.br/
- UFRJ
  https://www.coppe.ufrj.br/en
- H2 platform Green Hydrogen – German-Brazilian alliance
  https://www.h2verdebrasil.com.br/en/projects/?pais%5B%5D=269&area_aplicacao%5B%5D=288

Hydrogen - Market Update

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Current market situation for hydrogen

The Government of Canada, labor and business and population in general all show interest and commitment in shifting to a green economy. As Canada is a fossil fuel rich country, there is of course a pull and tug regarding the speed, and the strategy. Federal elections in Sept 2021 may impact current policies if there is a government change, but the movement will certainly continue.

- The overarching driver for developing the hydrogen business and green shift in Canada is the need to mitigate climate change as per Canada's commitments to meet net zero emission by 2050 and aiming to have and 30% of country's energy from hydrogen by then.
- The leading policy and strategy for the hydrogen is outlined in the Hydrogen Strategy for Canada, as developed over the past three years and announced by government is December 2020. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf.
- Funding and incentives: Multiple initiatives across the different provinces, but principally underpinned by the federal "Low Carbon and Zero Emissions Fuels Fund".
- ESG drivers are: Mitigating climate change, carbon pricing (taxation) and electability of governments by a population focused on greening the economy.
- Availability of funding for any major fossil fuel developments is becoming more difficult. Major hydrogen, renewable/green energy projects increasingly tend to have more investment appeal.
- Interest in hydrogen/green shift in general – ups and downs; There is high interest at present albeit the energy slump and pandemic impact proved a catalyst for looking away from fossil fuels and towards a green economy. The years between now and 2030 will focus on initial development of hydrogen hubs across the country. The implementation and success of that part of the strategy will determine the greater development afterwards towards the 2050 goals.

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
Thyssenkrupp (Green hydrogen) and Hydro Quebec	Varennes Quebec	88MW	1100MT	Estimated end 2023	Partnered with Hydro Quebec https://www.thyssenkrupp.com/en/newsroom/press-releases/pressdetailpage/first-green-hydrogen-project-becomes-reality--thyssenkrupp-to-install-88-megawatt-water-electrolysis-plant-for-hydro-quebec-in-canada-93778
BC Government	Vancouver		Build out existing fuel cell stations to 10	Completed in 2023	Funded by BC government https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program/dcfc-program/hydrogen-fuelling
Suncor and ATCO	Alberta (Fort Saskatchewan)		300000MT	Est 2028	Sanction 2024– on line 2028 (Blue Hydrogen) https://www.atco.com/en-au/about-us/news/2021/122920-suncor-and-atco-partner-on-a-potential-world-scale-clean-hydroge.html
Air Products	Blue Hydrogen Hub/Edmonton Alberta		550000	Expected onstream 2024	https://www.airproducts.com/campaigns/alberta-net-zero-hydrogen-complex
Renewable hydrogen Canada	RH2C/ located on BC Coast				http://www.renewableh2canada.ca/ Proposed project only – no dates set
Proton Technology	Proton Technology Project, Saskatchewan			No date	Pilot project with potential https://globalnews.ca/news/7104460/proton-hydrogen-saskatchewan/

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
Atura Power	Ontario			No date	Early stages of feasibility studies on Hydrogen projects. https://www.h2bulletin.com/canada-atura-power-to-explore-hydrogen-projects/
Evolugen and Brokfield renewable	Gatineau,Outaouais region. Quebec	20 MW		Est 2023	Water electrolysis hydrogen production plant. https://www.canadianbiomassmagazine.ca/quebec-companies-collaborate-on-one-of-canadas-largest-green-hydrogen-projects/
Heritage gas	Heritage gas project – Nova Scotia			No date	Feasibility proposal. https://www.heritagegas.com/net-zero/
Planetary Hydrogen	Planetary Hydrogen Dartmouth Nova Scotia			2022	https://www.planetaryhydrogen.com/ocean-air-capture/
NB Power and JOI Scientific	New Brunswick			Scheduled 2019 but delayed	Generation of Hydrogen on demand from seawater. Technology not working as planned. https://www.cbc.ca/news/canada/new-brunswick/joi-scientific-technology-update-1.5340245

General comments / strategic headlines

- Steam reforming and other technology for hydrogen production from fossil fuels exists. Technology from other industries like refineries and O&G and hydro is available to the extent it is transferrable. Fuel cell technology exists. Technologies that are used to produce hydrogen using renewable energy sources and which are being developed/piloted or unavailable will need to be further developed or imported.
- The technological focus varies, with the hydrocarbon rich provinces more focused on blue hydrogen while Quebec and some other provinces focus on green hydrogen. The provinces will mostly focus on domestic supply including transportation and power production and transportation (cars). Hydrogen export is certainly part of the national plan.
- The most important technologies going forward in the market: Technology for Blue hydrogen combined with CCUS for the west and electrolysis (water splitting) for the green hydrogen in Quebec. A variety of pilot projects proposed or in early stages may eventually drive other technologies.
- Players and shift: See the project list slides for players. Note that Suncor and other oil sands operators are making green investments as part of their portfolios.
- Most important clients/stakeholders: See project list for players and the links to the projects which in most cases will name the main players and companies. Engineering companies: Hatch.com and Stantec.com. Financial market/investors: see https://www.greeninvestmentgroup.com/en.html and https://www.canadiangreenfund.com/) Organizations: see http://www.chfca.ca/
- Norwegian companies should focus on the announced projects if they have helpful technology or experience. There may be opportunities for Norwegian companies who have developed new or improved technology, especially for green hydrogen production.

Useful information

- Hydrogen strategy and Hydrogen roadmap: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/environment/hydrogen/NRCan_Hydrogen-Strategy-Canada-na-en-v3.pdf
- https://www.bennettjones.com/Blogs-Section/British-Columbia-Announces-Hydrogen-Strategy
- Important domestic hydrogen organizations, clusters, government institutions etc.: https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/renewable-energy-facts/20069
- https://canadianlabour.ca/research/issues-research-making-shift-green-economy/
- R&D institutions focusing on Hydrogen: http://www.chfca.ca/wp-content/uploads/2019/10/CHFC-Sector-Profile-2018-Final-Report.pdf

Hydrogen - Market Update

China

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Strategy for hydrogen in China

- The country is committed to hit peak emissions by 2030 and carbon neutrality by 2060. It will need to mobilize all its resources to address the responsibilities it faces as the world’s largest carbon emitter.
- China is widely recognized as a global leader in clean-energy technologies, controlling over 60 percent of global manufacturing in every step of the solar supply chain and being home to five of the world’s top 10 wind turbine manufacturers. It leads the world in lithium-ion batteries, bio-power, hydropower, solar water heating and geothermal heat output.
- The importance hydrogen is set to play in fulfilling that goal, all eyes are on China to develop and scale hydrogen technologies.
- The country's central and local governments have inked the hydrogen industry into the 14th Five-Year Plan (2021-2025).The China Hydrogen Alliance, a government-supported industry group, predicts that by 2025 the output value of the country's hydrogen energy industry will reach 1 trillion yuan ($152.6 billion), and by 2030 that China's demand for hydrogen will reach 35 million tons, accounting for at least 5% of China's energy system.
- China currently lacks the key technologies to enable renewables-based hydrogen production, and it lags behind advanced economies in hydrogen storage and transport technologies.

Market advantages and challenges

- China's advantages lie in strong government support and a huge market. But to achieve those goals, technological obstacles need to be overcome to lower the costs of extracting, storing, transporting and delivering the material to end users.
- Transportation, distribution/infrastructure & storage of hydrogen onshore, maritime & offshore is very challenge especially for safety issues and not a practice roadmap globally.
- High production costs have kept hydrogen-powered cars from reaching a commercialized stage in China and elsewhere. The difficulties of storing and transporting the highly explosive gas add to the costs. At current market prices, hydrogen to power a fuel cell car in China costs about 70 yuan per kilogram. The figure needs to come down to less than 40 yuan per kilogram before hydrogen-powered cars can be competitive with traditional gasoline-powered vehicle.
- In terms of delivery, most of China's hydrogen is transported by truck, which is more expensive and less efficient than pipelines. China mainly uses trailers with a capacity of 300 kg of hydrogen, which is less than half the capacity of trailers commonly used in Western countries.
- Transporting hydrogen via pipeline would be efficient but requires high upfront investment. Building a national hydrogen delivery infrastructure would also be a big challenge. State-owned China Oil & Gas Pipeline Network, or PipeChina, included hydrogen pipeline research in its 14th five-year plan (2021-2025). State-owned China Petroleum and Chemical, or Sinopec, is accelerating infrastructure construction for hydrogen, including pipelines and filling stations.

Projects & prospects

Operator/owner	Name of project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks
Sinopec	Sinopec's Zhongyuan oilfield, in Henan province, China	2.5 megawatts	1.12 tonnes of green hydrogen per day with 99.9995% purity	Sept. 2022	China's second-largest oil company, Sinopec, plans to produce its first green hydrogen in September next year. The company last week kicked off a pilot project that will produce hydrogen through water electrolysis, using electricity to split water into hydrogen and oxygen. The project, with capacity of 2.5 megawatts, will be installed at, and will be supported by the company's own research houses, including Dalian Petrochemical Research Institute, Guangzhou Engineering and Qingdao Safety Engineering.

General Comments

- DNV is a leading company to lead JIP - Design and Operation of Hydrogen Pipelines globally. DNV will try to invite PipeChina and CNOOC to join this JIP now. As DNV's Comments in their presentation.
- Potential to transform the oil and gas industry - The scaling of CCS and hydrogen could transform the oil and gas industry into the decarbonizer of hydrocarbons and the world's supplier of carbon capture and storage. It could transform the sector so that it is an essential contributor to realizing climate ambitions, rather than to missing them. Crucially, these technologies are already available. They just need to scale.
- This would mean a bright future for gas - decarbonized and green gasses would have a bright future following such a transformation, with hydrogen and CCS complementing renewable electricity, battery technology and alternative low-carbon fuels to provide societies with a secure, affordable supply of clean energy.
- Public energy policies are key – policies don't just set out the path for the world and the oil and gas industry to decarbonize, but also decide how quickly it heads down that path.
- Government brings policy and incentives; industry rolls out the technology – the quicker that governments incentivize the industry to adopt technology, such as through a competitive carbon price, the quicker the industry takes the technology down the cost-learning curve for it to become independently financially viable.
- Forming partnerships between governments and industry will be crucial – working together to make hydrogen and CCS safe, effective, and commercially viable will give the oil and gas industry the certainty it needs to manage new risks and accelerate its transformation towards a low-carbon future.
- If any NORWEP member have innovation and approved hydrogen solutions, especially in green hydrogen, China will be a potential market for it. NORWEP will support them in China if so.

Hydrogen - Market Update

Denmark

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Current market situation for hydrogen

- A broad political agreement has set an over all target of 70% GHG reduction in 2030 and 100% carbon neutrality in the electricity sector in 2030. On June 29, 2021, the government presented an electrification strategy that later this year will be followed by a hydrogen and Power to X strategy.
- The public R&D facility Innovation Fund Denmark (IFD) will invest in mission-driven green research and innovation partnerships (Innomission-partnerships), which will accelerate the development of cutting-edge solutions ranging all the way from strategic coherent research to commercialization, with an equal focus on short-, mid- and long term impact.
- IFD has, in cooperation with market actors, developed two road maps: Roadmap for Green Fuels in Transport and Industry and Roadmap Leveraging Danish strengths to mature and scale up e-fuels for transport.
- IFD has a call for InnoMission partnership where they will invest 195 mio. DKK as a minimum in Green fuels for transport and industry (Power-to-X, etc.). The partnerships are encouraged to include international actors.

First round – IPCEI Hydrogen (IPCEI - Important Projects of Common European Interest)

Initiator(s) / project owner	Project	Remarks/link to project
Ørsted	Green Fuels for Denmark	https://orsted.com/en/media/newsroom/news/2021/06/857452362384936
Everfuel	HySynergy 2.0	https://www.everfuel.com/projects-archive/hysynergy/

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
Air Liquide	HyBalance/Hobro	1		2019	
Ørsted	Green Fuels for Denmark / Copenhagen	1.300		2030	IPCEI
GreenLab	GreenLab Skive	250			
Everfuel	HySynergy I / Fredericia	20		2022	
Everfuel	HySynergy II / Fredericia	300		2030	IPCEI
Everfuel	HySynergy III / Fredericia	700			
Copenhagen Infrastructure Partners	HØST / Esbjerg	1.000		2030	HØST
European Energy	Reintegrate / Aabenraa			2023	10.000 ton e-methanol per annum
Ørsted	H2RES / Copenhagen	2MW		Construction began summer 2021	H2RES

General comments / strategic headlines

- There is almost only focus on green hydrogen in Denmark. Hydrogen is seen as a key enabler for indirect electrification of heavy transport sector, marine and aviation.
- The whole value chain is well represented in the market. Green Hydrogen Systems, Everfuel, Haldor Topsøe, Vestas, Siemens Gamesa, Siemens, Copenhagen Infrastructure Partners, Ørsted, TotalEnergies, Better Energy, European Energy.

Useful information

- Danish Center for Energy Storage: Hydrogen Denmark
- R&D institutions focusing on Hydrogen: DTU, Aalborg University, DGC (Danish Gas Technology Centre)

Hydrogen - Market Update

France

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Current market situation for hydrogen

- Carbon-free hydrogen, a priority for France's energy and industrial sovereignty. France had set up a hydrogen plan in 2018. In February 2020, carbon-free hydrogen has been identified as a priority among 11 key markets.
- The first target is to install enough electrolysers to make a significant contribution to decarbonising the economy. This will be made possible by the installation of a 6.5 GW carbon-free hydrogen production capacity by electrolysis.
- The first phase aims at converting land transport of passengers and goods to hydrogen technologies (utility vehicles and heavy goods vehicles, buses, hydrogen trains), river shuttles and hydrogen-powered ships.
- National strategy with EU “Clean Hydrogen Alliance”
- The EC has created in 2020 the “Clean Hydrogen Alliance”, to coordinate the collective work of the Member States. Several Member States have already outlined their hydrogen strategy.
- France will notably push for the emergence of “gigafactory” electrolyser projects in France, and has reserved an exceptional financial allocation of 1.5 billion euros as part of this action.

First round – IPCEI Hydrogen (IPCEI - Important Projects of Common European Interest)

Initiator(s) / project owner	Project	Remarks/link to project
TOTAL ENERGIES	MASSHYLIA	Total and Engie partner to develop France's largest site for the production of green hydrogen from 100% renewable electricity| Total.com (totalenergies.com)
AIR LIQUIDE	H2V NORMANDY	Accueil - H2VNormandy Concertation (h2vnormandy-concertation.net)
ENGIE	HYGREEN PROVENCE	hygreen-provence.com

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
TOTAL ENERGIES	MASSHYLIA / La Mède (Marseille)	40 MW	5,5	2024	Investment: 200 M€
AIR LIQUIDE	H2V Normandy / Port-Jérôme sur Seine	100 MW	28	2023	Investment: 250 M€
H2V	H2V59 / Dunkirk	100 MW	28	2023	Investment: 250 M€
ENGIE	HYGREEN PROVENCE	435 MW	10,5	2027	Investment: 300 M€
STORENGY	HyPSTER	1 MW	0,15	2022	Investment: 13 M€

General comments / strategic headlines

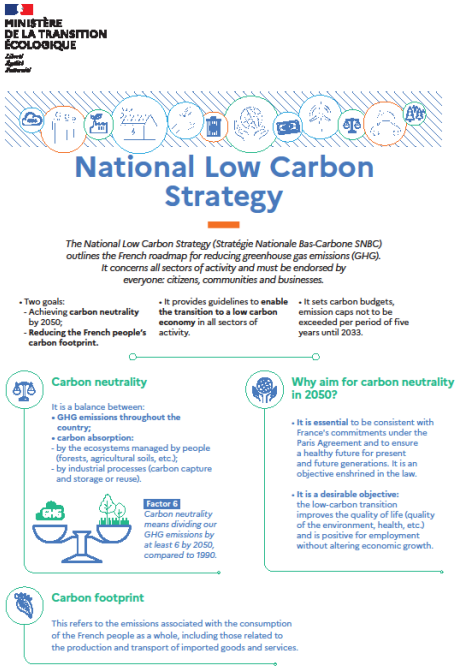
Decarbonize industry by replacing carbonated hydrogen

- Today, industry in France is by far the largest consumer of hydrogen. The aim is to replace production processes using fossil fuels to decarbonize this hydrogen. This is one of the axes of the multi-year energy program. Indeed, the decarbonisation potential is significant in the industry in the following segments:
    - in refining, a growing market for desulphurizing fuels;
    - in chemistry with in particular the production of ammonia and methanol;

Develop a heavy hydrogen mobility offer

- Particularly suitable for heavy vehicles, hydrogen technologies offer additional storage capacity to that of electric batteries. Hydrogen meets the needs of high power or the needs of long autonomy, in particular for captive fleets covering long distances at just-in-time flow: light commercial vehicles, heavy goods vehicles, buses, household garbage dumpsters, regional or inter-regional trains in non-electrified areas.
- A call for projects "Technological bricks and demonstrators" will be able to support demonstrator projects integrating strong value creation in France and allowing the sector to develop new solutions. This call is endowed with € 350 million until 2023.

Useful information



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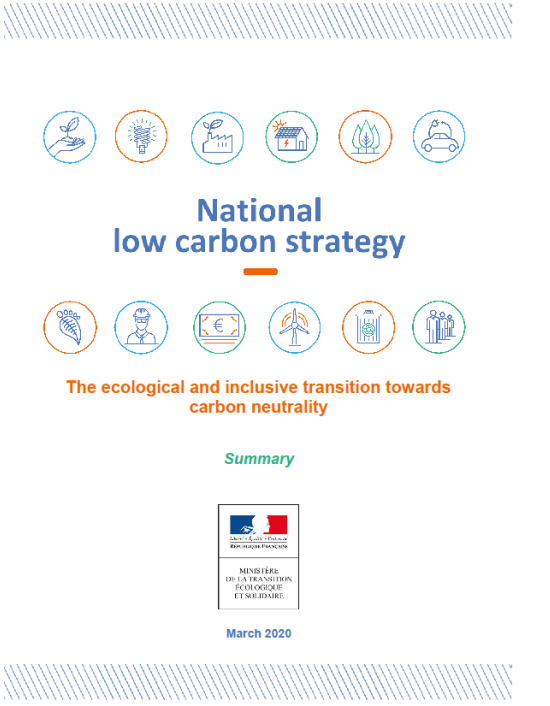

[Summary (30 pages)]

[10 major points (in French)]

Hydrogen - Market Update

Germany

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General comments / strategic headlines

- Green Hydrogen in focus regarding opportunities for applications in several sectors, i.e. transport, steel, pharma, cement.
- Major strategic and R&D activities initiated on federal and local goverment level, i.e. 3 lead projects (federal funding for production, transport and usage of Green Hydrogen)
  - https://www.wasserstoff-leitprojekte.de/leitprojekte
  - https://norddeutschewasserstoffstrategie.de
- Specific (Offshore Wind) specific application projects are established, i.e.

  Westküste 100 https://oge.net/de/wir/projekte/unsere-wasserstoffprojekte/westkueste-100

  Aqua Ventus https://www.aquaventus.org
- Major Drivers are industry majors like RWE, Thyssen-Krupp, Salzgitter, Ørsted, OGE.
- Reuse of existing or renewal of pipeline systems under discussion.

Useful information

- National Hydrogen Strategy: https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.html
- List of national (IPCEI) projects: https://www.bmwi.de/Redaktion/DE/Downloads/I/ipcei-standorte.pdf?__blob=publicationFile&v=6
- Important domestic hydrogen organizations, clusters, government institutions etc.
  - DWV: https://www.dwv-info.de/?lang=en
  - Wasserstoffgesellschaft Hamburg e.V.: https://www.h2hamburg.de
- R&D institutions focusing on Hydrogen
  - Fraunhofer ISE: https://www.ise.fraunhofer.de/en
  - Helmholtz-Zentrum Hereon: https://www.hereon.de/index.php.de

Hydrogen - Market Update

India

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Current market situation for hydrogen

- The major driver is the Government of India's commitment to reduce pollution and global warming. Also, it is also motivated by reducing dependence on fossil fuel since majority of energy demand is met by Non-renewable sources whereas around 80% of fossil is imported leading to skewed Trade balance & high fiscal deficit. India's total hydrogen demand is expected to touch 11.7 million tonnes (mt) by 2029-30 from the current 6.7 mt. Other drivers include continued rapid cost reductions of renewable electricity, cost reductions and performance improvements of electrolysers, and significant action on tackling climate change.
- The government has recently launched the National Hydrogen Mission to give boost to the hydrogen development. Many leading technical and research institutes are working in India to improve the safety and cost aspect of electrolysers so that hydrogen may be adopted as automotive fuel. India is considering a proposal to make it mandatory for fertilizer plants and oil refineries to purchase green hydrogen as part of plans to cut the nation's dependence on fossil fuels.
- The government also aims to extend the production-linked incentive (PLI) scheme for manufacturing electrolyzers to produce green hydrogen. Most of the state funding is going into research institutes to develop the technology. The government plans to implement the Green Hydrogen Consumption Obligation (GHCO) in fertilizer production and petroleum refining, similar to what was done with renewable purchase obligations (RPO).
- National Hydrogen Mission , announced on 15th Aug 2021 is expected to boost hydrogen uptake in India. The Ministry of New and Renewable Energy (MNRE) developed a Hydrogen and Fuel Cell Road Map, published in 2006 (MNRE, 2006). In 2016, MNRE published a further report, which laid out more up-to-date plans for the Government's ambitions for hydrogen (MNRE, 2016).
- Most of the investment in Hydrogen is coming from Public Sector companies like NTPC, Indian Oil , ONGC etc. Few private companies like Mahindra & Mahindra, Ashok Leyland are also showing interest in setting up
- The interest in Hydrogen shift is increasing however it is mainly driven by Government due to factors already described above. However, with reduction in prices of renewable due to advancement in technology, private investment is expected to increase. The green shift is acknowledged and is a concern in India however people may not be ready to pay a premium for the same. Thus, cost sensitivity is also quite high.

Projects & prospects

Operator/owner	Name of project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
Indian Oil	Mathura Refinery		~650	Ideation	First Green Hydrogen Production Unit in India
NTPC	Rann of Kutch			Ideation	Commercial Scale production of Green Hydrogen
NTPC	Hydrogen Mobility Project			Tendering	Buying Hydrogen fueled buses in Ladakh

General comments / strategic headlines

- Most hydrogen in India is produced through reforming methane (CH4), resulting in significant carbon dioxide emissions. India has claim to one of the first largescale alkaline electrolyser facilities in the world, which produced hydrogen from electricity at the Nangal Facility. Other technologies are Polymer electrolyte membrane (PEM) electrolysis, Alkaline electrolysis and Solid Oxide Fuel Cell (SOFC) electrolysis. The stress is to produce hydrogen domestically to make it competitive against other fuel sources.
- The technical focus is on producing green hydrogen with major implementation in mobility, process industry(chemical & petrochemical) & captive power.
- The most important technologies going forward in the market: Electrolyser based green hydrogen production is being stressed upon.
- Main players/drivers in the market: Indian Oil, NTPC, Reliance, Adani, Mahindra & Mahindra, IIT Delhi, BHU, Ashok Leyland
- The industry is developing and many energy based companies are now shifting gears to get into renewable business with hydrogen as a major portfolio component.
- Most important clients/stakeholders in your markets are Government of India, MNRE, NTPC, Indian Oil, Reliance , Adani etc. Main financial institutions are banks like SBI, ICICI, Axis, and NBFC’s, EPC companies like Larsen & Toubro.
- Opportunities for Norwegian companies are mainly in technology transfer, joint technology development, project management, platform development and digital solutions.
- Digitalisation would be a major area where Norwegian expertise would be seen competitive.

Useful information

- https://www.teriin.org/sites/default/files/2020-06/Hydrogen-Policy-Brief.pdf
- https://www.teriin.org/sites/default/files/2021-07/Report_on_The_Potential_Role_of_%20Hydrogen_in_India.pdf
- http://164.100.94.214/hydrogen-energy
- http://164.100.94.214/sites/default/files/uploads/abridged-nherm.pdf
- https://iocl.com/pages/r-and-d-centre
- https://www.idsa.in/issuebrief/india-national-hydrogen-mission-n-gcc-lpriya-270821
- https://www.teriin.org/
- https://home.iitd.ac.in/

Hydrogen - Market Update

Indonesia

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Current market situation for hydrogen

- Hydrogen development in Indonesia is still in the research stage and does not yet exist in commercial scale. Specific policy on hydrogen has not been drafted or issued. However, Indonesia will continue to follow trends in hydrogen technology and open opportunities to collaborate in hydrogen implementation.

- Drivers for developing the hydrogen business in Indonesia:
  - Indonesia's commitment to reduce GHG emission 29% from national effort — or 41% with international assistance by 2030.
  - The country's goal to increase the share of renewable energy in the country's energy mix to 23% by 2025 and 31% by 2050.
  - Creating new market for renewable energy.
  - Energy storage solutions for off-grid systems.
  - Better energy density than battery.
    Potential energy carrier in the industrial and transportation sectors.

- The Indonesian government encourages the development of green hydrogen in the country. The industry has started to evaluate the application of green hydrogen in Indonesia. First feasibility studies and pilot projects are in the making using geothermal and photovoltaic energy. A dedicated regulation is in discussion, but not available yet.

- Hydrogen source potentials are available in Indonesia. The country can potentially supply hydrogen from gas and lignite as fossil fuel sources, and solar, hydro, and wind as renewable energy sources. The challenge is how to make hydrogen economically viable, financially attractive, and socially beneficial in the country.

- Challenges in the widespread use of hydrogen in Indonesia, namely in developing significant storage or battery technology. IESR has conducted a study, and it showed that in an optimal decarbonization scenario where hydrogen will receive a larger portion of Indonesia's energy system, the demand for power storage will increase significantly, which means that the supporting infrastructure must also be prepared.

Hydrogen – pilot projects in Indonesia

- Hydrogen utilisation for power generation in Indonesia - Toshiba Energy Systems & Solutions Corporation (Toshiba ESS) concluded an MoU with Agency for the Assessment and Application of Technology (BPPT) on the implementation of the renewables-based H2One™ autonomous off-grid hydrogen energy system. Under the MOU, Toshiba ESS and BPPT will study the installation site, the optimum system specifications, and the operation system, including maintenance, and aim to install the first system by 2022. https://asia.toshiba.com/press-release/english/toshiba-and-bppt-conclude-memorandum-of-understanding-on-the-promotion-of-autonomous-hydrogen-energy-supply-systems-in-indonesia/

- Hybrid green hydrogen combined renewable power plant in Sumba Island, East Nusa Tenggara province - French-based independent power producer, HDF Energy plans to develop a power plant called Renewstable, a technology that combines Solar PV and or wind power to generate electricity during the day, and some portion of the electricity then stored in battery and the rest will be used to produce hydrogen by electrolysis. During the night, battery, and the hydrogen (by fuel cells) will work simultaneously to produce electricity. Capacity of 7-8 MW at daytime from solar and 1-2 MW at night-time from hydrogen storage (preliminary study on competitive prices with generation cost). https://www.petromindo.com/news/article/hdf-energy-to-develop-first-renewable-hydrogen-hybrid-power-plant-1

- Green hydrogen production from geothermal energy – Pertamina Geothermal Energy plans to start a pilot project producing 100 kg/day of green hydrogen from its geothermal working area this year. The company is currently completing studies for the final investment decision (FID) and undertaking technology assessments and market aspects. The company is also looking for strategic partners to run this business. https://www.pertamina.com/id/news-room/energia-news/pertamina-siap-kaji-produksi-hidrogen-hijau-dari-panas-bumi

General comments

- Indonesia will focus on development of green hydrogen for power production/to fuel power plants. Development studies have already begun.
- Pertamina through its geothermal and power subsidiaries will start the development study of green hydrogen:
  - Pertamina Power is currently developing hydrogen to fuel power plants with a capacity of 0.3 megawatts (MW). Pertamina Power expects that hydrogen can be used for power plants with a capacity of 20 MW by 2025
  - Pertamina Geothermal Energy (PGE) conducts an initial study to develop green hydrogen. The Ulubelu Geothermal Working Area is the first project for research on the development of this clean energy source.
- There is also a need to commercialize green and blue ammonia in the domestic market.
- Pertamina Geothermal is currently exploring:
  - green hydrogen export market, one of which is Singapore market as it is currently in need of green hydrogen supply to fuel ships.
  - the distribution of hydrogen for the needs of oil fuel refineries (BBM) managed by Pertamina Group to produce biodiesel, biofuels, and bio-aviation fuel.
  - the commercialisation of green and blue ammonia by using hydrogen produced by Pertamina as a raw material for fertilizer production.
- The deployment of hydrogen fuel cell vehicles is a further step in the EV national programme.

Useful information

- Hydrogen strategy - Indonesia has not drafted or issued a specific hydrogen policy. https://iesr.or.id/en/indonesia-needs-specific-strategy-to-develop-hydrogen-for-decarbonization; https://static.agora-energiewende.de/fileadmin/Projekte/2021/VAs_sonstige/2021-03-18_Presentation_IESR_on_H2_in_Indonesia_BETD.pdf
- Hydrogen roadmap – not yet available
- National reports – not available
- Country outlook - https://www.oecd.org/economy/indonesia-economic-snapshot/; https://www.iea.org/countries/indonesia
- Important domestic hydrogen organizations, government institutions – Directorate General of Electricity (DJLPE), Directorate of New and Renewable Energy (EBTKE), National Energy Council (DEN), Indonesia Fuel Cell and Hydrogen Energy (IFHE)
- R&D institutions focusing on Hydrogen: BPPT, LEMIGAS

Hydrogen - Market Update

Korea

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Current market situation for hydrogen

- In 2019 the Korean government announced H2 Economy Roadmap
- In 2020 Korea legislated Korea Hydrogen Act
- 2020. 03 : Established Hydrogen Economy Council
- 2021. 10 : Reported Hydrogen Leading National Vision

Current market situation for hydrogen

Hydrogen Production

Green Hydrogen:

- Development of Efficiency Improvement Techniques for Water-Electrolysis
- Development of Long Term Storage Technology for Hydrogen High Capacity

Overseas Import

- Import in earnest from 2030
- Construction of old takeover base for imported hydrogen
- Development, demonstration and commercialization of hydrogen transport ship

Hydrogen Infrastructure

- Early commercialization of Liquid H2 Carrier, Ammonia Fueled Vessel
- Construction of hydrogen port for overseas import of hydrogen
- Construction of hydrogen pipeline network : 10 cities (Incheon, Dangjin, Pyeongtaek, Gunsan, Yeosu, Changwon, Busan, Ulsan, Pohang, Samcheok)

Hydrogen Investment

- R&D Investment supported by government in 2011 : USD 200 mil
- Private companies' investment by 2030 : USD 40 bil
- Production of green/blue H2 : USD 11 bil
- Hydrogen liquefaction plant, storage, distribution : USD 7 bil
- Utilization (Power generation, FCEV, etc.) : USD 22 bil

Green H2 Project in Korea

Project	Period	Electrolysis Type	Budget (USD)	PI
Development of Next Generation Alkaline Electrolyzer	2015 - 2021	Alkaline (Renewable)	10 million (MIST)	KIER
Development Hybrid Hydrogen Conversion & Power Generation System for Utilization of 500kW Surplus Wind energy	2017 - 2020	Alkaline (Renewable)	8 million (MOTIE)	G-philos Ltd. (KIER)
Power to Gas Project in Jeju Island (3MW electrolyzer/Wind)	2020 - 2023	Alkaline (Nenewable)		G-philos Ltd.
Development of High performance 1 MW PEM electrolyzer for interation with renewable energy	2018 - 2021	PEM (Renewable)	7 million (MOTIE)	Elchemtech Ltd. (KIER)
Reversible High-temperature Cells using Multi-scale Solid Oxide	2016 - 2020	SOEC (Waste Heat)	12 million (MIST)	KIER
Development of core-technologies of alkaline water electrolyzer for renewable hydrogen production	2019 - 2022	Alkaline (Renewable)	14 million (MIST)	KIER
Core technology development of polymer electrolyte membrane (PEM) water electrolyzer	2019 - 2022	PEM (Renewable)	14 million (MIST)	KIER
Power to Gas Project (2 MW class)	2019 - 2022	Alkaline + PEM (Renewable)	28 million (MOTIE)	Korea Electric Power Co. (KEPCO) (KIER)

Current market situation for hydrogen

Global H2 Cooperation

- Expanding Global Hydrogen Cooperation Network
- Establishing a global cooperation system to foster the hydrogen industry in Korea
- International Joint R&D & Demonstration

Overseas H2 Supply-chain establishment

- Feasibility study on establishing CO2-free Hydrogen supply chain
- International Hydrogen Industry Cooperation

Global Cooperation at Private Level

- Planning to launch a global network at a private level
  Global Hydrogen Industrial Association Alliance (GHIAA)
- Promoting exchanges via hosting international seminars & foruma

Supporting entry into the international hydrogen market

- Hydrogen Mobility Business Cooperation Support
- International cooperation business matching of green hydrogen production, power generation, transportation, infrastructure, etc.

Current market situation for hydrogen

- Hydrogen Leading National Vision (Oct. 2021) : Roadmap on Jan. 2019 modified

	2022	2030	2040	2050
FECV: (Export)	81,000/year (14,000)	500,000/year	6.2 mil/year (3.3 mil)	
HRS:	310 units	660 units	1,200 units (incl. 200 bus garages)	
Fuel cell for power generation:	1.5 GW (1.0 GW)		15 GW (8 GW domestic demand)	
Hydrogen supply:	470 ton/year By-production LNG reforming hydrogen water electrolysis	3.9 mil ton/year By-production LNG reforming hydrogen water electrolysis		27 mil ton/year By-production LNG reforming hydrogen water electrolysis
Blue/Green Hydrogen production		0.25/0.75 mil ton		3.0/2.0 mil ton

Green H2 Project in Korea

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Hydrogen-related companies

Section	Company	Specification
Hydrogen Producion	DEOKYANG, SPG	• Gasification, LNG Reforming
	SK ENERGY, LINDE KOREA, HYOSUNG, Air Liquide, Air Products	• (In progress) Liquification, Oil Refining, CCS (SK)
	HYUNDAI OIL BANK, S-OIL, KNOC, etc.	• (In progress) LNG Reforming
	HANWHA SOLUTION	• (In progress) Water Electrolysis
	WONIK MATERIALS, WONIL T&I	• (In progress) Ammonia Reforming
Hydrogen Distribution (Transportation & Storage)	KOGAS	• Hydrogen Distribution Dedicated Organization
	HYUNDAI GLOVIS	• (In progress) Overseas Hydrogen transportation
	DEOKYANG, SPG	• Tube Trailer, Pipeline

Hydrogen-related companies

Section	Company	Specification
Hydrogen Refueling Station	HYNET, KOHYGEN	• Hydrogen Refueling Station Operator
	HYOSUNG HEAVY INDUSTRIES, EM SOLUTION, KWANGSHIN MACHINERY Co., JNK HEATER, HYUNDAI ROTEM, BUMHAN FUEL CELL, VALMAX, NKTECH, HAN YOUNG, Nel, Air Liquid, Air Products, etc.	• (GH2, 700 bar) HRS Consortium
Hydrogen Utilization	HYUNDDAI MOTO COMPANY	• Hydrogen Mobilities : FCEVs, FC Trucks, FC Buses, etc.
	HYUNDAI ROTHEM	• Hydrogen Tran & Tram
	HYUNDAI MOBIS	• Fuel Cell System and Parts
	HYUNDAI HEAVY INDUSTRY	• Hydrogen Fork Lifts
	HYUNDAI ENGINEERING	• Construction on a Hydrogen Fuel Cell Power Plant
	POSCO	• Industrial Use (H2 Reduction Steelmaking)
	KEPCO COMPANY & GROUP	• Renewable Energy and Fuel Cell Power Plant, etc.
	DOOSAN MOBILITY	• Hydrogen Drone
	DOOSAN FUEL CELL	• Fuel Cell Power Plant
	FUEL CELL, GPHILOS, SONAMU, BUMHAN	• Household FC, Building & Military Fuel Cell

Technical Development in Progress

Section	Specification
Hydrogen Production	• Reforming(High Purity H2 Production Unit, Capacity of 500kg/day (233Nm3/h) • Catalyst for Low-Temperature and Low-Pressure Ammonia Synthesis • Construction of LH2 Plant • Nano-particle Synthesis Catalyst • Green Hydrogen Production • High efficiency water electrolysis technology • Distributed H2 Extraction Facility, etc. • High-performance ammonia cracking technology
Hydrogen Transportation	• Pipeline, High Pressure Pipeline Design • H2 Tube Trailer, etc.
Hydrogen Refueling Station	• Liquified Hydrogen and Hydrogen Refueling Station • Hydrogen Refueling Station for Buses, etc.
Hydrogen Utilization	• FECVs, FC Trucks, FC Buses, Drone, etc. • FC Vessels, FC Trains, UAM, etc. • Ecofriendly Fuel Cell for Vessels • High Efficiency SOFC • AEM (Anion Exchange Membrane) Electrolysis • Fuel Cell for Power Generation • High Capacity Fuel Cell, etc.

Hydrogen - Market Update

Latin America

(Argentina, Chile, Colombia)

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Current market situation for hydrogen

Colombia

- The Colombian government issued in September 2021 its National Roadmap of Hydrogen as an important part of its goal to achieve carbon neutrality by 2050.
- The roadmap envision hydrogen investments of up to US$ 5.5bn by 2030.
- Ecopetrol, the Colombian state-owned energy company and the country's largest hydrogen producer, launched in March 2022 its Low-Carbon Hydrogen Strategic Plan involving a US$ 2.5bn investment by 2040 (US$ 140mn per year). Part of the announcement was a pilot project of green hydrogen at its Cartagena refinery with the objective to use 270 solar panels, together with industrial water from the refinery, to produce daily 20 kg of high purity green hydrogen
- Promigas, a regional natural gas distributor, has launched a project of production of green hydrogen and blending with natural gas in transmission and distribution networks. Further, in May 2022, Promigas announced an agreement with Sumitomo Corporation in order to assess the opportunities related to hydrogen mobility within the Colombian marketplace

Argentina

- In April 2022, the US based company MMEX Resources Corp announced an agreement with the Province Tierra del Fuego, Argentina to develop a green hydrogen project to produce 55tns /day with 160MW wind energy source.
- The Australian mining company Fortescue**,** announced a US$ 8.4 bn investment by 2028 to develop a green hydrogen production project in the Province of Rio Negro, Argentina.

Current market situation for hydrogen

Chile

- Chile continues its focus to position itself as a regional/global leader within green hydrogen.
- As part of this progress, the Chilean economic development agency - CORFU – approved through a call in total six projects with a cumulative electrolyzer capacity of 396MW for development, which in total will receive US$50 million in subsidies – see *next slide* for details, but in short those were:

  HyEx- project (US$ 9.5 mn) / Quintero Bay (US$ 5.7 mn) / Faro del Sur (US$ 16.9 mn) / HyPro Aconcagua (US$ 2.4 mn) / Antofagasta Mining Energy Renewable (AMER) (US$ 11.7 mn) / H2V CAP (US$ 3.6 mn)
- Of other projects underway in Chile the Haru Oni project by HIF Global/Siemens/Enel/Exxon/Porsche/ENAP officially started its construction in Sept.21. The project will use 3.4MW wind turbines / 1.25 MW electrolyzer and expects to yield an initial production of 350 tons a year of methanol and 130,000 liters a year of e-fuel.

Latin America (ex. Brazil)

- Green hydrogen has been put on the agenda in most Latin American countries.
- While mostly are at the starting point, Chile has already become a global player (ranked amongst top 6).
- Colombia and Argentina are both in process of implementing new road-maps regarding green hydrogen.
- Uruguay, as already decarbonized, the use of hydrogen will be towards the transport sector.

Projects & prospects

Operator/owner	Name of project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
Engie	Hyex	26 MW	3.200 tns/year		https://tractebel-engie.com/en/references/green-ammonia-production-hyex-project
Linde GmBH	HyPro Aconcaqua	20MW	3.000 tns/year		
GNL Quintero	Quintero Bay H2 HUB Project	10 MW	430 tns/year		
Enel Green Power Chile SA	Faro del Sur	240MW	25.000 tns/year	2025	https://www.enelgreenpower.com/media/press/2021/12/enel-green-power-awarded-16-million-us-dollars-green-hydrogen-proyect-hif-magallanes-chile
Air liquid SA	Antofagasta	80 MW	60.000 tns of e-methanol per year		
CAP SA	H2V Cap	20MW	1.550 tns / year		
HIF Global / Siemens	Haru Oni	300 MW	350tns of methanol 130k lts / year of e-fuel	2025	https://www.hifglobal.com/hif-chile

General comments / strategic headlines

- The green hydrogen in Chile will in principle be produced by water electrolysis powered by solar or wind renewable sources.
- The technological focus is of green hydrogen and the main output is ammonia-production. The first wave is intended for local use in order to decarbonize the mining industry. The 2nd wave will focus on exportation to global markets.
- Main players/drivers in the market: Engie, Siemens, ENAP, AES Chile, Mainstream. Most of the main players are already linked to solar or wind projects and thereof familiar with underlying technology and EPC.
- Opportunities for Norwegian companies: Although green hydrogen production is currently in the early stage, Chile is ranked top 6 globally and various projects are in progress. That being said, new technology, important know-how and project experience will be needed, and thereof the Chilian market will reach out to global innovation and solutions. The first round will be dedicated to pilot projects, while second round or industrial phase will be depending on innovative solutions whereof Norwegian companies can compete versus local or other international competence.

Useful information

- National Hydrogen Strategy: https://energia.gob.cl/sites/default/files/national_green_hydrogen_strategy_-_chile.pdf
- Chile's Green Hydrogen Strategy and investment opportunities : https://www.canninghouse.org/storage/uploads/events/2021-events/06-june/2506-juan-carlos-jobet/Slides_Chiles_Green_Hydrogen_Strategy_lbzgf.pdf
- Ecopetrol announcement: https://www.ecopetrol.com.co/wps/portal/Home/en/?1dmy&page=detailNews&urile=wcm%3Apath%3A%2Fecopetrol_wcm_library%2Fas_en%2Fnews%2Fnoticias-2021%2Fgreen-hydrogen-production
- Colombia Hydrogen Roadmap: https://www.minenergia.gov.co/documents/10192/24309272/Colombia%27s+Hydrogen+Roadmap_2810.pdf;jsessionid=PKN+LxeU+3oV-6H2mWVTTwAF.portal2
- MMEX Resources Corp: https://mmexresources.com/press-release/mmex-resources-corp-and-the-province-of-tierra-del-fuego-argentina-jointly-announce-the-potential-development-of-a-green-hydrogen-project-from-wind-power-in-rio-grande-province-of-tierra-del-fuego/

Hydrogen - Market Update

The Netherlands

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Current market situation for hydrogen

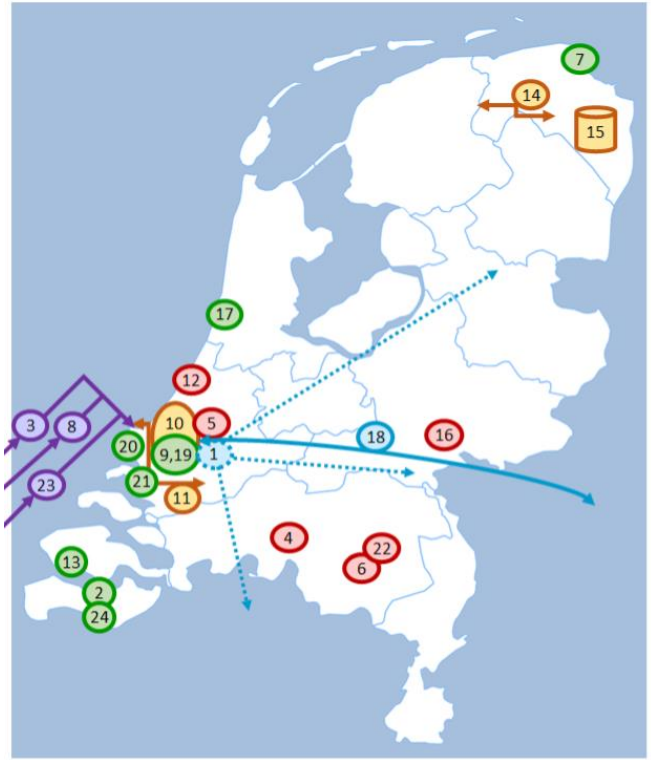
- The Dutch governments renewable energy ambitions are high: On 11 February 2022, the government increased its offshore wind target to 21 GW (from 11 GW) by 2030. That would meet approximately 75% of the electricity needs and zero carbon dioxide (CO_2) emissions from the energy supply by 2050.
- The Dutch government's policy agenda is underpinned by the vision for the future of the clean hydrogen supply chain and the first steps to be taken for its realization. The policy agenda aligns with the agreements on hydrogen outlined in the National Climate Agreement and shows what developments are already underway.
- The National Climate Agreement includes an ambition to scale up electrolysis to approximately 500 MW of installed capacity by 2025 and 3-4 GW of installed capacity by 2030. The Port of Rotterdam has an ambition to serve as a hub handling 20 MTPA Hydrogen in 2050, form which 10% is being produced in Rotterdam.
- Governmental financial support schemes are appliable for 1. Applied research and innovative pilot projects 2. Scaling up through new, temporary operating cost support 3. A subsidy intensity of € 1064 per avoided tonne of carbon dioxide.
- Major drivers for developing the hydrogen business and green shift are the depleting gas reserves in The Netherlands and the National Climate Agreement
- Rules of engagement have been defined in the National Climate Agreement
- The government provides subsidies during various phases of Hydrogen projects
- Governmental subsidies, however no tax holidays
- Banks are in support to finance Hydrogen projects. This will help to underpin their "sustainable" image. Moreover, there is a void to be filled with less financing in the conventional O&G industry
- There is a need to store "green" energy. With the present technology, Hydrogen is a suitable storage medium. Down – a lot of energy efficiency is lost in the transition (more than 25%). Hydrogen is not yet cost competitive with conventional energy supplies.

First round – IPCEI Hydrogen (IPCEI - Important Projects of Common European Interest)

Naam initiatiefnemer	Naam project
Air Liquide B.V.	HyTrucks
Air Liquide Industrie B.V.	ELYgator
Air Products	Pink Camel, “Low carbon energy import (NH3) and distribution (NH3/H2) for Mobility, with kickstart aid for Buses and HDV uses”
Bosch Transmission Technology B.V.	“Electrolyser Stack_project_proposition”
Chemgas Shipping B.V.	H2 Danube-Main-Rhine
DAF Trucks N.V.	Hydrogen Powered Trucks - HyPoTs
ENGIE Energie Nederland N.V.	HyNetherlands
Havenbedrijf Rotterdam N.V.	H2Sines.RDAM – a European shipping corridor for Green Hydrogen
Havenbedrijf Rotterdam N.V.	H2-Fifty
Havenbedrijf Rotterdam N.V.	Hydrogen conversionpark Rotterdam
Havenbedrijf Rotterdam N.V.	Open-access hydrogen infrastructure Rotterdam-Germany | Phase A1: Maasvlakte-Pernis
Hydron Energy B.V.	Enabling breakthrough cost reduction of PEM electrolyser technology
Lukoil and TotalEnergies	H2ero – Green Hydrogen
N.V. Nederlandse Gasunie	Dutch Hydrogen Backbone
N.V. Nederlandse Gasunie	Hydrogen storage; HyStock
NedStack fuel cell technology B.V.	Fuel Cell Giga Factory
Nouryon Industrial Chemicals B.V.	H2ermes
Provincie Zuid-Holland	RH2INE
SHELL Nederland B.V.	An integrated green hydrogen supply chain from production to use Netherlands
Uniper Benelux N.V.	Hydrogen to Maasvlakte (Rotterdam, The Netherlands)
Vattenfall N.V.	CurtHyl, 'renewable hydrogen'
VDL Nederland B.V.	Energy Systems for mobile and stationary applications
Vopak Europa & Africa B.V.	Green H 2 Imports in Europe
Yara Sluiskil B.V.	Haddock

- IPCEI Hydrogen is an initiative by the European Commission. It has the goal of bringing national projects together and create one big European project with a robust hydrogen value chain.
- IPCEI stands for Important Project of Common European interest.
- A total of 25 prospects have been nominated for this first round of IPCEI Hydrogen in The Netherlands

First round – IPCEI Hydrogen



1: Air Liquide – Rotterdam – Hytrucks
2: Air Liquide – Terneuzen – 200 MW
3: Air Products – Rotterdam - Import and distribution for mobility
4: Bosch – Tilburg - Electrolyser Stacks
5: Chemgas Shipping – Rotterdam – inland shipping fleet
6: DAF Trucks – Eindhoven- Hydrogen Powered Trucks
7: Engie – Eemshaven – 100 MW
8: HBR – Rotterdam – A European shipping corridor
9: HBR/BP/Nouryon – Maasvlakte – 250 MW
10: HBR – Maasvlakte – Conversionpark
11: HBR – Infrastructure Maasvlakte to Pernis
12: Hydron Energy – Noordwijkerhout- PEM electrolyser technology
13: Lukoil/Total – Vlissingen – 150 MW
14: GasUnie – Groningen – Backbone
15: GasUnie – Zuidwending – Hydrogen storage
16: NedStack – Arnhem – Fuel Cell Giga Factory
17: Nouryon/PoA/Tata – A'dam Port – 100 MW
18: Province South Netherlands – Rotterdam – RH2INE
19: Shell – Maasvlakte – 200 MW
20: Uniper – Maasvlakte – 50/500 MW
21: Vattenfall – Maasvlakte – 100 MW
22: VDL – Eindhoven - Energy Systems for mobile and stationary applications
23: Vopak – Rotterdam – H_2 Imports in Europe
24: Yara/Ørsted – Sluiskil – 100 MW

Green: H_2 production
Orange: H_2 Infrastructure
Purple: H_2 Import/export
Blue: H_2 use in mobility
Red: H_2 Enabling technologies

Projects & prospects

Operator/owner	Project name	Capacity (MW)	Capacity (mtpa)	Operational	Remarks	Link to project
Shell	NorthH2 Project	2,000		2030	Expansion to 5 GW by 2040	
Air Liquide	ELYgator, Terneuzen	200		2024	170 million m³ /yr	https://industrie.airliquide-benelux.com/en/renewable-hydrogen-electrolyzer-mobility-and-industry
Engie	HyNetherlands Eemshaven	100		2025	Potential expansion to 1 GW	https://www.engie.nl/over-ons/projecten/hynetherlands
HBR/Shell	Maasvlakte	200	0.020	2023	FEED Study 2021	https://www.portofrotterdam.com/en/news-and-press-releases/rotterdam-focuses-on-hydrogen
HBR/BP/Nouryon	H2/Fifty, Maasvlakte	250	0.045	2025	Concept phase	https://www.nouryon.com/news-and-events/news-overview/2019/bp-nouryon-and-port-of-rotterdam-partner-on-green-hydrogen-study/
Lukoil/Total	H2ero, Vlissingen	150	0.023	2026	Feasibility Study 2021	file:///C:/Users/jleo4/Downloads/bb585697-4241-4d4b-9f37-779fc5d24ca6.pdf
Nouryon/PoA/Tata	H2Ermes, Port of A'dam	100	0.015	2024	FEED Study 2021	https://www.portofamsterdam.com/nl/nieuws/h2ermes-groene-waterstof
Orsted/Yara/DOW	SeaH2Land, Schelde	1,000	0.100	2030	Dutch Flemish port	https://seah2land.nl/en/news/2021/03/orsted-to-develop-one-of-the-worlds-largest-renewable-hydrogen-plants
Uniper/HBR	Maasvlakte	100-500		2025	Feasibility Study 2021	https://www.uniper.energy/news/uniper-and-port-of-rotterdam-authority-start-feasibility-study-for-green-hydrogen-plant-at-maasvlakte
Vattenfall	Eemshaven West	10-100		2024	100 MW by 2027	https://www.topsectorenergie.nl/sites/default/files/uploads/TKI%20Gas/publicaties/Overview%20Hydrogen%20projects%20in%20the%20Netherlands.pdf
Vattenfall/HBR	CurtHyl Maasvlakte	10-100		2023	FEED study 2021	https://www.europoortkringen.nl/interesse-vattenfall-in-conversiepark-maasvlakte/
VoltH2/NS Port	Vlissingen	25	0.0036	2024	FEED study 2021	https://volth2.com/
Yara/Orsted	Sluiskil	100		2025	Green amonia, 0.075 MTpa	https://www.yara.com/corporate-releases/orsted-and-yara-seek-to-develop-groundbreaking-green-ammonia-project-in-the-netherlands/

General comments / strategic headlines

- Dutch green electrolysers mainly exist as pilot developments. Siemens is a large player of commercial electrolysers, although still a scale increase of the going 10 MW units that is required.
- Technology focus is on large green hydrogen onshore and offshore plants.
- Siemens electrolysers seem to be the leading technology in the market.
- The main players in the market is: Port of Rotterdam (HBR), Shell and Shell/Uniper, Yara and Orsted.
- Shift in the most important players (newcomers, companies changing business etc.): Conventional O&G players (Shell, Lukoil), suppliers like Air Liquide and Port authorities such as the Port of Rotterdam
- Main contractors are McDermott, Worley Parsons, FLUOR.
- Most important technology provider is Siemens.
- Financial support by Dutch Government whilst conventional banks will be eager to provide project financing.
- Opportunities for Norwegian companies are likely in the area of main contractors e.g. Aker Solutions, Aibel and Subsea 7. The market is waiting for smart electrolyse technologies – would be a good fit, if available in Norway.
- IT/digitalization will be important, with the benefit of reducing CAPEX and OPEX.

Useful information

- Hydrogen strategy: https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/overheid-stimuleert-de-inzet-van-meer-waterstof
- Hydrogen roadmap: https://www.klimaatakkoord.nl/themas/waterstof/documenten/publicaties/2019/06/28/klimaatakkoord-hoofdstuk-waterstof
- Country outlook: https://www.topsectorenergie.nl/sites/default/files/uploads/TKI%20Gas/publicaties/Overview%20Hydrogen%20projects%20in%20the%20Netherlands.pdf
- R&D institutions focusing on Hydrogen: https://www.tno.nl/nl/aandachtsgebieden/energietransitie/roadmaps/co2-neutrale-industrie/waterstof-voor-een-duurzame-energievoorziening/
- EU Commission approves Dutch State Aid for hydrogen production https://www.lexology.com/library/detail.aspx?g=4cc5d750-c776-423c-b688-9be34c97f262
- New Offshore Wind Energy Roadmap https://english.rvo.nl/information/offshore-wind-energy/new-offshore-wind-energy-roadmap

Hydrogen - Market Update

Malaysia

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Current market situation for hydrogen

- As part of the Malaysian government and Petronas initiative to achieve net-zero carbon emissions by 2050, Petronas has started on the hydrogen journey.
- Sarawak Energy, a state energy company in the state of Sarawak has completed a pilot project – hydrogen production plant and refueling station - jointly with Linde. This pilot plant can fully refuel up to five hydrogen fuel cell buses and ten fuel cell cars.
- Sarawak Energy is currently embarking on a feasibility study with Mitsubishi and Chiyoda to look into bulk production of hydrogen for the export market.
- SEDC Energy, Sumitomo Corp and ENEOS Corp signed MoU with plans to commence a feasibility study in January 2021 to establish a hydrogen supply chain using renewable energy in Bintulu, Sarawak. The plant under consideration will involve the production of tens of thousands of tons of CO2-free hydrogen at a hydroelectric power station in Sarawak, Malaysia
- A Malaysian company, Prestech International Bhd signed an MoU in May 2022 with Hydrogène De France SA (HDF Energy) to collaborate on green hydrogen production from hydro power plants in Cambodia and Malaysia. The potential collaboration would address multi sectors decarbonation such as, among others, grids services and industrial application
- Samsung Engineering, Lotte Chemical and POSCO signed a (MoU) with Sarawak Economic Development Corporation (SEDC) in May 2022 to develop green hydrogen and ammonia at a plant to be built at Bintulu, Sarawak. The Sarawak H2biscus Green Hydrogen/Ammonia Project, or H2biscus Project will build a plant with the annual capacity to produce 630,000 mt of green ammonia, 600,000 mt of blue ammonia, 460,000 mt of green methanol and 7,000 mt of green hydrogen

Projects & prospects

Operator/owner	Project/place	Capacity (mtpa)	Remarks
Petronas/ ENEOS Corp	Malaysia	n/a	Petronas signed MOU with ENEOS Corp of Japan to jointly develop a competitive, clean hydrogen supply chain between Malaysia and Japan, and explore other hydrogen opportunities. The MOU will see both parties embark on a technical commercial joint-study of a hydrogen supply chain that includes hydrogen production and its transportation in methylcyclohexane form. In addition, both parties will explore low carbon hydrogen production from Petronas petrochemical facilities and in future green hydrogen produced by renewable energy
Sarawak Energy	Sarawak, Malaysia	Est 120 ton/day	Sarawak Energy jointly with Mitsubishi and Chiyoda undertaking feasibility study on bulk production and export of hydrogen. The study is expected to be completed by end of 2021. Production of hydrogen will be through electrolysis from renewable hydropower energy in the state of Sarawak
SEDC Energy, Sumitomo & ENEOS	Bintulu, Sarawak Malaysia	n/a	MoU to conduct feasibility study in January 2021 to establish a hydrogen supply chain using renewable energy in Bintulu, Sarawak with production of tens of thousands of tons of CO2-free hydrogen

Hydrogen - Market Update

Mexico

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Current market situation for hydrogen

- Mexico’s biggest advancement in Hydrogen has been the creation of the Mexican Hydrogen Association to promote the industry by articulating strategies and actions.
- Low cost of Hydrogen production in Mexico is the main driver. GIZ estimates a cost between 1.1 and 1.8 dollars per kg produced with solar or wind energy by 2030.
- Currently there are no regulations for hydrogen, and it is in a grey legal area
- Some state governments are beginning to look at Hydrogen as a viable alternative
- There is only one mention of green or blue hydrogen in the 2021-2035 Development Program for the National Electric System (Prodesen)
- Interest is growing with over 150 initiatives entering evaluation and planning stages
- Government shies away from renewable energies and is seeking to diminish the participation of the private sector in the energy market

Important and realistic projects

Even with growing interest from privates, the government is avoiding renewables and is currently pursuing legislation to diminish their participation in the market in order to strengthen NOCs. Therefore, there is no assurance that the ongoing initiatives will proceed any further

- Mexico has a network of natural gas pipelines that can be used for transport of green and blue hydrogen; however, it lacks storage infrastructure.
- Main prospects target electrical production via onshore wind and solar
- The state of Oaxaca recently signed an agreement with the Mexican Hydrogen Association to promote hydrogen projects in the state
- Northern border states, particularly Coahuila, Sonora, Chihuahua, Durango and Nuevo León have initiatives to promote projects

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
Dhamma Energy	Delicias Solar II	58	4.425	No	Awaiting permits from energy regulators

- Delicias Solar project is halted by refusal to grant electrical generation permits
- Construction was expected to begin in 2022 and full operation by 2027
- There are other two visible projects in Mexico, one being a cement manufacturer plant that wants to include green hydrogen as source of energy and the other being a solar park in the state of Durango
- Both these prospects are in very early phases

General comments / strategic headlines

- Most industry specific technology would have to be imported. Mexico´s Hydrogen industry is nascent.
- No focus has been defined, so it looks like all bets are on at this point.
- Players in the market have not been identified yet.
- Early stages of industry. As mentioned before. Some interest from Cement industry, maybe steel (very large energy consumers).
- Norwegian companies should monitor market to see what projects start to materialize and how legislation is adapted to the new technology.
- IT/digitalization, yes, when the projects materialize

Useful information

- Mexican Hydrogen Association: https://h2mex.org/en/
- German-Mexico Energy Alliance: https://www.energypartnership.mx/home/potentials-of-green-hydrogen-in-mexico/

Hydrogen - Market Update

Middle East

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Current market situation for hydrogen

- The UAE is aiming for renewables and nuclear facilities to account for half of its installed power capacity by 2050
- The country will adopt carbon capture and storage (CCS) technology to mitigate emissions from continued fossil-fuel production and support blue hydrogen production.
- With ADNOC as the key player, the UAE become a major player in the emerging blue hydrogen market.
- ADNOC believes its existing gas infrastructure and commercial-scale carbon capture utilization and storage (CCUS) capabilities make it well-positioned for the opportunities in the hydrogen market.
- The UAE is the first country in the region to pledge its commitment to achieving net-zero targets by 2050 – and won the bid to host COP 28

Projects (UAE)

Operator/owner	Name of project/place	Capacity (mtpa) / (MW)	Operational	Remarks/links to project
ADNOC, Fertiglobe	World-scale “blue” ammonia production facility in Ruwais, Abu Dhabi	1mn metric tons blue ammonia per annum	FID expected 2022, start up 2025	Builds on ADNOC's advantaged position as a leader in carbon capture and underground storage at Middle East’s first commercial CCUS facility at Al Reyadah (May 2021)
Masdar, ENGIE	Green hydrogen facility to supply Fertiglobe’s ammonia production plants at Ruwais	Capacity of up to 200 MW	Targeted to be operational by 2025	(January 2022)
Korea Electric Power Corporation, Samsung C&T Corporation and Korea Western Power, UAE's Petrolyn Chemie	Green hydrogen and ammonia, KIZAD Industrial Area	Up to 200,000 tons of green ammonia		Agreement to build a $1 billion green hydrogen and ammonia production plant in the United Arab Emirates (June 2022)
Siemens, DEWA	Dewa’s outdoor testing facility of the Research and Development (R&D) Centre at the Mohammed bin Rashid (MBR) solar park in Dubai.	Daylight solar power from the MBR park will allow the plant to produce 20.5kg/hr of hydrogen at 1.25MW of peak power.	Commissioned 2021	• Commissioned the first industrial scale solar-powered green hydrogen facility in the Middle East and North Africa (Mena) region • Contains electrolysis, storage and re-electrification capabilities. • (May 2021)

Prospects (UAE)

Parties	Agreement
ADNOC, bp	• BP and ADNOC will conduct a joint feasibility study for a new blue hydrogen project in Abu Dhabi. • ADNOC, BP, and Masdar will work with Abu Dhabi Waste Management Centre (Tadweer) and Etihad Airways to explore the use of hydrogen and municipal waste to produce sustainable aviation fuels. (May 2022)
ADNOC, bp Masdar, Tadweer, Etihad Airways	The parties have agreed to explore production of sustainable aviation fuels in the UAE using solar-to-green hydrogen and municipal waste gasification (May 2022).
ADNOC, German counterparts (Aurubis, RWE, GETEC and STEAG)	• ADNOC signs MoU and joint study agreements in order to accelerate and deepen collaboration in clean hydrogen. • The UAE has identified Germany as a key export market with a target of providing up to 25% of the country's imported clean hydrogen. • ADNOC entered into a JSA with Uniper and Hydrogenious of Germany and JERA to explore hydrogen transportation between UAE and Germany using Hydrogenious' Liquid Organic Hydrogen Carrier (LOHC) technology. • (March 2022)
TAQA Group, Emirates Steel	MoU to develop a large-scale green hydrogen project enabling the first green steel produced in the MENA region, utilizing green hydrogen to optimize clean steel production level. (August 2021)
Masdar, Siemens Energy and TotalEnergies, Abu Dhabi Department of Energy, Etihad Airways, Lufthansa Group, Khalifa University of Science and Technology, and Marubeni Corporation	Signed a collaboration agreement on the sidelines of Abu Dhabi Sustainability Week (ADSW) 2022, to act as co-developers for a demonstrator plant project for SAF (January 2022)
ADNOC, INPEX Corporation (INPEX), JERA Co., Inc. (JERA), and a government agency, the Japan Oil, Gas and Metals National Corporation (JOGMEC)	Joint study agreement (JSA) to explore the commercial potential of blue ammonia production in the United Arab Emirates (UAE). (July 2021)

Hydrogen – policies (UAE)

- Energy Strategy 2050 was launched in 2017. The US$160bn strategy is the principal framework for renewable energy and wider sustainability initiatives in the UAE. Its goal is for 44% of the energy consumed in the UAE to be from renewable sources by 2050, with a further 38% from natural gas, reducing the carbon footprint of power generation by 70%. The hydrogen projects that we are seeing in the UAE are to help achieve these goals.
- The UAE and Germany entered into an energy partnership in 2017 to promote dialogue and research on the transition to renewables and provide a framework for collaboration on individual elements of sustainable energy. Germany considers hydrogen to be an important tool to meet its commitments to the Paris accord (more detailed information on the German Hydrogen strategy can be found here) and sees the UAE's potential for hydrogen production.

Projects & prospects (Oman)

Operator/owner	Name of project/place	Capacity (mtpa) / (MW)	Remarks/links to project
Scatec, ACME Group	Green ammonia, Duqm Special Economic Zone	First phase expected to produce 100,000 mtpa green ammonia, to be expanded over time to 1.2 million tons, powered by 500MW of solar capacity.	50-50 JV (March 2022)
Oman's Ministry of Energy and Minerals, bp	Renewable energy, green hydrogen and ammonia, Duqm Industrial zone		Strategic framework agreement with BP to deliver a multiple-GW renewable energy and green hydrogen project by 2030. (January 2022)
Oman Hydrogen Center (OHC), Siemens Energy Oman	Hydrogen energy projects		Sign MoU to collaborate on hydrogen projects (November 2021)
Marubeni, Linde, Dutco Group, OQ	SalalaH2: Green hydrogen and green ammonia production facility in the Salalah Free Zone, Oman	1,000 tons a day, Electrolysis capacity of 400MW to produce green H2, Electrolyser will be powered by approximately 1GW of solar and wind power	Signed a joint development agreement (JDA) to conduct technical and commercial feasibility studies on developing a (October 2021)

Projects & prospects (Oman)

Operator/owner	Name of project/place	Capacity (mtpa) / (MW)	Remarks/links to project
OQ, DEME, Uniper	Hyport: green hydrogen, Duqm Special Economic Zone	Electrolyser capacity of between 250MW to 500MW, which will be powered by up to 1.3GW of solar and wind renewable energy.	Uniper will provide engineering services and negotiate an exclusive offtake agreement for green ammonia which will be produced by the Hyport scheme (July 2021) The consortium began undertaking a solar and wind monitoring study for the project in 2019.
OQ, Intercontinental Energy EnerTech	Green hydrogen plant, Oman	Will be powered by 25GW of renewable energy.	The consortium began undertaking a solar and wind monitoring study for the project in 2019, and has identified an area in the central Al-Wusta governorate (May 2021)
ACME Group, Oman Company for the Development of the Special Economic Zone at Duqm (Tatweer)	Green ammonia	2,200 mt per day	• Signed an MoU to develop a facility with the capacity to produce up to 2,200 metric tonnes of green ammonia per day. (March 2021) • $2.5bn hydrogen investment

June 2022: Oman is planning to launch a national energy firm, Hydrogen Development Oman, focusing on green hydrogen projects, will be a wholly owned subsidiary of the country's energy transition champion Energy Development Oman, or EDO.

Key players: OQ, Ministry of Energy and Minerals, EDO, HDO

Projects & prospects (Qatar & Kuwait)

- In Qatar, despite its huge natural gas resource base and emerging CCS capacity, there is no sign yet of the country developing a hydrogen industry. The gas-rich Gulf state is boosting its CCS capacity to 7 million tons/yr by 2027 and aims to make utility-scale renewables a significant share of the country's energy mix. However, the country appears to be focusing on decarbonizing Qatar Petroleum's LNG exports, while also lowering domestic electricity costs and emissions. Qatar is the world's largest LNG exporter.
- Saudi Arabia has committed to converting LNG to hydrogen. If it were to export LNG it would be in direct competition with Qatar. Qatar has not indicated any plans to do the same with its LNG.
- https://www.middleeasteye.net/news/gulf-qatar-saudi-arabia-uae-hydrogen-green-next-fuel
- https://www.energyintel.com/pages/eig_article.aspx?DocID=1099142

News

- February 2022: Kuwait is developing a low-carbon strategy that will ease its transition through to 2035 on a "continuous basis". It is considering a pilot project in "blue and green hydrogen technology"
- May 2022: On 20 May, Qatar's minister of state for energy affairs Saad Sherida Al-Kaabi and the German minister for economic affairs and climate action Robert Habeck signed a joint declaration of intent to further promote the cooperation between the two countries in the field of energy. The Working Group on LNG and hydrogen will support the development of LNG and hydrogen trade relations between Qatar and Germany.
- October 2021: Qatar Energy and H2Korea will collaborate on supporting growth in the hydrogen industry, technology development, and the hydrogen energy supply
- October 2021: Qatar Energy and Shell sign agreement to work together on blue and green hydrogen projects in the UK

General comments / strategic headlines

- Technological focus UAE: To export to Europe
- Technological focus Oman: To export, they have wind and solar capabilities. UAE does not have wind capability.
- Main players/drivers in the market:
  - Saudi: ACWA Power and Air Liquide – they could play a role in other GCC (Gulf Cooperation Council) countries as well.
  - UAE: ADNOC, Mubadala.
  - Oman: Ejaad, OQ, PDO.
  - Policy/Non-governmental organizations in GCC: Dii Desert Energy, MENA Hydrogen Alliance
- Most important clients/stakeholders in your markets; technology providers, operators, main contractors/EPCI, engineering companies, financial market/investors, organizations etc.:
  - Saudi, ACWA Power and Air Liquide – they could play a role in other GCC countries as well.
  - UAE: ADNOC, Mubadala.
  - Oman: Ejaad, OQ, PDO.
  - Policy/Non-governmental organizations in GCC: Dii Desert Energy, MENA Hydrogen Alliance

Hydrogen - Market Update

Poland

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Current market situation for hydrogen

- Poland, with its annual production of 1,3 million ton of H2 is presently the 3rd largest producer of hydrogen in Europe, after Germany and the Netherlands. It is almost entirely grey H2, produced with high CO2 emission and widely used in domestic industrial processes. 32% of the H2 is produced in the chemical industry (4 large facilities belonging to the Azoty Group), 15% in the petrochemical sector (PKN Orlen and Lotos), 12 % in the coke industry (mainly owned by JSW and Arcelor Mittal), and the remaining 41% in various different plants. In Poland, production of H2 for self-use in industry i larger than in other EU countries, and the amount of hydrogen for commercial use is small. Most of the H2 traded on the Polish market comes either from excess capacity from chemical plants or refineries, or is a by-product of chemical processes.
- The main documents shaping the hydrogen market in Poland are: (1) the European Green Deal, (2) the Hydrogen Strategy for a Climate-Neutral Europe (2020), (3) Directive of the EU on the promotion of the use of energy from renewable sources (RED II Directive, 2018), (4) the so-called taxonomy, i.e. unified classification of sustainable development actions introduced by Regulation (EU) 2020/852 from 2020 establishing a framework to facilitate sustainable investment and amending Regulation (EU) 2019/2088, (5) Fit for 55 Package., (6) the Polish National Energy and Climate Plan 2021-2030, (NECP from 2019), (7) Energy Policy of Poland until 2040 (PEP2040 from 2021), and (8) the recently adopted Poland's Hydrogen Strategy (PHS from Dec. 2022), slides 3,4.
- All these documents outline directions in which H2 economy should develop and some of them name possible support mechanisms. The aim is to gradually go away from technologies producing grey H2 towards production of blue H2 implementing CCUS technologies, and green H2 produced from water using RES. The potential for blue and green H2 in Poland is large, as there is a need to convert the presently used technologies of H2 production for the purpose of the above mentioned industries, develop the use of H2 in the energy sector, which is presently relying mainly on fossil fuels, and in the transport sector.

Current market situation for hydrogen

- The ETS mechanism, which gradually increased the cost of allowances, provides a market-based incentive for a gradual shift from fossil-based H2 to other forms of its production. Municipalities in Poland are interested in using hydrogen in public transport, as the Fit for 55 Package obliges the to resign totally from buying fossil fuelled buses. The municipalities have their local support instruments for hydrogen projects.
- Some important actions regarding green H2 development have taken place before the Polish Hydrogen Strategy was announced. The National Fund for Environment Protection announced in the beginning of 2021 the program “Nowa Energia”, with a budget of 2,5 billion PLN (2,3 billion in the form of loans and 200 million of subventions), enabling support of innovative energy projects, including pilots for production, storage and usage of H2 e.g. for transport purposes. The programme received many applications. Some of them are included in the table on slide 6.
- The first Polish H2 Cluster was established in 2017 in Gdansk. The Cluster runs a number of projects aimed at H2 development in Poland and especially in the Pomerania region, such as the Pommerania H2 Valley, NeptHyne (Energy for Offshore windfarms for H2 production, with desalination of seawater), The fist Agricultural H2 Valley in Europe (LoI signed). The Cluster organises also PCHET, an annual Hydrogen Conference in October in Gdansk. A LoI for establishing the second hydrogen cluster, Swietokrzyski Klaster Wodorowy in Kielce.
- The first steps have been taken, e.g. Letters of Intent signed, to establish 6 Hydrogen Valleys: Pomorska (Gdansk), Mazowiecka (Warszawa), Podkarpacka (Rzeszow), Dolnoslaska (Wroclaw), Wielekopolska (Poznan), Slasko-Malopolska (Krakow-Katowice).
- The Ministry of Climate and Technology is currently working on The Polish Sector Deal for Development of Hydrogen Economy.

Polish Hydrogen Strategy by 2030 with an outlook by 2040

- On Dec. 7 2021, the Polish Hydrogen Strategy until 2030 with an outlook until 2040 (PHS) was announced, setting out the main objectives for the hydrogen economy development in Poland and the actions needed to attain them. PHS is a part of the global European and national efforts to achieve a low carbon economy, such as outlined in: 1992 UNFCCC Convention, 1997 Kyoto Protocol, Paris Agreement and the European Green Deal.
- On the national level, PHS is in line with the objectives with the following policy documents: Strategy for Responsible Development 2020 with an outlook until 2030 (SRD), Polish Energy Policy by 2040 (PEP 2040), National Energy and Climate Plan for 2021/2030 (NECP), and the National Policy for the Development of Alternative Fuel Infrastructure.

Polish Hydrogen Strategy by 2030 with an outlook by 2040

- The document is an important part of a national strategy aimed at decarbonization of Poland's economy and will play the key role in the Polish energy transformation. It specifies 3 key areas of development, i.e., the industry, the power generating sector and transport, and sets out 6 specific OBJECTIVES to be achieved:

1. Use of H2 technologies in the power and heating sector

Support of R&D and implementation in co-and poly-generation systems for residential and office buildings and small estates using fuel cells, and in P2G and G2Ps systems. Support of effective cooperation of the gas system and electric power system, according to the concept of „sector coupling".

2. H2 as an alternative fuel for transport

Mainly for urban bus transport, heavy long-haul transport, light fleet vehicles (forklifts, etc.), rail transport incl. H2 locomotives, maritime and river transport, in a longer run also aviation (drones). H2 will be an alternative fuel for those means of transport where electrification is impossible or unprofitable. By 2030, 800-1000 buses and at least 32 refueling stations will be in operation. Production of H2 based fuels (ammonia and methanol) will take place.

3. H2 use for decarbonization of industry

The industries that today use large quantities of H2, i.e., the chemical, petrochemical and refinery sectors, will be able to use low-carbon H2. This applies also to sectors requiring temperatures exceeding 200oC, e.g. steel, ceramics, glass production. To develop such H2 solutions public support will be given for relevant pilot installations. By 2030 at least 5 Hydrogen Valleys, i.e., centers of excellence for implementation of H2 economy are planned.

Polish Hydrogen Strategy by 2030 with an outlook by 2040

- The document is an important part of a national strategy aimed at decarbonization of Poland's economy and will play the key role in the Polish energy transformation. It specifies 3 key areas of development, i.e., the industry, the power generating sector and transport, and sets out 6 specific OBJECTIVES to be achieved:

4. H2 production in new installations

Launching H_2 production facilities from low- and zero-emission sources: renewables and based on fossil fuels equipped with CCUS solutions. Within the next 5 years, support will be provided to R&D and implementation of low-emission technologies producing H_2. Launching such facilities with a total capacity of 50 MW. The aim is to increase the installed H2 production capacity to 2 GW by 2030.

5. Efficient and safe transmission, distribution and storage of H2

In the initial stage, H2 till be transported by road and rail in tank-trucks and tanks. In parallel an adjustment of existing LNG networks for H2 transmission and distribution will take place. When the demand increases, the networks will be ready for transporting LNG/H2 mixture, and some will be dedicated to clean H2 transport. For storage of large amounts of H2, underground salt caverns will be used; smaller quantities, especially in the initial phase, will be stored in aboveground tanks.

6. Creation of a stable regulatory framework for H2 handling

This is a priority for the Polish government and administration. It is necessary to come with regulations that will remove the existing barriers, develop a hydrogen market, and establish such conditions that there will gradually grow the use of renewables for electrolysis purposes. The legal regulations and market standards will be designed by Ministry of Climate and Environment in cooperation with industry and science organizations.

Polish Hydrogen Strategy by 2030 with an outlook by 2040

Within the scope of the objectives, the PHS lists and describes 42 activities that will be supported by the government and administration enabling building a H_2 economy. In pursuit of the objectives defined in the PHS the government plans to undertake the following activities:

1. Conclude a Polish Hydrogen Economy Sector Deal
2. Create a Hydrogen Valley Ecosystem
3. Establish a Hydrogen Technology Centre
4. Support education aimed at building competences for the hydrogen economy
5. Carry out informative activities and public campaigns
6. Engage broadly in European and international cooperation

Polish Hydrogen Strategy by 2030 with an outlook by 2040

The costs

The implementation of the PHS requires allocation of approx. **1 billion PLN** (200 mln EUR) by 2025 and approx. **10 billion PLN** (2 bln EUR) by 2030. Total allocation is estimated at over **11 billion PLN**.

Expenditures foreseen in this period will include hydrogen technologies in the energy, transport, and production sectors.

Timeline for implementation of the Strategy

2021	Establishment of funding programmes. Formation of the Polish H2 Partnership. First draft of H_2 policies. Active participation in the EU law policy creation
2022	Introduction of a set of H_2 policies. Establishment of the Hydrogen Technology Centre
2023	Introduction of new programmes aimed at hydrogen economy development
2025	Verification of the achievement of the strategy objectives. Possible revision.
2025-30	Financial and legislative support to hydrogen economy
2030	Strategy evaluation and necessary revision

IPCEI Hydrogen Poland

Name of initiator(s)/project owner	Name of project*	Remarks/link to project
EkoEnergetyka Polska S.A.	Infrastructure for fueling H2 driven vehicles (buses)	Ekoenergetyka is presently producing charging stations for electric vehicles. The aim of their IPCEI project is to develop a pilot network of H2 fueling stations for municipal bus transport. The company's policy is to inform as little as possible about it on internet: https://ekoenergetyka.com.pl/pl/elektromobilnosc-napedzana-wodorem-ekoenergetyka-pracuje-nad-rozwojem-technologii-wodorowych/
LOTOS Asfalt Sp. z o.o.	LOTOS Green Hydrogen	The project is the first phase of a large scale green H2 production for the refinery. Phase 1: Electrolysis installation of 100MW, fuel cells - 20 MW, software development for M&O, H2 storage facilities. Phase 2&3 of the project (outside the IPCEI spplication) will by 2030 lead to LOTOS becoming the regional leader in Green H2 production and distribution, operating electrolyzers of 4 GW (dispersed units), fuel cells – 1 GW, a network of H2 fueling infrastructure for trasnport, large scale H2 storage in underground caverns, transmission of H2 by using gas pipeline distribution infrastructure https://www.lotos.pl/322/p,174,n,5178/centrum_prasowe/aktualnosci/lotos_chce_produkowac_zielony_wodor
PGNiG S.A.	Hydrogen – Clean Fuel for the Future	The ICPEI project is one of the modules of the large-scale complex H2 programme, consisting of development of full-scale H2 storage in underground geological structures (salt caverns). Construction of demontstration plant including underground energy storage in the form of green H2, including high power electrolyser, fuel cells and hydrogen turbine and integrated ifrastructure for H2 distribution, including transport throough the existing gas pipeline infrastructure. https://pgnig.pl/aktualnosci/-/news-list/id/startuje-nowy-program-wodorowy-pgnig/newsGroupId/10184

IPCEI Hydrogen Poland

Name of initiator(s)/project owner	Name of project*	Remarks/link to project
PGNiG TERMIKA S.A.	New LNG heat block for H2 and biomethane firering	Green hydrogen will be produced using energy from the biomethane fired combined heat and power block, being a part of Warsaw district heating system. The hydrogen is planned to be used fuel for green transport. https://termika.pgnig.pl/node/1125
PKN ORLEN S.A.	“Hydrogen Eagle”	The aim is to develop an international chain of hydrogen hubs powered by RES and build innovative facilities to convert municipal waste into zero- and low-emission hydrogen. Six hydrogen hubs, 3 in Poland, Two in the Czech Rep. And one in Slovakia. Cconstruction of more than 100 hydrogen refuelling stations for individual, public and cargo transport. www.orlen.pl/en/about-the-company/media/press-releases/2021/orlen-group-to-launch-international-hydrogen-program
PESA Bydgoszcz S.A.	Hydrogen Locomotive	https://pesa.pl/en/railway-premiere-of-the-year-pesa-presented-the-hydrogen-locomotive-at-trako/ https://www.railvolution.net/news/pesa-presented-its-hydrogen-locomotive

IPCEI Hydrogen Poland

Name of initiator(s)/project owner	Name of project*	Remarks/link to project
POLENERGIA S.A.	Renewable Hydrogen Factory	The project is an innovative solution for district heating aimed at Installatio of an energyblock for cofiring natural gas with hydrogen. Polenergia is also working on establishing the first Polish hydrogen valley located in southeastern Poland. https://www.polenergia.pl/wp-content/uploads/2021/11/reportontheoperationsofthepolenergiagroupforthefirsthalfof221.pdf
Grupa SYNTHOS	Hydrogen from high temperature steam from SNR reactor	https://www.synthosgroup.com/en/energy-and-services/eco-energy/ https://biznesalert.com/synthos-says-when-the-construction-of-smr-in-poland-starts-and-announces-investments-in-green-hydrogen/
TAURON Wytwarzanie S.A.	A complex H2 project including all the elements of the H2 value chain	The project is only in an early conceptual phase. No information availble on Tauron's website, so far. Most likely the project will include the concept of methanisation desribed https://www.tauron-wytwarzanie.pl/innowacje/co2-sng-logo

Projects & prospects

Operator/owner	Name of project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
ZE PAK	H2 production in the Konin CHP plant	70 MW (PV farm)		2022	The hydrogen will be produced using electrolysis. Received financing from Innovation Fund.
Marine-Service	H2 production plant in Kamien Pomorski, near Szczecin	42 MW (wind farm)	4 MW for H2 production	Initial stage	H2 produced by using electrolysis with energy form neighboring wind farm. Application to NFEP for 130 million PLN
Hydropolis United	H2 production from plastic waste			Initial stage	DMG technology from Powerhouse Energy in the UK. Application to NFEP for 80 million PLN
PAK-PCE & Respect Energy	Polish H2 Bus plant			Initial stage	The plant will be placed between Lublin and Swidnik. Planned annual production: 500 buses per year.

Projects & prospects

Operator/owner	Name of project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
Lubeslski MPK (punicipal enterprice)	H2 filling stations for busses			Initial stage	Lublin will be the first Polish city with a H2 bus for municipal transport
Ultralight Green Cylinders	H2 storage facilities in composite carbon fiber tanks			Initial stage	Applied to NFEP for 46 million.
Sescom	Infrastructure for H2 fueling. 3 stations			Initial stage	H2 fueling stations for municipal buses and cars. Self designed electrolyser giving 530 kg of H2 perd day. Project worth 71 million PLN. Application for 60 million PLN. Sescom has a LoI signed with the city of Pila .
Sescom	Electroliser of own design	100 MW		Initial stage	LoI signed with LOTOS. The project will be preceded by a pilot installation of 1MW.

General comments / strategic headlines

- The presently used technologies for producing hydrogen, mainly steam reforming of methane/LNG, will need to be replaced by blue and green hydrogen production. There is and will be a demand for electrolysis equipment and other elements of the H2 value chain.
- What is the technological focus: The development is very broad, covers all the subsectors and all kinds of end-users. The development is at an early stage.
- The most important technologies going forward in the market will be production of green hydrogen from RES, especially from wind and PV farms. Infrastructure for using H2 for transport, mainly municipal.
- The large Polish state-owned energy groups, e.g. Tauron, PGE; big state-owned players form the petrochemical sector, LOTOS, PKN ORLEN, PGNiG, private energy companies: ZE PAK, Polenergia, other private enterprises: e.g. Synthos, Sescon, PESA, Ekoenergetyka
- The market is at an early stage. Newcomers have the possibility to influence the directions in the market development.
- Norwegian companies should contact the driving local players. Focus could be joint development of projects with Norwegian technological input.
- IT/digitalization is a a wide field for cooperation. Poland is still in an initial stage of development.

Useful information

- Polish Hydrogen Strategy, https://www.gov.pl/web/klimat/polska-strategia-wodorowa-do-roku-2030
- Polish Wind Energy Association's Report on Green Hydrogen in Poland, www.psew.pl/wp-content/uploads/2021/12/Raport-Zielony-Wodor-z-OZE-77MB.pdf
- Important domestic hydrogen organizations, clusters, government institutions etc.
  - Ministry of Climate and Environment, https://www.gov.pl/web/climate
  - Ministry of Economic Development and Technology, https://www.gov.pl/web/development-technology
  - IGG, The Chamber of Natural Gas Industry, https://www.igg.pl/en/node/369
  - Cluster of Hydrogen Technologies in Gdansk, https://klasterwodorowy.pl/home,1,en
  - Swietokrzyski Hydrogen Cluster, only a LoI signed, https://sksmkielce.pl/o-firmie/swietokrzyski-klaster-wodorowy.html
- R&D institutions focusing on Hydrogen:
  - Gdansk Technical University, PG Center for Hydrogen Technology, https://centrumwodorowe.pl/en
  - Institute of Flow Machinery PAN, https://www.imp.gda.pl/en/, https://www.imp.gda.pl/projekty/programy-ncbir/programy-strategiczne/ps4/prototypy/produkcja-wodoru/
  - Warsaw Technical University, https://www.pw.edu.pl/engpw, https://www.pw.edu.pl/Aktualnosci/PW-bedzie-wspoltworzyc-Mazowiecka-Doline-Wodorowa
  - Wroclaw Technical University, https://pwr.edu.pl/en/
  - AGH University of Science and Technology in Krakow, https://www.agh.edu.pl/en/
  - Rzeszow Technical University, https://w.prz.edu.pl/en/, https://wch.prz.edu.pl/aktualnosci/technologie-wodorowe---nasze-nowe-propozycje-379.html

Hydrogen - Market Update

Portugal

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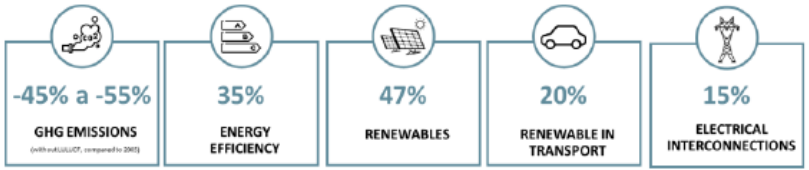
Norwegian Energy Partners

Current market situation for hydrogen

- Portugal is a leading country in renewable energies in Europe and has achieved high levels of renewable penetration.
- Portugal's hydrogen includes building hydrogen fuel stations and making fuel cell buses like those produced by domestic company Caetano (in cooperation with Toyota). In addition, the share of hydrogen used in the national gas network is to rise to 15% by 2030 (up from just 1% in 2020).
- The national hydrogen strategy called EN-H2 has as main objective to introduce an element of incentive and stability for the energy sector, promoting the gradual introduction of hydrogen as a sustainable pillar and integrated in a more comprehensive strategy of transition to a decarbonized economy.

Portugal targets for 2030 (source: PNEC 2030)

	2018	EU position	2020 target	2030 target
RES in Final Energy consumption	30.3%	6th	31%(1)	47%
RES in the Electricity sector	52.2%	5th	60%	80%
RES in the Transport sector	9.0%	5th	10%(1)	20%
RES in the Heating and Cooling sector	41.2%	7th	36%	49%



First round – IPCEI Hydrogen (IPCEI - Important Projects of Common European Interest)

Name of initiator(s) / project owner	Name of project	Remarks/link to project
STATE OF PORTUGAL (EDP / GALP / VESTAS)	H2SINES	Initially a huge project (2.85 b€ budget), but the main industrial stakeholders have leaved the project as the government subsidy level was too low (around 200 M€).

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
State of Portugal	H2 SINES				Cancelled
EDP	TDB				Following its resignment from H2SINES this summer, EDP will develop its own projects of green hydrogen.
GALP	TBD				Following its resignment from H2SINES this summer, GALP will develop its own projects of green hydrogen.

General comments / strategic headlines

Portugal has selected multi-billion post-coronavirus hydrogen projects

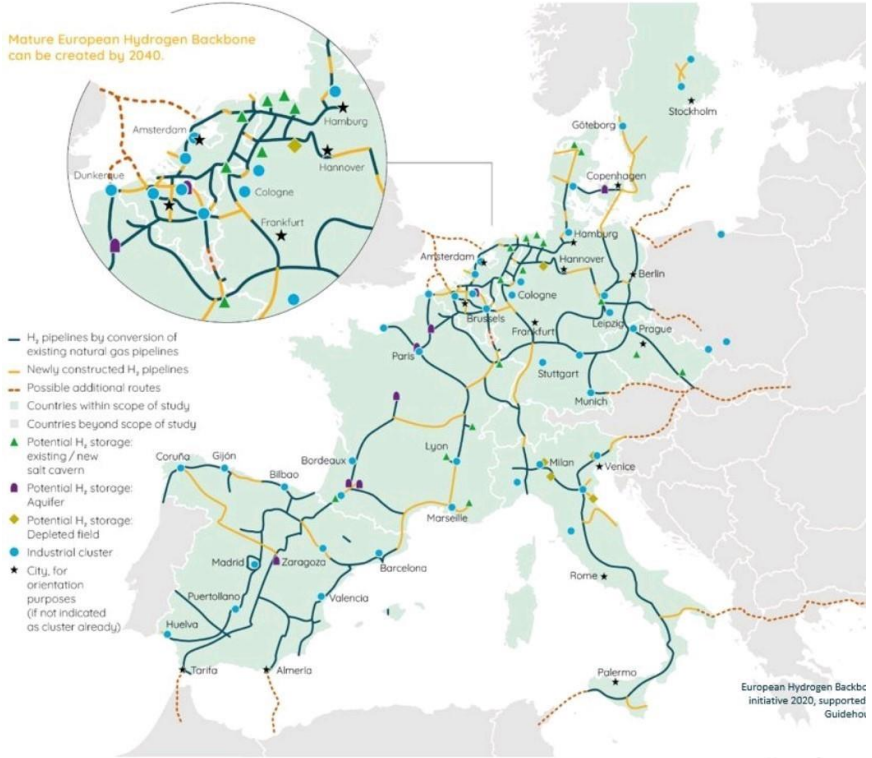
- In August 2020 Portugal’s government selected more than 30 multi-billion euro hydrogen projects interested in building production units of so-called “green” energy in the country after the coronavirus pandemic. The selection comes as Portugal prepares an application to Europe’s Important Project of Common European Interest (IPCEI) scheme for hydrogen, part of a strategy to speed up renewable hydrogen projects in polluting sectors.
- Portugal's utility EDP-Energias de Portugal EDP.LS, oil group Galp GALP.LS, holding company REN RENE.LS are among the selected consortiums. They aim to create an industrial project for the production of "green" hydrogen near Sines, south of Lisbon. The goal is to build a solar-powered hydrogen unit near the port of Sines, which would start in 2021 and could attract up to 5 billion euros of private investment.

Portugal and the Netherlands sign green hydrogen agreement

- Two months after Portugal announced its national hydrogen strategy, Portugal and the Netherlands have signed a green hydrogen agreement which features a €7 billion investment by 2030. It consists of plans to develop the Sines hydrogen facility, the creation of a national laboratory focused on the technology as well as efforts to decarbonise heavy transport. Portugal have received 74 expressions of interest from parties eager to tap into the move to bring forward green hydrogen projects capable of decarbonizing heavy industry.

General comments / strategic headlines

The transportation of green hydrogen from Portugal to the Netherlands will be explored thanks to a new memorandum of understanding signed between the countries. As part of the agreement, which links both countries' 2030 hydrogen plans, a strategic export-import value chain will be developed to enable the shipping of renewable hydrogen from a project being planned in the Portuguese city of Sines to the port of Rotterdam.



Useful information

22/02/2021 The Portuguese Hydrogen Strategy to Decarbonise its Economy: The Project to Produce Green Hydrogen by Electrolysis - The Europe...

Climate Energy Environment Industry

The Portuguese Hydrogen Strategy to Decarbonise its Economy: The Project to Produce Green Hydrogen by Electrolysis

22 February 2021

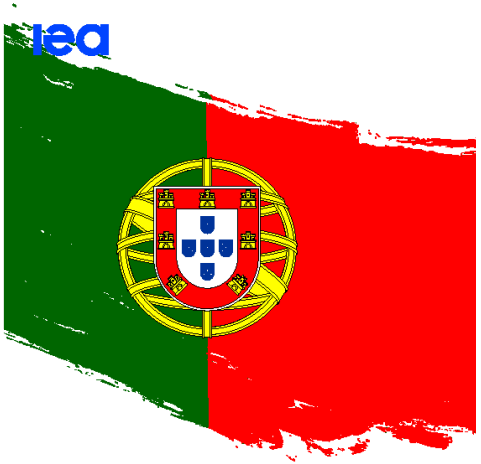
By **João Pedro Matos Fernandes**, Portuguese Minister of Environment & Climate Action

Guardar

Portugal was the first country in the world to assume the goal of being carbon neutral in 2050. Working towards that objective our last coal-fired power station will be closed this year. We believe 2021 will be a decisive one in driving the European economy towards recovery and growth, preparing for the future, namely through the two-fold – green and digital – transition and strengthening society's resilience. Within the Portuguese Presidency of the Council of the EU we look forward to conclude the negotiation of the European Climate Law with the European Parliament, enshrining climate neutrality and an ambitious emission reduction target for 2030 of at least 55% when compared to 1990.

https://www.europeanfiles.eu/energy/the-portuguese-hydrogen-strategy-to-decarbonise-its-economy-the-project-to-produce-green-hydrogen-by-electro... 1/3

[Summary]



Portugal 2021
Energy Policy Review

International Energy Agency

[Portugal 2021 energy policy review]

[Presentation of the Portuguese association of renewable energy (in Portuguese, but easy to catch)]

Hydrogen - Market Update

Singapore

Norwegian Energy Partners

Current market situation for hydrogen

- Hydrogen can serve as an energy carrier to store and transport renewable energy and has the potential to diversify Singapore's fuel mix towards low-carbon options for electricity generation and heavy transportation.
- Leading regulatory, policy and strategy space for the hydrogen: Singapore Government actors at National Research Foundation, National Climate Change Secretariat (NCCS), Singapore Economic Development Board (EDB) and Energy Market Authority (EMA)
- Public fundings and incentives: Available for Singapore and Singapore incorporated entities
- Influences from the bank, finance and investors: Temasek (Singapore Sovereign Wealth fund and local major banks are providing green financing options with better interest rates
- Strong interest in Singapore to complement its long-term strategy to halve emissions from its 2030 peak and achieve net-zero emissions as soon as viable in the second half of the century.

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
New Zealand	MOU	NA			1. Chart standards and certifications and scale up respective hydrogen economies 2. Establish supply chains for low-carbon hydrogen and its derivatives 3. Conduct joint research, development, and deployment studies and 4. Strengthen networks and partnerships
Australia	MOU				Same as above
Chile					Same as above
Keppel, MOL and Vopak	MOU			TBA	Keppel Data Centres announced an MoU with Kawasaki Heavy Industries, Mitsui O.S.K. Lines, Vopak LNG, and Linde to study the commercial viability of a liquefied hydrogen supply chain in May 2021
MPA, SLNG	MOU				Chiyoda, Mitsubishi, PSA, Jurong Port, City Gas, Sembcorp, SLNG (with the support of MPA and NRF) signed an MoU to develop a business case for the technical and commercial feasibility of hydrogen import to Singapore

General comments / strategic headlines

- For Singapore with its limited renewable energy resources, producing green hydrogen will be challenging. This makes the cost of storing and transporting hydrogen even more salient.
- What is the technological focus: maritime sector, aviation, power sector and the mobility sector (transportation).
- Singapore is one of the most solar-dense cities in the world. By 2030, we aim to quintuple the amount of solar energy produced domestically to at least 2 gigawatt-peak (gwp) and the need to embrace hydrogen as a key energy source to improve sustainability of our power supply and ensure energy security and affordability.
- Main players/drivers in the market: government actors, academia and established players like Singaporean yards and global energy players based in Singapore.
- Opportunities for Norwegian companies: maritime and offshore suppliers with major projects with yards and energy suppliers and car transportation.

Useful information

- Hydrogen strategy https://www.nccs.gov.sg/media/press-release/submission-of-singapores-enhanced-nationally-determined-contribution-and-long-term-low-emissions-development-strategy
- National reports : https://www.nccs.gov.sg/docs/default-source/default-document-library/hydrogen-study-report.pdf

Hydrogen - Market Update

Spain

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Norwegian Energy Partners

Current market situation for hydrogen

- The Spanish Hydrogen Strategy, approved in October 2020, sees hydrogen as an enabler for the decarbonization of sectors where electrification is not the most efficient solution or is not technically possible in the medium term.
- The plan involves government investment of around €8.9billion in the next 10 years.
- By 2030, Spain aims to install 4 gigawatts-worth of the electrolysers needed to split water into hydrogen and oxygen (10% of the EU's target of 40 gigawatts).

First round – IPCEI Hydrogen (IPCEI - Important Projects of Common European Interest)

Initiator(s) / project owner	Project	Remarks/link to project
ACCIONA	Green Hysland Initiative	Green Hysland in Mallorca, the first green hydrogen project in a Mediterranean country due to get European funding (acciona.com)
IBERDROLA	Iberlyzer	Hidrógeno verde producción 100% sostenible | IberLyzer

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
ENDESA	Galician power plant As Pontes	100 MW		2024	
ENAGAS	La Robla hydrogen plant	60 MW	9	2024	
REPSOL SAUDI ARAMCO	Synthetic fuel production in Bilbao plant		3.6 Ml/year	2024	Budget: 60 M€

General comments / strategic headlines

Main target sectors of analysed H2 strategies per country (Source: World Energy Council – Sept. 2020)

Hydrogen use sectors	EU	DE	NL	FR	ES	IT	UK	NO	CH	UA	RU	JP	KR	CN	AU	CA
Industry	✓	✓	✓	✓	✓	(✓)	✓	✓	✗	✗	✓	(✓)	✗	✗	✓	(✓)
Power	(✓)	(✓)	(✓)	✓	(✓)	✗	✓	✗	✗	✓	✓	✓	✓	✓	✓	(✓)
Transport	✓	✓	✓	✓	✓	(✓)	✓	✓	✓	✓	(✓)	✓	✓	✓	✓	✓
Buildings	(✓)	(✓)	(✓)	(✓)	✗	✗	(✓)	✗	✗	(✓)	(✓)	✓	✓	✗	(✓)	(✓)
Export	✗	✗	✗ [1)]	✗	✓	✗	✗	✗ [2)]	✗	✓	✓	✗	✗	✗	✓	✗

✓ main sector (✓) less relevant ✗ not addressed

1) Hydrogen imports transit to other countries (e.g. Germany) considered.
2) For Norway, hydrogen is not targeted for direct export, but indirectly through the export of NG with local CCS.

Useful information

News from Spain (Oct 2020-March 2021)

- Recovery plan for Spain

The Government of Spain presented the Spanish recovery transformation and resilience plan. IDAE will manage 5.4 billion euros of the plan

In accordance with Sustainable Recovery, and taking into account the current worldwide pandemic context, we'd like to highlight that the Government of Spain presented the "Recovery, Transformation and Resilient Plan for the Spanish Economy" on October 7th, 2020. A roadmap for the modernization and growth of the Spanish economy and the creation of employment after the impact of the #COVID19 pandemic.

Spain recovery plan will invest €72bn of European funds to create 800,000 jobs

This Plan derives from the priorities shown in the Flagship Initiatives, recently released by the European Commission in the Annual Strategy for Sustainable Development 2021. This Plan is inspired in different documents and measures such as the SDG Sustainable Developments Goals of the United Nations.

The Plan is structured around **FOUR TRANSVERSAL AXES** that will provide the backbone for the transformation of the economy as a whole and which the Government has placed at the center of its economic policy strategy from the outset: **ecological transition, digital transformation, gender equality and social and territorial cohesion**

These axes will guide the entire recovery process, inspiring the structural reforms and investments that will be implemented, with the ultimate goal of returning on the path to growth, promoting the creation of companies and accelerating the generation of employment.

The Government aims at **mobilizing 72 billion euros, in the first three years (2021- 2023),** to maximize their impact on the rapid reconstruction of the economy.

The Plan has ten structural reform levers for sustainable and inclusive growth, of which the State Secretary of Energy is directly responsible for the lever 3 (A Just Inclusive and Energy Transition) and additionally, is the executive organism for a part of two other levers closely related to the energy field (policy lever 1: Urban and rural agenda, the fight against rural depopulation and agricultural development; policy lever 4: An administration for the 21st century). Within this framework, **IDAE will manage 5,400 million euros.**

[Spain recovery plan]

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO

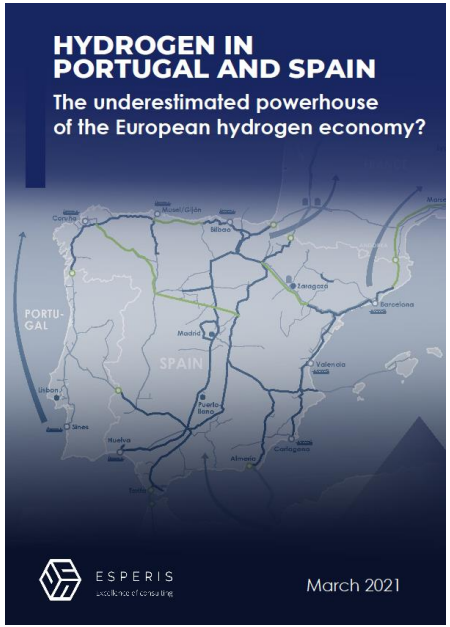
Hydrogen Roadmap

MINISTRY FOR THE ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE

European Gas Regulatory Forum

14/10/2020

[Spain Hydrogen roadmap]



[H2 in Spain and Portugal]

Hydrogen - Market Update

Taiwan

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Norwegian Energy Partners

Current market situation for hydrogen

- Taiwan is an island which Up to 98% of Taiwan‘s energy comes from imports. Security of supply and energy prices are easily affected by international events especially in current global situations.
- According to “Taiwan’s 2050 Net Zero Emission Strategy”, the hydrogen power generation in 2050 is estimated to reach 9% to 12%.
- Taiwanese industries have been developing hydrogen fuel cells for 20 years.
- Although the domestic market is not very large, Taiwan has always been committed to integrating with international standards and has achieved many achievements.
- At present, Taiwan already has a small infrastructure value chain for developing hydrogen supply.
- This year (2022), ITRI (Industrial Technology Research Institute) will start promoting the "Taiwan 2050 Hydrogen/Ammonia Development Technology Blueprint Plan.
- From 2019 to 2021, the Taiwan Energy Bureau has launched the "High Efficiency Hydrogen Energy and Fuel Cell Technology Development Plan", and from 2021 to2025, a forward-looking infrastructure “carbon cycle key technology development plan" will be established.
- Taiwan hydrogen related industry supply chains, academia and research institutes have formed the "Taiwan Hydrogen Energy and Fuel Cell Partnership Alliance" and the "Taiwan Hydrogen Energy Industry Development Alliance" to promote hydrogen technology cooperation, cost reduction and efficiency improvement for green hydrogen manufacturing in the future.

General comments / strategic headlines

- The supply chain of related industries in Taiwan is currently dominated by transportation, hydrogen power generation and energy storage.
- The cost reduction and efficiency improvement of green hydrogen manufacturing are the problems that need to be overcome to promote hydrogen energy in the future.
- Taiwan also has opportunities in light vehicles (such as locomotives, drones), or large trucks and buses.
- The major industrial companies such as Taipower, Formosa Plastics, and Sinosteel will rely on hydrogen energy technology to significantly reduce carbon.

Useful information

- Bureau of Energy https://www.moeaboe.gov.tw/ECW/english/home/English.aspx
- Taiwan Hydrogen and Fuel Cell Partnership https://www.thfcp.org.tw/en
- Industrial Technology Research Institute https://www.itri.org.tw/english/index.aspx

Hydrogen - Market Update

UK

Local Energy Advisor

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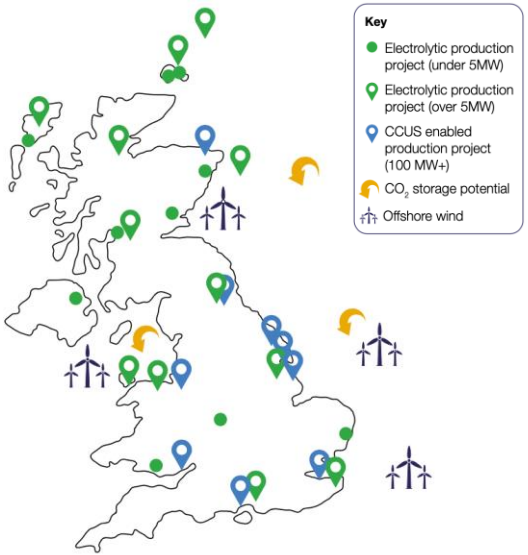
Norwegian Energy Partners

Current market situation for hydrogen

- UK Government published the UK Hydrogen Strategy in August 2021 with a stated ambition to establish 5GW of low carbon hydrogen capacity by 2030 in support of the Net Zero 2050 target (whilst also targeting 1GW by 2025).
- In December 2020, the devolved Governments in Scotland and Wales also published hydrogen strategy documents:
  - Scotland - Hydrogen Policy Statement (with a Hydrogen Action Plan to be published later in 2021)
  - Wales – Hydrogen Pathway (with a Hydrogen Strategy to be published later in 2021)
- The Strategy also commits to the following:
  - Launch a £240m Net Zero Hydrogen fund in early 2022 to encourage co-investment in early hydrogen production projects
  - Delivery of a £60m Low Carbon Hydrogen Supply 2 competition to develop novel hydrogen supply solutions
  - Publish a UK standard for low carbon hydrogen by early 2022 to define max levels of of GHG emissions associated with low carbon hydrogen production
  - Launch a Hydrogen Business Model in 2022, with first contracts awarded from Q1 2023 to provide long-term support to hydrogen producers to overcome initial cost challenges of producing low carbon hydrogen

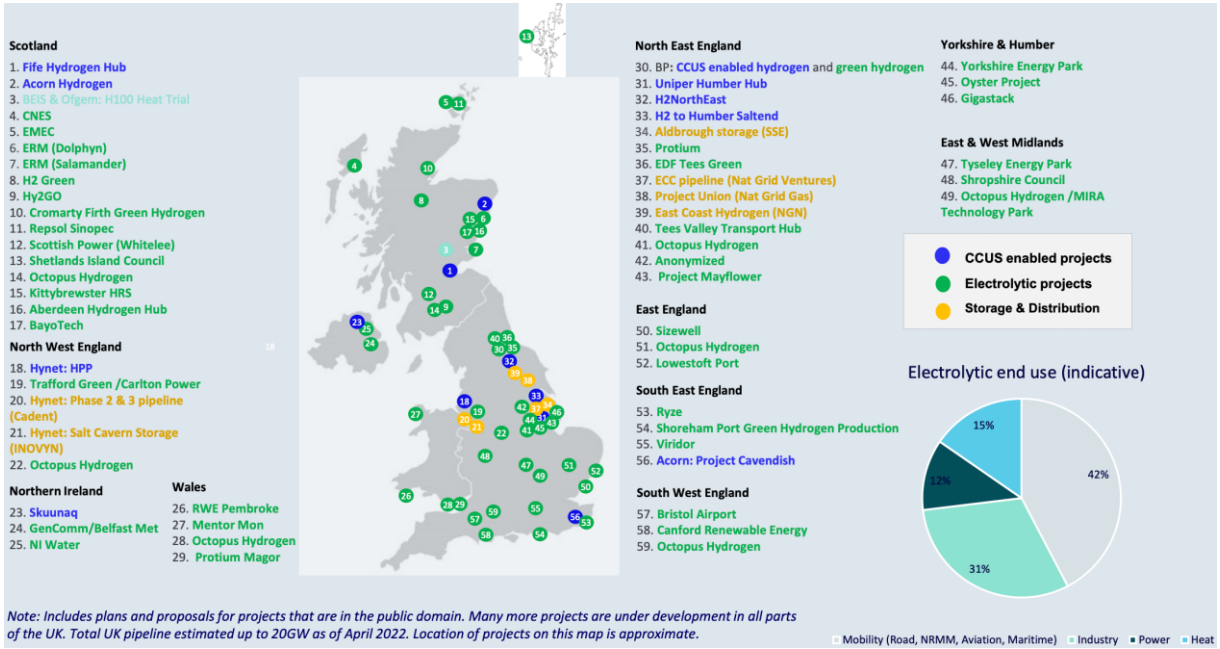
Proposed UK electrolytic & CCUS-enabled hydrogen production projects



Current market situation for hydrogen

In 2022, the following has been/will be published:

- UK Government Hydrogen investor roadmap (April 2022)
- UK Government Dept for Business, Energy & Industrial Strategy (BEIS) Hydrogen funding landscape
- Industrial Energy Transformation Fund (SIETF) phase 2 competition round (summer 2022)
- Scottish Industrial Energy Transformation Fund (SIETF) 3rd call for projects (late summer 2022)

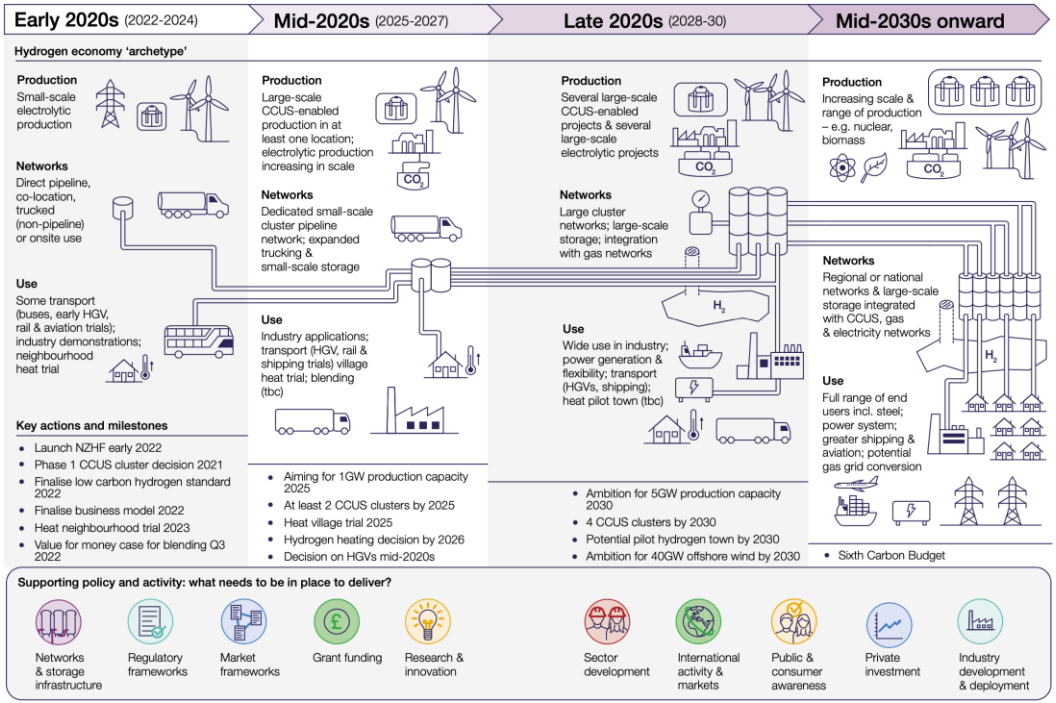


Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
Storegga / Shell / Harbour	Acorn Hydrogen	200	12	2025	Hydrogen will be used to blend with natural gas in National Transmission System for domestic & industrial use
BP	H2 Teesside	1000		2027	Initial 500MW blue hydrogen production in 2027, increasing to 1GW by 2030
ENI	Hynet North West		10	2025	Phased increase in hydrogen production and CO2 storage from 2025-2030. Intial H2 production of 3TWh pa in 2025, reaching 30TWh pa in 2030
Equinor	H2H Saltend	600	1.4	2026	H2H Saltend is Zero Carbon Humber's anchor hydrogen project
Vitol / VPI / Phillips	Humber Zero	1000		2030	Equinor is a partner
ERM	Dolphyn	10MW	800 Te	2024	https://www.neccus.co.uk/project/erm-dolphyn/
EMEC	Kirkwall Airport			?	https://www.neccus.co.uk/project/emec-hydrogen/
SGN	SGN H100			2023	https://www.neccus.co.uk/project/sgn-h100/
Neptune Energy	DelpHYnus	1.8 GW			https://www.neptuneenergy.com/esg/new-energy/delphynus-project

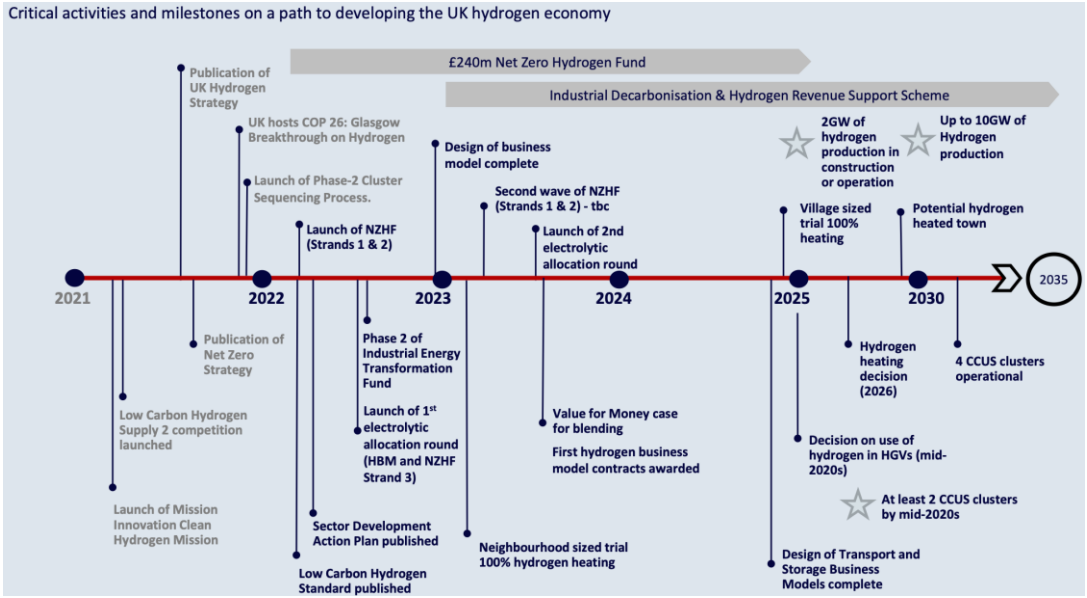
General comments / strategic headlines

UK Hydrogen economy 2020s Roadmap *(UK Government Hydrogen Strategy, August 2021)*



- UK is focused on "twin track" approach
  - i.e. produce electrolytic 'green' alongside CCUS-enabled 'blue' hydrogen
- The UK Hydrogen Strategy maps out an aim to develop a hydrogen economy which envisages hydrogen as a flexible energy for industrial and domestic power, heat and transport

General comments / strategic headlines



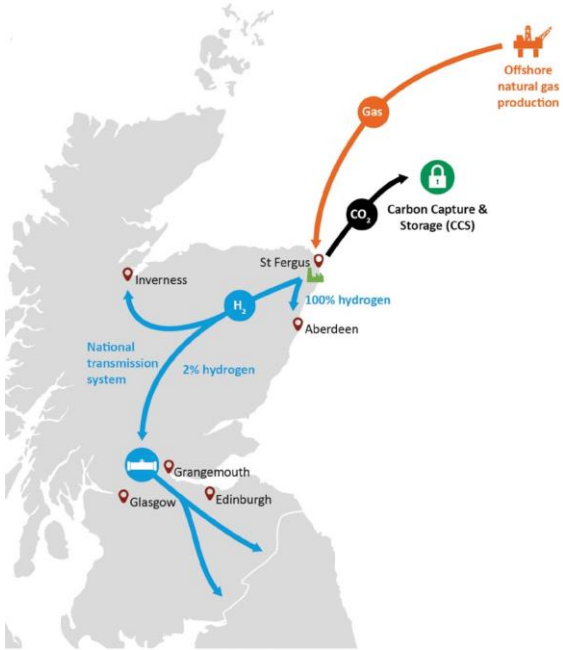
UK Government 2035 Delivery Plan

- UK is focused on “twin track” approach
  - i.e. produce electrolytic ‘green’ alongside CCUS-enabled ‘blue’ hydrogen
- The UK Hydrogen Strategy maps out an aim to develop a hydrogen economy which envisages hydrogen as a flexible energy for industrial and domestic power, heat and transport

Useful information

- https://www.gov.uk/government/publications/uk-hydrogen-strategy
- https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/
- https://gov.wales/sites/default/files/consultations/2021-01/hydrogen-in-wales-consultation.pdf
- https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1067408/hydrogen-investor-roadmap.pdf
- https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1067402/beis-hydrogen-funding-landscape-infographic.pdf
- https://www.gov.scot/policies/energy-efficiency/scottish-industrial-energy-transformation-fund/
- https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
- https://www.netzerotc.com/reports-publications/closing-the-gap/
- https://theacornproject.uk/about/
- https://www.bp.com/en/global/corporate/what-we-do/gas-and-low-carbon-energy/h2teesside.html

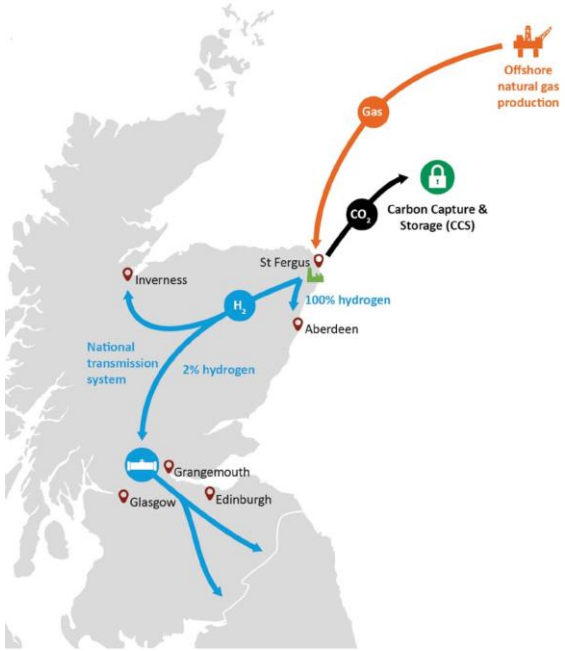
Acorn hydrogen project
(Hydrogen Coast report, Acorn Project, 2021)



Useful information

- https://www.zerocarbonhumber.co.uk/the-vision/
- https://hynet.co.uk/phases/
- https://www.eni.com/en-IT/eni-worldwide/eurasia/united-kingdom.html
- https://www.humberzero.co.uk/
- https://www.neccus.co.uk/
- https://theacornproject.uk/wp-content/uploads/2020/05/Hydrogen-Coast-DIGITAL.pdf
- https://theacornproject.uk/wp-content/uploads/2020/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf
- https://www.netzerotc.com/reports-publications/floating-offshore-wind-powered-hydrogen-case-study-review-for-local-supply-chains/

Acorn hydrogen project
(Hydrogen Coast report, Acorn Project, 2021)



Hydrogen - Market Update

USA

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Current market situation for hydrogen

Hydrogen is considered part of a comprehensive energy portfolio that can enable energy security and resiliency and provide economic value and environmental benefits for diverse applications across multiple sectors in the U.S. Hydrogen can be derived from a variety of domestically available primary sources, including renewables; fossil fuels with carbon capture, utilization, and storage (CCUS); and nuclear power. Diverse, sustainable, and abundant domestic resources are essential for the nation to:

1) provide for a variety of end uses and a range of energy needs,
2) reduce dependency on single or limited resources,
3) retain energy independence and expand opportunities for net exports, and
4) be prepared for future scenarios where resources, end-use needs, and constraints may change significantly.

Flexibility is a key asset and hydrogen is considered to provide that opportunity.

The United States has been at the forefront of hydrogen and related technology R&D, from its inception in the space program, to enabling technology commercialization in transportation, stationary power, and portable-power applications. The interest in hydrogen technologies date back to the establishment of Department of Energy itself in the mid-1970s when energy security and dependence on foreign oil were a major concern.

Current market situation for hydrogen

National drivers

- The Department of Energy has a Hydrogen Program. The mission of the program is to research, develop, and validate transformational hydrogen and related technologies including fuel cells and turbines, and to address institutional and market barriers, to ultimately enable adoption across multiple applications and sectors.
- Development of hydrogen energy from diverse domestic resources has the ambition ensure that the United States has an abundant, reliable, and affordable supply of clean energy to maintain the nation's prosperity throughout the 21st century and beyond.

A DoE report list these key benefits of hydrogen:

- Hydrogen can be produced from diverse domestic resources for use in multiple sectors, or for export.
- Hydrogen has the highest energy content by weight of all known fuels—3X higher than gasoline—and is a critical feedstock for the entire chemicals industry, including for liquid fuels.
- Hydrogen, along with fuel cells or combustion-based technologies, can enable zero or near-zero emissions in transportation, stationary or remote power, and portable power applications.
- Hydrogen can be used for gigawatt-hours of energy storage and as a "responsive load" on the grid to enable grid stability, increasing the utilization of power generators, including nuclear, coal, natural gas, and renewables.
- Hydrogen can be used in a variety of domestic industries, such as the manufacturing of steel, cement, ammonia, and other chemicals.

It's worth noticing the emphasis on 'domestic' in the first and last bullets. Hydrogen is looked at as (potentially) strategic both in terms of being available in-country and for use in domestic industries.

Current market situation for hydrogen

DoE Hydrogen Program

- The Department of Energy has a Hydrogen Program. The mission of the program is to research, develop, and validate transformational hydrogen and related technologies including fuel cells and turbines, and to address institutional and market barriers, to ultimately enable adoption across multiple applications and sectors.
- Development of hydrogen energy from diverse domestic resources has the ambition ensure that the United States has an abundant, reliable, and affordable supply of clean energy to maintain the nation's prosperity throughout the 21st century and beyond.

- In addition to participation from EERE, FE, NE, OE, and SC, the Program also coordinates with other relevant DOE efforts, including those in the Advanced Research Projects Agency-Energy (ARPA-E); the Office of Cybersecurity, Energy Security, and Emergency Response; and crosscutting DOE initiatives such as the Energy Storage Grand Challenge, Advanced Manufacturing, Grid Modernization, Integrated Energy Systems, Water Security Grand Challenge, and Artificial Intelligence.
- Each of these offices and initiatives manage hydrogen technology activities related to their missions. EERE (The Office of Energy Efficiency and Renewable Energy), FE (The Office of Fossil Energy), and NE (The Office of Nuclear Energy) focus their RD&D activities on their respective energy sources, feedstocks, and target applications. All of these activities are coordinated to achieve a cohesive and strategically managed effort.

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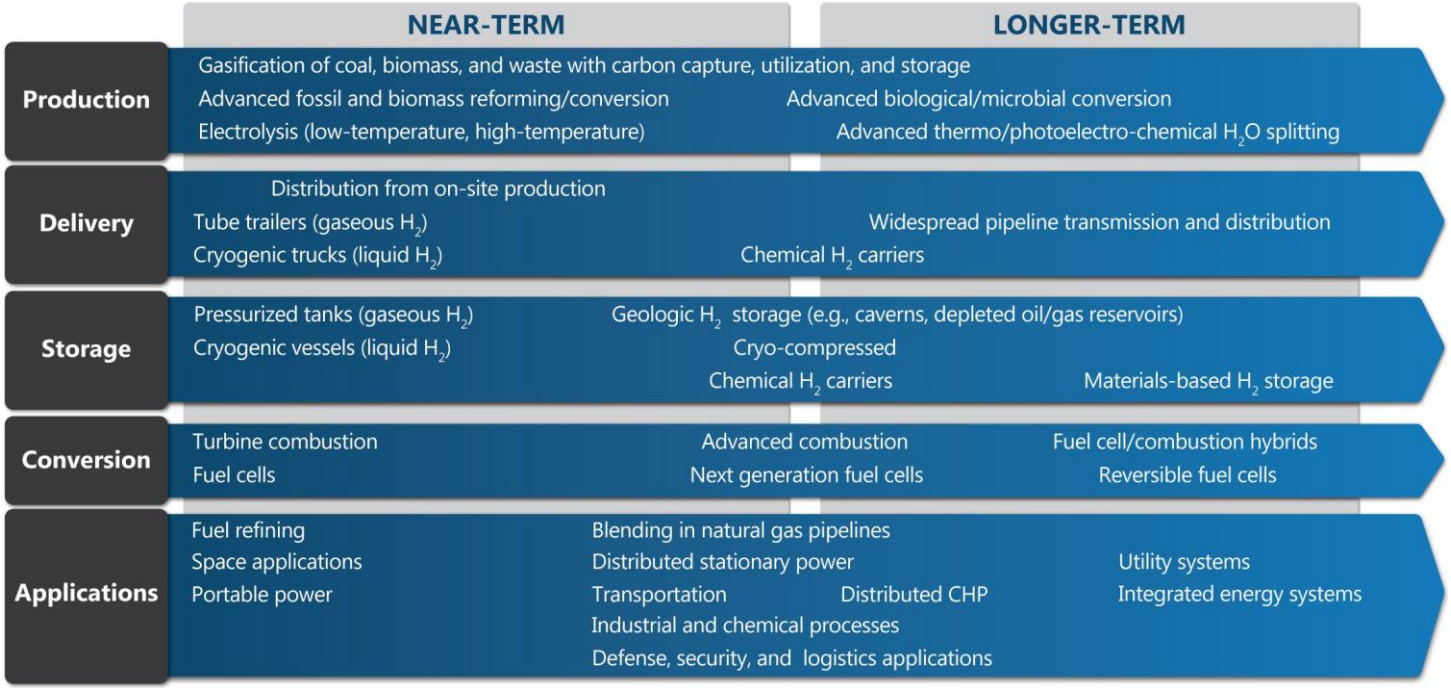
U.S Hydrogen Technologies

Key Options



U.S. Demand for Hydrogen

Existing and emerging demands

	Transportation Applications	Chemicals and Industrial Applications	Stationary and Power Generation Applications	Integrated/Hybrid Energy Systems
Existing Growing Demands	• Material-Handling Equipment • Buses • Light-Duty Vehicles	• Oil Refining • Ammonia • Methanol	• Distrubuted Generation: Primary and Backup Power	• Renewable Grid Integration (with storage and other ancillary services)
Emerging Future Demands	• Medium-and Heavy-Duty Vehicles • Rail • Maritime • Aviation • Contruction Equipment	• Steel and Cement Manufacturing • Industrial Heat • Bio/Synthetic Fuels	• Reversible Fuel Cells • Hydrogen Combustion • Long-Duration Energy Storage	• Nuclear/Hydrogen Hybrids • Gas/Coal/Hydrogen Hybrids with CCUS • Hydrogen Blending

Current market situation for hydrogen

Public funding and incentives

- The U.S. Department of Energy (DOE) Hydrogen and Fuel Cell Technologies Office (HFTO) in the Office of Energy Efficiency and Renewable Energy (EERE) offers information about open and closed funding opportunities, requests for information, and links to related opportunities from other DOE offices and federal organizations.

- Subscribe to receive news and funding opportunity updates by email.
  Find more information about the application process.

- Other federal organizations, including the Department of Defense, also offer funding opportunities for hydrogen-related technologies. The Hydrogen and Fuel Cells Interagency Working Group website lists some of these related funding opportunities. In addition, federal and state financial incentives, such as tax credits and grants, can help minimize the cost of hydrogen and fuel cell projects.

- The bipartisan infrastructure law passed last year includes $500 million in grant funding for clean hydrogen projects, plus $1 billion for research and development into electrolyzers that can use electricity from renewable sources to convert water to hydrogen.

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Current market situation for hydrogen

ESG drivers

- In January 2021, the US Department of Energy (DOE) announced a US$160 million federal funding plan “to help recalibrate the nation’s vast fossil-fuel and power infrastructure for decarbonized energy and commodity production. The funding, for cost-shared cooperative agreements, is aimed to develop technologies for the production, transport, storage, and utilization of fossil-based hydrogen, with progress toward net-zero carbon emissions,” said the DOE.
- The DOE and the US Office of Fossil Energy jointly published a report titled “Hydrogen Strategy: Enabling a Low-Carbon Economy.” The report concluded that fossil fuels currently provide the lowest cost pathway for producing hydrogen. It was due to this finding that the DOE decided to fund new technologies aimed at improving the performance, reliability, and flexibility of methods to produce, transport, store, and use hydrogen.
- When coupled with carbon capture and storage capabilities, low-cost hydrogen sourced from fossil energy feedstocks and processes will significantly reduce the carbon footprint of these processes and enable progress toward hydrogen production with net-zero carbon emissions.
- The DOE is funding net-zero or negative carbon hydrogen production from modular gasification and co-gasification of mixed wastes, biomass and traditional feedstocks, solid oxide electrolysis cell technology development, carbon capture, advanced turbines, natural gas-based hydrogen production, hydrogen pipeline infrastructure, and subsurface hydrogen storage.

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Current market situation for hydrogen

Taxonomy

- A Hydrogen Taxonomy similar to EU's Hydrogen Taxonomy has not been officially established in the U.S., however, similar terminology and descriptions are being widely used. E.g. green, blue, grey, and black hydrogen.

Influence from the bank, finance and investors

- The U.S. is engaged in the hydrogen economy with hundreds of millions of dollars of public and private investment per year and boasting more than half the world's fuel cell vehicles, 25,000 fuel cell material handling vehicles, more than 8,000 small scale fuel systems in 40 states, and more than 550 MW of large-scale fuel cell power installed or planned.
- The U.S. is a major player, but to remain dominant, and meet future energy challenges, the U.S. has to raise its game with further investments and public policies that reduce regulatory barriers, promote research, development, and deployment, and reward innovation. Other countries are laying plans for hydrogen economies and the U.S. will need to move quickly to continue to lead in this growing industry.

Projects & prospects

Operator/owner	Project/place	Capacity (MW)	Capacity (mtpa)	Operational	Remarks/links to project
SoCalGas and SDG&E	TBN	TBN	TBN	Over next five years	Proposals for blending of up to 20% hydrogen in natural gas pipelines for combustion (source)
Florida Power & Light	H2 Teesside	1000	TBN	2023	This hydrogen will be used in a 20% blend at FP&L's 1.75-gigawatt Okeechobee gas-fired plant (source).
Green Hydrogen International (GHI)	Hydrogen City	60 MW	2.5	2 GW (Phase 1) 2026	www.ghi-corp.com
JERA Americas	Linden Cogeneration Plant	TBN	TBN	TBN	Linden Cogen will take Bayway Refinery produced hydrogen-containing fuel gas and blend it with natural gas used to fuel the 172MW Linden Cogen unit 6 gas turbines. The modification will enable using a fuel gas blend containing up to 40% hydrogen (source).
NRG	TBN	TBN	TBN	2040	NRG has filed for a repowering of their Astoria, Queens peaker power plant based on a plan to convert to hydrogen by 2040 (source).
Balico LLC	TBN	1.65 GW	TBN	TBN	Balico has signed a hydrogen integration contract with Mitsubishi Power for its 1.65GW natural gas-fired power plant in Charles City County, Virginia (source).

Projects & prospects

Operator/owner	Remarks/links to project
JERA Americas	JERA Americas has signed an agreement with GE to develop a green hydrogen demonstration project in Dover Plains. The agreement calls for using hydrogen for 5% of the fuel in one of the three units at the power station. This initiates the first step toward converting to a 100% hydrogen fuel capable plant (source).
Dominion Energy	Dominion Energy North Carolina has asked regulators for approval of a $215,000 pilot project to blend 5% hydrogen with natural gas. The proposed project will be run on a closed loop to customers near Dominion's NC headquarters in Gastonia. Dominion is running a similar project with its partner utility in Utah (source).
New Fortress Energy	New Fortress Energy is currently building new GE H-class gas turbines in its Hannibal, Ohio plant. The 485 MW plant will burn a 15-20% blend of hydrogen and natural gas (the highest amount the H-class turbines can burn), starting in November 2021. New Fortress has plans to burn 100% hydrogen at this plant in the next decade (source).
Southern Company	has started its HyBlend research and development project through a partial grant from the U.S. Department of Energy. Southern Company Gas serves 4.2 gas utility customers throughout the southeast (source).
Entergy	Entergy has announced plans to use existing oil industry hydrogen pipeline networks and underground salt caverns to ship and store hydrogen and replace natural gas fired power. The utility has announced plans to build a plant near its existing hydrogen pipelines in Sabine, Texas, that will run on a 30% hydrogen/natural gas blend when it begins commercial operation (source).
Intermountain Power Project	The Intermountain Power Project has partnered with Mitsubishi Power on a $2 billion power plant upgrade that will have the plant running a 30% natural gas/hydrogen blend by 2025 (source).
Danskammer	Danskammer in New York has released a $500 million proposal to covert the River-Road peaker power plant into a full-time facility, based on a plan to convert to at least 30% hydrogen by 2030 and 100% hydrogen by 2040 (source).

General comments / strategic headlines

- There is focus on climate change and the energy transition
- Hydrogen is one of the key topics in the debates and media picture
- There are abundant ideas and proposed projects. Very few are being realized.
- Production technologies for all three hydrogen types (grey, blue, green) are available in the USA. There are various challenges with transport, storage and distribution of hydrogen.
- Types of fuel cells that appear to be available in USA:
  - Alkali fuel cells
  - Molten Carbonate fuel cells (MCFC)
  - Phosphoric Acid fuel cells (PAFC)
  - Proton Exchange Membrane (PEM) fuel cells (the largest type in terms of revenue generation)
  - Solid Oxide fuel cells (SOFC)
- The two most common Hydrogen production methods:
  - Steam-methane reforming (SMR)
  - Electrolysis
- Most important clients/stakeholders:Prominent hydrogen production companies, in addition to refineries, fertilizer companies and metal mills, include: Plug Power, FuelCell Energy, ITM Power, Ballard Power Systems, Air Products & Chemicals, Air Liquide
- IT/digitalization including AI, machine learning, remote monitoring and control, etc. will be a natural and logical part of the hydrogen industry and supply chain as for other energy and process industries.

General comments / strategic headlines

- Beyond the already traditional industrial use, there is not so much happening. The potential future supply side says that they can't produce more hydrogen because there isn't any demand, and the potential demand side says that they can't invest in infrastructure, vehicles or similar because there isn't reliable supply.
- I.e. there is a wait and see game going on right now. The moment the business case(s) make(s) sense and or sufficient tax incentives are on the table, there is going to be a "ketchup bottle" effect, and everything and everybody are going to start moving very quickly.
- Norwegian companies should focus where they have something to bring to the market in the form of value proposition, differentiators, references etc. That's were there is going to be opportunities. In general, U.S. companies will not buy technology, equipment, services etc. from a Norwegian company thousands of miles and six, seven, eight or nine time zones away if they can buy the same from American companies. The Norwegian companies will have to have differentiators to set themselves apart.

Useful information

- Department of Energy's Hydrogen Program Plan may be regarded as a national strategy for USA
- USA Energy Information Administration
- Use of hydrogen
- USA Hydrogen and Ammonia Markets report

DOE national laboratories that perform hydrogen and fuel cell R&D:

- Argonne National Laboratory
- Brookhaven National Laboratory
- Lawrence Berkeley National Laboratory
- National Energy Technology Laboratory
- National Renewable Energy Laboratory
- Pacific Northwest National Laboratory
- Sandia National Laboratories

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