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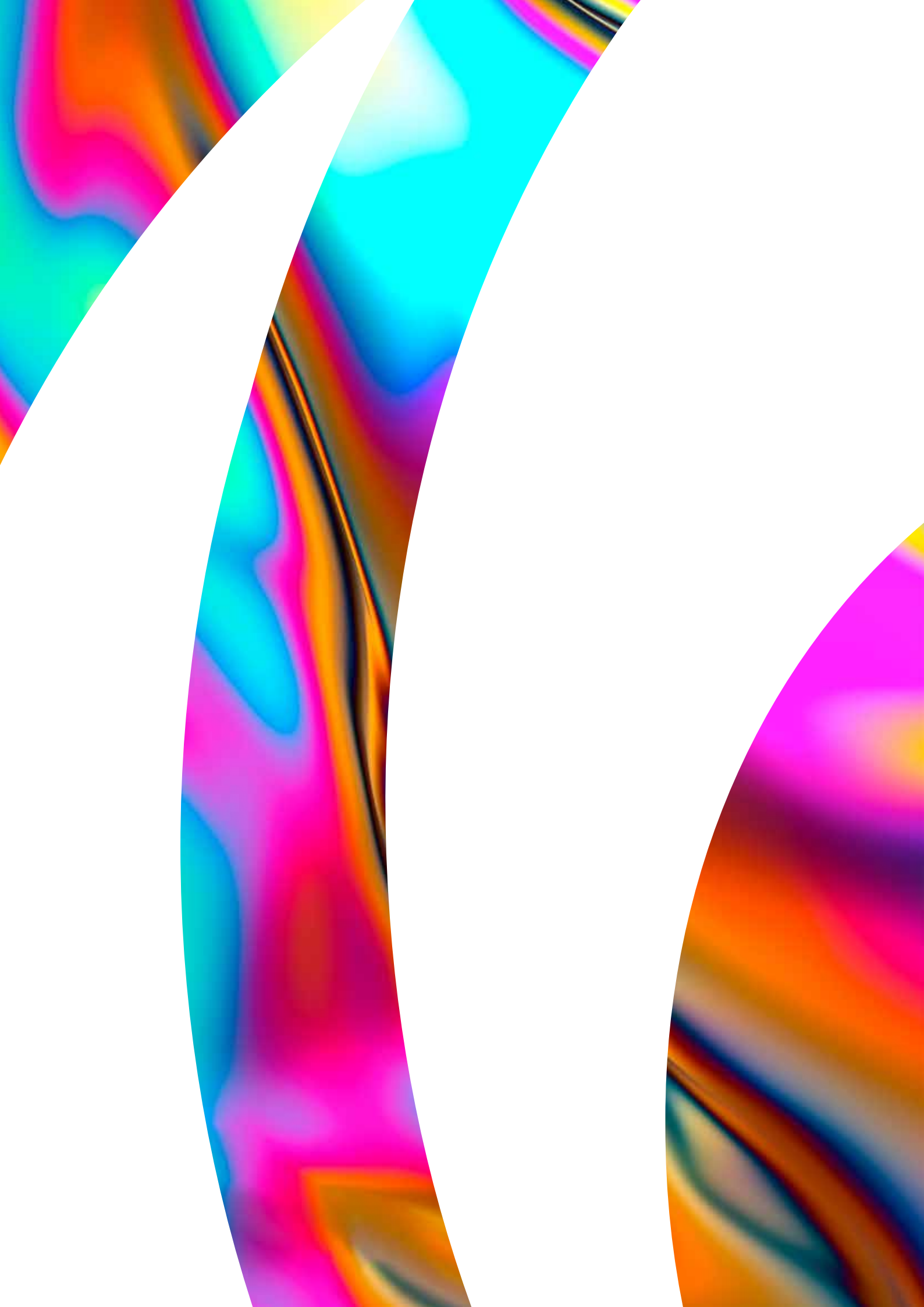
Facing the Future of Hydrogen: An International Guide

November 2021

Net Zero Pathways



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Introduction

A consensus is fast emerging that hydrogen will play a key role as an energy vector and a pillar in the ongoing energy transition. It promises to accelerate transformative changes across many sectors, most notably energy and transport. This guide draws together the insight of some of the most experienced global energy experts to provide a timely and insightful perspective on how hydrogen projects may proceed, and the sector develop, across the globe.

The important role that low-carbon hydrogen will play in decarbonising our energy usage is becoming increasingly widely recognised. Its versatility and broad range of applications render it uniquely placed to reduce emissions across the economy, and particularly in areas where electrification – another stalwart application in the emissions reduction arsenal – is not practical.

The second edition of this guide draws on insights from some of the most experienced global energy experts, providing an insightful perspective on the extent to which hydrogen has already been embraced by different countries, the challenges faced in optimising hydrogen application and on developments in the worldwide hydrogen economy since the first edition of this guide.

News stories in the years 2020 and 2021 have been dominated by one thing – COVID-19 or SARS-CoV-2. Against the backdrop of this global challenge, however, the issue of decarbonisation has never been far from the headlines. With the passing of five years since the signing of the Paris Agreement in 2015, the pathway to achieving the long-term goals to combat emissions in an effort to achieve the Paris Agreement target of limiting global warming to well below two degrees Celsius above pre-industrial levels is yet developing. All the same, a number of pledges made by governments and businesses at UN Climate Conference, COP26, in Glasgow in 2021, featured hydrogen. In this guide, our experienced energy lawyers shine a light on the practicalities of hydrogen playing a serious part in these decarbonisation goals.

Low-carbon hydrogen presents new opportunities for a decarbonised future

The hydrogen economy is not a new concept. Demand for hydrogen has grown more than threefold since 1975,[1] with the compound being a fundamental component of various chemical production processes as well as used in oil refining. At present, however, hydrogen production is a fossil fuel intensive process, accounting for approximately 6% of global natural gas demand, 2% of coal and responsible for around 830m tonnes of carbon dioxide emissions a year. Put into perspective, annual carbon dioxide emissions from global hydrogen production well exceed those of Germany.[2]

The opportunity therefore is to harness the potential of low-carbon hydrogen – usually referred to as "green" or "blue" depending on production method – which currently only accounts for about 5% of global hydrogen production. Please refer to the Appendix of this guide for an explanation as to the different types of hydrogen. According to the International Renewable Energy Agency (IRENA), increasing production of green hydrogen and its derivatives can cut carbon dioxide emissions by 10% in the period up to 2050. This guide explains how, to a greater or lesser extent, the jurisdictions covered are advancing such low-carbon hydrogen production.

However, to embrace these opportunities and climate change ambitions requires the understanding and overcoming of a number of hurdles.

[1] https://www.iea.org/fuels-and-technologies/hydrogen
[2] https://www.ucsusa.org/resources/each-countrys-share-co2-emissions

Legal and commercial challenges are still holding back low-carbon hydrogen ambitions

One of the greatest challenges faced by low-carbon hydrogen production is that it remains, for the most part, commercially nascent. With this comes the following specific challenges:

— **demand uncertainty –** given that there is currently very little commercial scale, low-carbon hydrogen production (though projects are planned in a number of places), it remains to be seen what the demand from consumers will be. This is particularly the case given that hydrogen is a counterfactual for existing fuels, meaning that price plays a large part in its eventual uptake.

— **lack of dedicated regulatory and policy structure –** dedicated hydrogen legislation and policy lags behind the initial implementation of low-carbon hydrogen production that can be seen in some areas. This means that elements of the hydrogen production, transport, storage and distribution process often fall within the remit of various different rules and regulators, while other aspects remain without clear regulation.

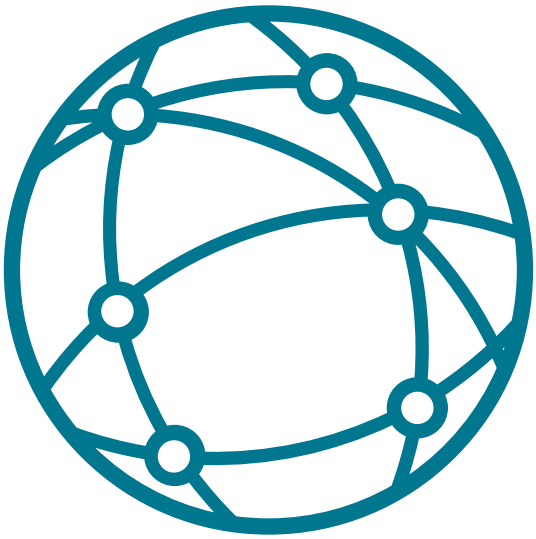
— **lack of physical infrastructure for distribution and storage –** in order to fully capitalise on low-carbon hydrogen's ability to decarbonise our energy system and energy use, effective infrastructure for distribution and storage is required. The ability to store hydrogen means that, as an example – legislation permitting – green hydrogen can be generated at times of excess renewable energy and then stored until needed, such as when energy demand spikes. Effective distribution infrastructure is needed to ensure that low-carbon hydrogen can be used to meet energy demands outside of its production locale. In the US, for example, an estimated 85% of hydrogen produced is consumed on-site.

Each of these challenges adds complexity and risk to the investment into and the development of such projects, at least initially. In addition, the fact that low-carbon hydrogen is a growing and developing sector, with multiple applications, means the current production and associated technology will likely advance quickly once it gets going.

In this guide, we discuss the legal landscape in which hydrogen currently exists. This will differ from jurisdiction to jurisdiction, and is often challenging to navigate owing to the lack of specific "hydrogen laws" in most countries, in contrast to the treatment of other energy sources. As we discuss, many of the laws applicable to methane gas also apply to hydrogen, however, perceived risks around leakage and flammability mean that it is also subject to a host of safety regulations applicable to major hazards.

Notwithstanding the lack of specific legislation, there is ongoing policy development to pave the road for the development of a hydrogen economy. The projects that succeed will be those who bravely took the opportunities and shaped this developing landscape to their needs.

National hydrogen strategies and new laws are emerging as a global hydrogen market begins to take shape



Many governments are now adopting hydrogen strategies – setting out the intention for how low-carbon hydrogen will be deployed across their economies. These are important steps giving some clarity to investors as to what the future legislation of and support for hydrogen in different jurisdictions may be. Japan has been an early mover in the hydrogen market, having formulated its "Basic Hydrogen Strategy" in 2017 and built on this since. In other jurisdictions such as the US, there is also a combined push amongst the private sector to develop coherent thinking on hydrogen deployment, with the *Road Map to a US Hydrogen Economy* being developed by a coalition of US energy sector players. Furthermore, a number of countries are gearing themselves up to be the top global green hydrogen exporters aiming to beat the competition on price (e.g. Chile) or through geographic positioning (e.g. United Arab Emirates which based on its hydrogen strategy aims to hold a fourth of the global hydrogen market by 2030.)

Germany is one of the few jurisdictions to have passed dedicated legislation by updating its Energy Act to provide for regulation of hydrogen networks, although aspects such as the capture and storage of emissions associated with blue hydrogen production are not covered at all. In addition to Germany, France is taking steps to entrench hydrogen into national law, amongst other things defining "renewable hydrogen", "low-carbon hydrogen" and "carbon-based hydrogen" in legislation. In the UK, the government is developing dedicated hydrogen "business models" aimed at reducing these risks through revenue support for producers of eligible hydrogen via the "contracts for difference" regime, familiar to renewable generators in that jurisdiction. Revenue support for initial projects is likely to play an important role in getting them off the ground.

Large scale demonstration projects are already underway in some jurisdictions aiming to demonstrate applications ranging from urban transport to gas grid injection. Looking forward, the ambition will be to move from demonstrators to full-size projects producing low-carbon hydrogen at commercial scales.

In order to facilitate commercialisation of low-carbon hydrogen production and supply, the development of standards of good practice and market-standard documents will be essential. Jurisdictions which are already developing a regulatory framework to facilitate hydrogen production may be quicker to develop these standards than others. Importantly, given the ambition of many countries to export a portion of the hydrogen produced, these standards may also need to be internationally recognised. One element of this will be developing internationally recognised standards for certifying hydrogen as low-carbon.

The scale up of low-carbon hydrogen will likely also see the development of hydrogen "hubs" – where infrastructure for hydrogen transport and storage is shared by a number of players, and production may be co-located with end users e.g. industrial users, to decarbonise their own production. This is the start of what looks to be a global hydrogen market with production and consumption on a cross-border scale seen in other fuels and commodities. For example, in April 2021, Australia's Prime Minister pledged AUD USD 275.5m to accelerate the development of hydrogen hubs,[3] as well as to implement a clean certification scheme. If built, the Asian Renewable Energy Hub in Western Australia will produce about 1.8 mtpa of green hydrogen for use both on the continent and possibly by the neighbouring countries of Japan and South Korea. Japan has also signed memorandums of understanding with New Zealand, Argentina and the Netherlands for cooperation with a view to developing hydrogen technology and international supply chains.

[3] https://www.lexology.com/library/detail.aspx?g=74a6dd9d-bd7a-4f8a-9c55-63f884a73bf9

Fortune favours the brave

As is seen throughout this guide, the way is being paved for low-carbon hydrogen to play a vital role in decarbonising our energy usage. Be that through fuel cell technology in transport, decarbonising our heating systems via gas grid blending or greening our chemical and industrial sectors, the versatility of hydrogen means that its potential cannot be overstated. Both governments and the private sector are taking action to realise this potential – through the publication of ambitious strategies, development of public-private sector partnerships and cross-border cooperation to develop international trade in hydrogen. This is a time of great opportunity and challenge for the hydrogen industry. As with any major shift to the status quo, the major rewards fall to those who succeed as the first movers in the emerging landscape. As was seen with the renewables industry a few decades ago, the hydrogen projects which successfully navigate the dynamic landscape will set the tone and pace of the regulatory foundations and development in the market for future projects. As collaborations turn to construction and offtake structures, the projects that succeed will be the pioneers remembered for setting a new course where hydrogen has a prominent part to play.

Our contributors and energy specialists in each jurisdiction remain at your disposal and would be delighted to discuss more specific details and developments.

What role can Hydrogen play in the Automotive Sector

Author:
Martin Wodraschke

In recent years, hydrogen technology has been at the forefront of environmental discussions in the attempt to meet increasingly tough climate protection goals and particularly low emissions targets in the transportation sector.

Although the following chapter will focus primarily on the automotive sector, it has become evident that breakthroughs in terms of hydrogen technologies also occur in other areas of the transportation sector. Trains are now using the so called *"Hydrails"* technology. The world's first commercial hydrogen-powered passenger train in Germany, the Coradia iLint, was produced by the French railway manufacturer Alstom in 2016.[1] In Asia, East Japan Railway announced at the end of 2019 that it is investing JPY 4bn into the development of a hydrogen two-car trainset.[2] Also, in November 2019 Swiss rail manufacturer Stadler secured in the US a contract from San Bernardino County Transportation Authority to deliver the first hydrogen-powered train.[3] The UK is catching up too, having introduced the *"Hydroflex"* in 2020, the UK's first train to be powered by hydrogen.[4]

In the automotive sector, innovative hydrogen technology is pioneered as the most energy efficient alternative power source to engines, mandated as necessary to achieve a 60% to 80% reduction in greenhouse gases by 2050, according to the European Strategic Energy Technology Plan.[5]

Major automotive players in the EU and around the world are gearing up towards the hydrogen drive, already planning and implementing significant investments in the innovative technology of the future in car manufacturing, particularly hydrogen-based fuel-cell electric vehicles (**"FCEVs"**).

1 https://www.welt.de/wirtschaft/article158262466/Erster-Wasserstoff-Zug-der-Welt-faehrt-in-Deutschland.html
2 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
3 https://www.railway-technology.com/news/stadler-deliver-hydrogen-powered-train-sbcta/
4 https://www.bbc.com/future/article/20200227-how-hydrogen-powered-trains-can-tackle-climate-change
5 https://ec.europa.eu/transport/themes/urban/vehicles/road/hydrogen_en

Comparison: Battery-Electric Cars and Hydrogen fuelled Cars

To fully appreciate and value the benefits of hydrogen fuel cell cars in comparison to lithium ion battery powered electric cars, and to understand why some automotive producers invest more into one technology than the other, one must first outline the mechanics of both, considering that hydrogen fuel cell cars are powered by an electric motor and are therefore also classified as EVs.[6]

Currently, almost all EVs are powered by a lithium-ion battery. The energy from the battery powers the electric motor, which can be refueled not by fossil fuels, but using electricity (usually bought from the grid).

A hydrogen powered car on the other hand, despite also having an electric motor, is powered through the reaction of hydrogen with oxygen inside a fuel cell. The water vapor produced is then used to generate the electricity needed to power the vehicle. To refuel the car, the pressurised hydrogen fuel tanks must be refilled. This is possible at hydrogen refueling stations.

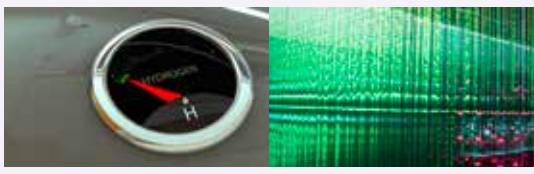
As revealed by the latest hydrogen technology deployed by car manufacturers (BMW, Toyota), the new technology can be integrated into existing models with minimal design changes, but at a significant cost.

Whilst it is widely acknowledged that hydrogen fuel cell technology is locally emission-free, the overall efficiency in the *"power to vehicle drive"* will ultimately depend on whether the hydrogen production has a neutral carbon footprint (similar to battery EVs which are only carbon neutral in their fuel if the electricity used in the process comes from renewable energy sources).[7]

Some recent studies also advocate the establishment of a dual infrastructure for battery powered EVs and hydrogen fuelled cars. This may be even recommendable from an economic perspective.[8]

Pros and Cons of Hydrogen Technology in the Automotive Sector

Hydrogen-powered vehicles have been praised for their positive effects on the environment. The hydrogen technology is believed to result in less pollution (compared to typical lithium-ion batteries in EVs, which have a limited lifecycle and are hard to recycle) and reduce dependence on fossil fuels, while using a widely available resource – hydrogen.



6 https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html
7 https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html#pwjt-3 and https://www.wardsauto.com/alternative-propulsion/europe-nurturing-hydrogen-vehicle-market
8 NPM_AG5_Infrastrukturen-fuer-Wasserstoffmobilitaet.pdf (plattform-zukunft-mobilitaet.de)

A key advantage of hydrogen EVs or FCEVs, compared to battery-powered EVs, are the consumer benefits. The refuelling time is estimated to take no longer than three to five minutes and the process hardly differs from the current one of ICE vehicles (instead of waiting several hours to recharge as may be the case with some EVs). Moreover, hydrogen fuel cell cars allow for a longer range of driving, and so are better suited in countries where long distance travel is the norm, as well as for fleet transport.[9]

Despite undoubted benefits, sceptics point towards the difficulties of turning hydrogen technology into large scale production, emphasising especially the high costs associated with the manufacturing, operation and infrastructure of the technology. By way of illustration, without public subsidies, models already available on the market cost around USD 80,000 for a mid- or upper-mid-range vehicle, almost twice as much as comparable fully electric or hybrid vehicles. Secondly, as with EVs, FCEV refuelling infrastructure is also lacking. As detailed below, private and public funding is becoming increasingly available to mitigate this issue and make hydrogen FCEVs more affordable.

A number of critics also question whether having hydrogen gas onboard a vehicle may pose a safety hazard, due to possible tank failures (e.g. leaks or ruptures) and possible unforeseen other chemical reactions. Both research studies and input from the car industry[10] address these concerns:

— Firstly, it is widely accepted that outdoor accidental releases of hydrogen from single vehicles will disperse quickly, and not lead to any significant explosion hazard,[11] contrary to gasoline which is also an extremely flammable fuel[12] and can leak out and pool beneath the damaged vehicle, creating a ready source of fuel for a prolonged burn.[13]

— Secondly, the risk of a leak and an explosion from a hydrogen tank is also much lower since the fuel tanks are usually made of Kevlar, a bulletproof material,[14] thus confirming the high safety of the fuel storage tanks (which has also been tested through numerous crash tests).

— Thirdly, this technology is not novel, as shown by trials and testing of hydrogen technology in other fields which confirm the secure use of this product (e.g. storage of hydrogen and operation of pipelines, processing of crude oil and the use of hydrogen as a process gas).

Therefore, many industry experts state that hydrogen fuel cell vehicles are safer than cars with internal combustion engines,[15] with only a few expressing some concern for cases where safety becomes an issue, such as accidents in parking garages, workshops, or tunnels.[16]

Rolling out of FCEVs in passenger and heavy freight vehicles and the question of refuelling.

Considering the high costs currently associated with hydrogen fuelled transport, a fuel supply and refuelling infrastructure that meets the needs of the market is critical. Currently operating almost 100 hydrogen gas stations in seven German metropolitan areas, along the connecting arterial roads and motorways, Germany is at the forefront of hydrogen technology in the EU. However, most of these hydrogen refuelling stations are mainly geared towards passenger FCEVs. Recent trends, on the other hand, have shown a growing focus in using hydrogen for heavy freight transport and fleet vehicles. This poses the question, to what extent must the existing infrastructure be altered?

The refuelling of passenger cars requires gaseous hydrogen at 700bar, whereas trucks only travelling a short range need a mere 350bar. For long distances, 700bar alternatives or even liquid hydrogen are being considered.[17] A key advantage of liquid hydrogen is its high energy density, which enables longer distances to be driven. The current use of gaseous hydrogen at 700bar has a range of 800 to 1000km, which suffices for most heavy freight transport.[18]

In transport, hydrogen is already seen as a promising option where electrification is more difficult – early adoption of hydrogen already occurs in captive uses, such as local city buses (as well as rail networks), where electrification is not feasible.

Especially for short range heavy freight and public transport, HFCEVs have become an attractive alternative, not only for Germany (which funded WSW Mobil GmbH for the purchase of ten fuel cell buses and refuelling infrastructure and the Oberbergische Verkehrsgesellschaft (**"OVAG"**) for the procurement of a hydrogen fuel cell bus and a hydrogen storage unit) but several other European countries. Examples include France developing the world's first hydrogen-powered bus rapid transit (**"BRT"**) system, with eight buses built by the Belgian manufacturer Van Hool in a project launched by French

9 https://www.transportenvironment.org/wp-content/uploads/2021/07/2020_06_TE_comparison_hydrogen_battery_electric_trucks_methodology.pdf
10 https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html
11 https://www.sciencedirect.com/science/article/abs/pii/S036031990900202X
12 https://www.computerworld.com/article/2852323/heres-why-hydrogen-fueled-cars-arent-little-hindenburgs.html
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14 https://www.forbes.com/sites/jamesmorris/2020/07/04/why-hydrogen-will-never-be-the-future-of-electric-cars
15 https://www.computerworld.com/article/2852323/heres-why-hydrogen-fueled-cars-arent-little-hindenburgs.html
16 https://www.sciencedirect.com/science/article/abs/pii/S036031990900202X

public transport operator, Keolis, in partnership with local transport operator Société de Transport de l'Agglomération Paloise. Additionally, the Netherlands, where Keolis won the largest electric bus contract in its history in what is claimed to be Europe's largest electric bus fleet, with 300 operating vehicles. Similarly, Switzerland has implemented a Hyundai Xcient Fuel Cell truck for its postal service and has developed the necessary hydrogen fuelling stations for its use.

For more detail on the role hydrogen plays in transport in individual countries, please see the relevant country-specific chapter of this guide.

Despite significant costs, private companies in the automotive sector are seizing the potential and widening their portfolio to offer vehicles based on hydrogen technology.

— Car pioneers include:
  - Japanese companies such as Honda (with the Honda Clarity), Toyota (with its Toyota Mirai, one of the first hydrogen fuel cell vehicles to be sold commercially), Hyundai (with the Hyundai Nexo), and Kawasaki are currently at the forefront of hydrogen technology;[19]
  - BMW recently announced that it has plans to invest in an X5 version powered by Toyota's fuel cells in a joint venture with the latter and that it will produce the I Hydrogen Next in small numbers from 2022;[20]
  - a group formed by Ford, Daimler, and Nissan announced a collaboration on hydrogen technology development in 2013, but some of them later abandoned this cooperation (in 2020 Daimler's Mercedes-Benz gave up production of GLC F-Cell and limited its hydrogen program to trucks and vans in association with Volvo);[21] and
  - tested since 2014, Renault's hydrogen technology was developed in partnership with Symbio, a Michelin subsidiary. Renault presented its Kangoo Z.E. Hydrogen (a light vehicle) and Master Z.E. Hydrogen van in 2020.[22]

— Heavy-duty vehicles also continue to thrive, with the following global players:
  - United Parcel Service (**"UPS"**) began testing of a hydrogen powered delivery vehicle in 2017;[23]
  - in 2017, US Hybrid (manufacturer of battery and fuel cell propulsion systems), Toyota, and Kenworth were announcing plans to test Class 8 hydrogen fuel cell trucks to move containers at the Ports of Los Angeles and Long Beach, expecting to build and deliver 1,200 of its fuel cell "engines" over the next 36 months;[24]
  - Toyota Kenworth has a long track record of developing trucks using fuel cell technology, and it added ten T680s in 2019 to be used at the Port of Los Angeles and throughout Southern California;[25]
  - in July 2020, Hyundai was reported to be shipping the first ten units of XCIENT Fuel Cell, the world's first fuel cell heavy-duty truck, to Switzerland, with plans to roll out 50 trucks in the same year and a total of 1600 units by 2025. In 2019, Hyundai formed, for its future development, Hyundai Hydrogen Mobility (**"HHM"**), a joint venture with Swiss company H2 Energy;[26]
  - in 2017, Tesla was launching its Semi prototype truck based on hydrogen technology. However, it was still reported in 2019 to limit its use for its own internal operations, while continuing efforts to develop durable hydrogen technology for commercial trucking;[27] and
  - the commercial vehicles manufacturer Faun (of the German Kirchhoff Group) will launch from 2021 the first hydrogen-powered refuse and sweeper vehicles in series production.[28]

— There is one more possibility – one which is already being explored by Renault in its Kangaroo Z.E. Hydrogen model.[29] This is a dual fuelling system with both electricity and hydrogen fuel cells. This combination enables the amalgamation of the benefits yielded from both fuelling systems and could sustain the demand especially in the passenger car sector. A dual system and infrastructure supporting both hydrogen and battery fuelled cars could be a future option, rather than putting the sole focus into one technology.

17 NPM_AG5_Infrastrukturen-fuer-Wasserstoffmobilitaet.pdf (plattform-zukunft-mobilitaet.de)
18 NPM_AG5_Infrastrukturen-fuer-Wasserstoffmobilitaet.pdf (plattform-zukunft-mobilitaet.de)
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20 https://www.cnet.com/roadshow/news/bmw-hydrogen-fuel-cell-x5-production-toyota
21 https://electrek.co/2020/04/22/daimler-ends-hydrogen-car-development-because-its-too-costly; https://www.autocar.co.uk/car-news/motor-shows-frankfurt-motor-show/bmw-i-hydrogen-next-concept-previews-fuel-cell-range
22 https://www.renaultgroup.com/en/news-on-air/news/kangoo-z-e-hydrogen-and-master-z-e-hydrogen/
23 https://www.cnet.com/roadshow/news/ups-begins-testing-hydrogen-fuel-cell-delivery-truck/
24 https://www.ballard.com/about-ballard/newsroom/market-updates/ballard-and-kenworth-fuel-cell-truck-validation-program-moves-to-next-stage; https://www.trucks.com/2017/05/04/us-hybrid-hydrogen-fuel-cell-truck/
25 https://energypost.eu/hydrogen-fuel-cell-trucks-can-decarbonise-heavy-transport/
26 https://hyundai-hm.com/en/2020/07/08/worlds-first-fuel-cell-heavy-duty-truck-hyundai-xcient-fuel-cell-heads-to-europe-for-commercial-use/
27 https://www.teslarati.com/tesla-semi-rival-nikola-get-1-million-us-department-of-energy-fuel-cell-research/ https://www.teslarati.com/tesla-semi-dublin-supercharger-sighting-lathrop-fremont-factory/
28 https://fuelcellsworks.com/news/the-kirchhoff-group-starts-manufacturing-the-worlds-first-refuse-and-sweeper-vehicles-with-hydrogen-fuel-cells/
29 Wasserstoff oder Elektroauto? Ein Vergleich – Easy Electric Life (renault.com)

EU Framework for Hydrogen in the Automotive Sector

To frame the transition towards a green energy strategy, the European Commission launched a Hydrogen Strategy for Europe in 2020 to be further implemented by the European Clean Hydrogen Alliance.[30] The European Commission aims to work within this frame to introduce common standards, terminology, and further certification in an effort to make renewable or low-carbon hydrogen more competitive and easier to use as an alternative fuel resource.

The current EU legal framework offers flexibility in terms of regulations applicable to the deployment of hydrogen technology in the automotive sector, with limited rules that bear only an indirect impact (e.g. environmental rules on greenhouse gas (**"GHG"**) intensity of hydrogen, technical requirements to be followed by refuelling stations).[31]

At an international level, the United Nations Economic Commission for Europe (**"UN/ECE"**) develops harmonised requirements under regulations which serve as the basis for the national regulatory standards for hydrogen vehicles and in particular FCEVs safety in North America (led by the United States), Japan, Korea, and the European Union. Regulation No 134 of the UN/ECE, containing provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen fuelled vehicles [2019/795], is currently in force and recognised as being equivalent to the corresponding separate EU directives or regulations.[32]

Many of the barriers to hydrogen deployment are a result of regulatory gaps caused by a lack of harmonisation of rules and approaches, or by involuntary mismatches between rules imposed at national level rather than high legal and regulatory barriers imposed at EU level.[33] A major issue is the lack of standardisation in the fuelling procedure for heavy freight transport, which is the targeted sector of the hydrogen technology. Without a harmonised framework for the fuelling procedure, the countries run the risk of additional costs for retrofitting.[34] In order to encourage and secure expansion and funding in the hydrogen sector, the member states should develop a standardised fuelling regulation.

Nevertheless, especially through the so-called "*Fit for 55*" legislative package in the EU and introduction of automotive specific or clean air driven laws elsewhere, steady progress is being seen around the globe as countries take on initiatives to change national policies with the aim to decarbonise vehicle transport, with several countries pioneering concrete steps to invest in and develop hydrogen-based vehicles in public and private transport (also including heavy-duty road vehicles, amongst others).

[30] https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf and https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en

[31] This includes (amongst others): Commission Delegated Regulation (EU) 2019/1745 of 13 August 2019 supplementing and amending Directive 2014/94/EU of the European Parliament and of the Council as regards recharging points for L-category motor vehicles, shore-side electricity supply for inland waterway vessels, hydrogen supply for road transport and natural gas supply for road and waterborne transport and repealing Commission Delegated Regulation (EU) 2018/674; the Recast Renewable Energy Directive (Directive (EU) 2018/2001 (RED II) on the promotion of the use of energy from renewable sources (RED); Alternative Fuels Infrastructure Directive 2014/94/EU (AFID).
Source: https://www.hylaw.eu/sites/default/files/2019-02/D4.4%20-%20EU%20regulations%20and%20directives%20which%20impact%20the%20deployment%20of%20FCH%20technologies_0.pdf

Funding the Hydrogen Automotive Market

Around the world, states, organisations, and private companies are making significant efforts to secure financial funding for hydrogen technology in the automotive sector.

At EU level,[35] the European Commission is funding two research projects (H2ME1 and H2ME2) that aim to see an additional 49 hydrogen filling stations and more than 1400 cars, vans, and trucks run on hydrogen within the EU by 2022. These projects have had budgets of EUR 70m and EUR 100m, with the EU's Horizon 2020 research program sinking EUR 67m in total into both, which run until May 2020 and June 2022, respectively. The research projects involve more than 40 partners from nine countries and from across the transport, hydrogen, and energy industries, including Audi, BMW, Engie, H2 MOBILITY, Hyundai, Michelin, OMV, and Renault. In the EU, the Fuel Cells and Hydrogen Joint Undertaking is the public-private partnership made up of the European Union, represented by the European Commission and the Industry and Research Grouping represented by "*Hydrogen Europe*", responsible for implementing the Fuel Cells and Hydrogen Joint Technology Initiative (**"FCH JTI"**), the political initiative proposing this public-private partnership in fuel cell and hydrogen technologies.

At national level, EU member state and other governments have already initiated incentive schemes for renewable and low-carbon hydrogen mobility, with notable examples set out in the relevant country-specific chapter of this guide.

Undoubtedly, FCEVs are already changing the automotive landscape and hydrogen-based technology is no longer a novelty for the future, but rather a current reality that stakeholders must be equipped to deal with. Although the road ahead may hold financial, regulatory, and technical challenges, hydrogen technology in the automotive sector is an important alternative energy source. Thinking ahead, the sector will need to be prepared for everchanging economic and environmental realities.

32 Regulation 134 (published in the OJ L 129, 17.5.2019, p. 43–89) is available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.129.01.0043.01.ENG
For example, Directive 2007/46 establishes a framework for the type approval of motor vehicles classes M (passenger cars and busses), N (trucks), O (trailers), and of systems and components intended for such vehicles. Specific technical requirements concerning the construction and functioning of vehicles is laid down in subsequent regulatory acts, the exhaustive list of which is set out in Annex IV. The UNECE Regulations listed in Part II of Annex IV are recognised as being equivalent to the corresponding separate directives or regulations in as much as they share the same scope and subject matter.

33 https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c162864e&appId=PPGMS

34 NPM_AG5_Infrastrukturen-fuer-Wasserstoffmobilitaet.pdf (plattform-zukunft-mobilitaet.de)

35 https://www.wardsauto.com/alternative-propulsion/europe-nurturing-hydrogen-vehicle-market

What role can Hydrogen play in the Industrial Processes

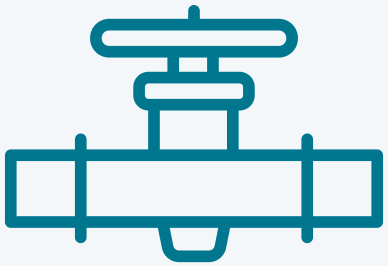
Authors:
Dalia Majumder-Russell
Andrew Shaw

Industrial applications are the most widespread and significant of hydrogen uses in operation today; 33% of all hydrogen (in pure and mixed forms) is used in oil refining, 27% in ammonia production, 11% in methanol production and 3% in steel production.[1] Almost all hydrogen used in these industrial applications is derived from fossil-fuel sources. Unsurprisingly, the industrial sector is therefore often cited as the hardest sector to decarbonise and one where a scale of need would help catalyse the roll out of low-carbon hydrogen.

There are significant opportunities to use low-carbon hydrogen technologies in the heat generation process across a much broader range of industries, subject to overcoming the current barriers – in particular, substantial adoption costs and insufficient scale of capacity of low-carbon hydrogen production.[2] To this end, legal and regulatory frameworks capable of supporting the growth of industrial low-carbon hydrogen use are needed. Given the wide range of applications and uses for hydrogen in the industrial sector, this chapter focuses primarily on hydrogen use as a feedstock in industrial heat-generation and draws on international examples to highlight the key legal considerations for investors, developers and financiers entering this sector.

[1] https://webstore.iea.org/download/direct/2803
[2] https://webstore.iea.org/download/direct/2803

Hydrogen Technology in the Industrial Processes



High-intensity heat generation is required for a number of reasons: melting, drying, gasifying, facilitating chemical reactions, and so on.[3] Heat can be used directly, in furnaces, or indirectly, for example to produce steam which is then used for heating.[4] At present, the primary source of energy in high-temperature industrial heating is fossil fuels (coal provides 32%, with natural gas supplying 31% and oil 15%).[5] As the demand for industrial heat continues to increase, it's share in energy-related CO_2 is also likely to increase, accounting for a quarter of global emissions by 2040.[6]

However, hydrogen may provide a solution.[7][8][9] In an ambitious high adoption scenario, it has been estimated that hydrogen could provide approximately half of the energy required to power the UK's industrial, heating and transport sectors by 2050.[10]

Yet, in terms of industrial heating, this progress would need to start from a low base. At present there is almost no dedicated hydrogen production for use as a feedstock in heat-intensive industries (other than chemicals, iron and steel).[11]

3 https://webstore.iea.org/download/direct/2803
4 https://webstore.iea.org/download/direct/2803
5 https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/plugging-in-what-electrification-can-do-for-industry
6 https://www.iea.org/commentaries/clean-and-efficient-heat-for-industry
7 https://www.carbonbrief.org/in-depth-hydrogen-required-to-meet-uk-net-zero-goal-says-national-grid
8 https://www.nationalgrideso.com/document/173791/download
9 https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf
10 https://www.edie.net/news/8/Hydrogen--could-provide-half-of-the-UK-s-net-zero-energy-demand-/
11 https://webstore.iea.org/download/direct/2803

Opportunities and Barriers for Hydrogen Use in Industrial Processes

The scale of hydrogen production needed for the industrial sector lends it to favouring blue hydrogen – i.e. where the associated carbon dioxide is captured, transported and stored using CCUS technologies. This is where countries such as the UK and US are placing emphasis for the roll out of hydrogen projects at scale. However, for others countries, where carbon capture is impractical, the use of low-carbon hydrogen in industrial heating may be achieved, for example through the use of small-scale localised electrolysis.[12] In any event, focusing on geographic clusters or industrial pockets is an opportunity for stimulating large-scale demand in given areas, which would in turn encourage investment in these areas.

Nevertheless, the process would not be so simple as to merely replace fossil fuel feedstocks with hydrogen. This is because heat-generation technologies across industrial sectors are diverse and specific to those sectors and there are a number of practical challenges which would need to be overcome. In the cement industry, for example, the high combustion velocity of hydrogen relative to carbon-based fuels, as well as its non-luminous flame, makes the application of hydrogen difficult to monitor.[13]

Further, although some infrastructure needed for such processes already exists, new infrastructure would need to be developed, including new pipelines and storage infrastructure.[14] With the requirement for significant capital outlays, the lack of assured demand is therefore a dilemma policymakers and the private sector need to address.

One opportunity for policymakers, here, is in creating a new regulatory environment that facilitates the development and uptake of low-carbon hydrogen technologies. For instance, while there are clear benefits to using low-carbon hydrogen in the steel industry, regulations on production quality mean that careful and thorough investigation is necessary before this technology can be rolled out.[15]

Ultimately, significant policy support is required if there is to be a significant uptake in hydrogen technology across heat-intensive industrial sectors. Although industrial heat demand is likely to rise in the medium term – a 9% increase is anticipated by 2030 – without additional policy support, it is difficult to anticipate noticeable increases in low-carbon hydrogen use.[16]

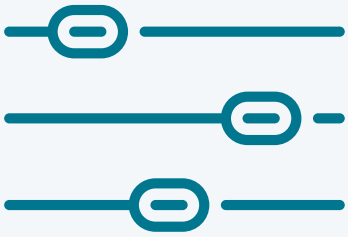
12 https://webstore.iea.org/download/direct/2803 – see p.119
13 https://webstore.iea.org/download/direct/2803 and Li, J. et al. (2014), "Study on using hydrogen and ammonia as fuels: Combustion characteristics and NOx formation", International Journal of Energy Research, Vol 38, pp. 1214–23.
14 https://www.auroraer.com/wp-content/uploads/2020/06/Aurora-Hydrogen-for-a-Net-Zero-GB-An-integrated-energy-market-perspective.pdf?eid=G%2FuTryBZDHrp6kDwxxMybQ%3D%3D#gf_25
15 http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/11/Element-Energy-Hy-Impact-Series-Study-4-Hydrogen-in-Yorkshire-the-Humber.pdf
16 https://webstore.iea.org/download/direct/2803

As globalisation of the hydrogen economy progresses, it is expected that locally generated hydrogen will become increasingly supplemented by trans-border shipment of hydrogen, with it being generated in jurisdictions where renewable electricity and the ability to store CO_2 is more readily available. The economics of these types of projects is still uncertain, however if the price can compete with locally sourced hydrogen then this will open up this market to industrial users.

Currently the contractual frameworks for these projects are developing. For some entities at least these projects look similar in structure to LNG and large-scale cross-border gas transportation projects and projects for the transportation of petrochemicals (areas where the economics do stack up). For others, these will need to follow offtake structures more familiar with renewable generation such as power purchase agreements. Or there will be an adaptation of both approaches as the market develops.

The challenges with trans-border shipment of hydrogen is more on the technical side. In order to be shipped in liquid form, hydrogen has to be cooled to minus 253 degrees Celsius, which is 20 degrees above absolute zero (the lowest level of the thermodynamic scale), and 100 degrees cooler than LNG. There are also issues with the volatility of liquid hydrogen. That said, liquid hydrogen carriers and stabilising catalysts are being developed and tested and expected to be deployed in full scale projects in the near future. In the meantime, green ammonia (constituted of nitrogen and hydrogen) is seen as a less technically challenging and currently commercially viable type of hydrogen transportation project, so this is another route to a hydrogen market for industrial users to consider.

Towards an Effective Framework for Hydrogen in the Industrial Sector



Developers, investors and advisers in the energy sector will appreciate that energy projects must navigate a complex regulatory regime. A variety of different regulatory bodies and key stakeholders operate within this framework; offshore seabed owners, marine management authorities, oil and gas authorities, government departments, shipping authorities, environmental bodies and health and safety executives are but a few of the stakeholders low-carbon hydrogen projects may need to consider.

Therefore, to integrate blue and green hydrogen technologies into existing energy systems, so that they may be used as an industrial feedstock, requires a more joined up approach across these stakeholders.[17] It will be especially important to ensure that regulatory frameworks can successfully facilitate and manage the key infrastructure in blue and green hydrogen: transportation and storage facilities.

Some jurisdictions covered by this guide, notably Japan, South Korea and some EU jurisdictions, have already taken steps in this regard.

For example, in the UK, the Oil and Gas Authority (**"OGA"**) has acknowledged that, as well as clarifying the content of regulations for hydrogen technologies and associated infrastructure, the roles played by the myriad of stakeholders and authorities must also be rationalised. Guidance issued by those authorities must be aligned, where possible, to assist developers of first-of-their-kind projects in understanding how to apply existing rules in this novel field.[18] In practice, this will result in additional time and cost to the project while the rules and guidance are assessed and put to use. For example, in relation to consenting hydrogen projects, some authorities may not have sufficient guidance to inform an application for consent to develop a hydrogen project. It is through further alignment with the policies of the wider decarbonisation agenda that pilot projects and industry, as a whole, can proceed in a timely manner, paving the way for greater uptake of hydrogen technologies in industrial settings over the coming decade.[19]

Similarly, countries like the Netherlands have been clear in voicing their expectation that hydrogen networks will be regulated in a similar way to existing gas and electricity networks.[20] The Dutch authorities have also recognised the challenges in the current laws for the storage of hydrogen. While preferring to have European or international safety guidelines and standards developed, they have begun establishing general principles relating to the safety risks of hydrogen storage with the ultimate aim of developing a bespoke framework specific to hydrogen.[21]

17 https://www.ogauthority.co.uk/media/6625/ukcs_energy_integration_phase-ii_report_website-version-final.pdf see page 18
18 https://www.ogauthority.co.uk/media/6625/ukcs_energy_integration_phase-ii_report_website-version-final.pdf see page 22
19 https://www.ogauthority.co.uk/media/6625/ukcs_energy_integration_phase-ii_report_website-version-final.pdf see page 31
20 https://www.lexology.com/library/detail.aspx?g=84848b41-0541-4269-a151-30c87f6e20ff
21 https://www.government.nl/documents/publications/2020/04/06/government-strategy-on-hydrogen see page 6

Funding the Hydrogen Industrial Market

In a number of jurisdictions covered by this guide, the availability of public and private financing to develop hydrogen technologies for industrial applications is nascent, though improving. However, in comparison to the use of hydrogen in transportation, there are fewer examples of funding mechanisms which are specific to the industrial use of hydrogen.

Nevertheless, there are some examples of financing mechanisms, often combining public and private funding, which are being harnessed to develop hydrogen technologies for industrial feedstocks:

— **Italy:** in 2019, SNAM S.p.A (**"SNAM"**) launched a project (**"SNAMTEC"**) aimed at increasing energy efficiency, reducing pollutant gas emissions and promoting innovation in the energy sector. Among the initiatives included in SNAMTEC, SNAM launched a trial that took place for a month in the Campania Region. The trial introduced a quota of 5% hydrogen into the energy mix and has,[22] proven that the introduction of even a small portion of hydrogen in the energy mix would allow a substantial reduction in carbon dioxide emissions.

— **Germany:** there is a well-established precedent of public funding for hydrogen technologies in Germany. In respect of industrial hydrogen use, the German Federal Ministry of Education and Research is providing more than EUR 60m in funding to the "Carbon2Chem" project, which explores how industrial gases from steel production can be used to create valuable primary products for fuels, plastics or fertilisers. It is expected to make 20m tonnes of the German steel industry's annual CO_2 emissions economically exploitable in the future. This represents 10% of Germany's annual CO_2 emissions produced by industry and manufacturing. The project's other partners intend to invest more than EUR 100m by 2025.[23]

— **Czech Republic:** although there is no specific funding mechanism for hydrogen technologies, there are examples of collaborative approaches to support such schemes. For instance, in 2019, the Region of Ústí and Labem along with UNIPETROL, a.s. (a PKN Orlen Group company) assembled a consortium of 17 public and private entities to sign a memorandum on partnership and cooperation in the development and use of hydrogen as a clean source of energy. The goal of this initiative is to support the use of hydrogen in local industry.

[22] https://www.snam.it/en/Media/Press-releases/2020/Snam_results_first_nine_months.html
[23] https://www.fona.de/en/measures/funding-measures/carbon2chem-project.php

— **UK:** in February 2020, the Department for Business, Energy and Industrial Strategy (**"BEIS"**) announced a GBP 90m package as part of its larger innovation fund. GBP 28m of this is earmarked for the development of hydrogen production projects, including two of Europe's first-ever large-scale, low-carbon hydrogen plants.[24] One of these is the HyNet project, which is discussed in more detail in the UK chapter of this guide. This is led by Progressive Energy Limited, in collaboration with Johnson Matthey, SNC Lavalin and Essar Oil. It involves the development of a hydrogen production facility on Merseyside, to be part of the UK's first net-zero industrial zone using carbon capture and storage technology. From 2025, HyNet will produce, store and distribute hydrogen as well as capture and store carbon from industry in the North West of England and North Wales using state-of-the-art technology to build new infrastructure whilst also upgrading and reusing existing infrastructure which is currently involved in fossil fuel production.[25] Hydrogen produced at this plant will be used at a Unilever manufacturing site close by, as well as Pilkington's Greengate glassworks – this will be the first time hydrogen is used in glass manufacturing worldwide.[26] Further, in October 2021 the Chancellor of the Exchequer confirmed in the UK's Budget and Spending Review for 2021 that the government plan to spend GBP 240m on the Net Zero Hydrogen Fund (**"NZHF"**), originally announced in the Prime Minister's Ten Point Plan for a Green Industrial Revolution, which will be delivered between 2022 and 2025. The NZHF aims to support the commercial deployment of new low-carbon hydrogen projects during the 2020s, with an ambitious target of 5GW of low carbon hydrogen production by 2030.

[24] https://www.gov.uk/government/news/90-million-uk-drive-to-reduce-carbon-emissions
[25] https://hynet.co.uk/
[26] https://www.theengineer.co.uk/hynet-3m-funding-boost/

Hydrogen Industrial Clusters

In an effort to coordinate how clean hydrogen may become a viable solution for decarbonising European economies, in 2020, the European Commission (the **"Commission"**) launched a Hydrogen Strategy for Europe. This sets out a strategic framework which the European Clean Hydrogen Alliance can then use to develop an investment agenda and project pipeline. The strategy envisages that from 2025 to 2030, hydrogen will need to become an intrinsic part of European energy systems. During this period, it is anticipated that demand-side policies will be required to ensure that uptake of hydrogen technologies is realised in industrial settings. The development of hydrogen industrial clusters – where decentralised renewable energy production will be located alongside energy-intensive industries – is a fundamental part of this vision.

In time, the Commission considers that a need will develop for Union-wide hydrogen transmission infrastructure, so that hydrogen may be transported from renewable energy generation centres to areas where industry is heavily concentrated. To scale up the deployment of hydrogen technologies, EU support and stimulus packages will be required, with the aim of having a competitive hydrogen market operational in the Union by 2030. This will allow hydrogen to penetrate all sectors of the economy, including industries where decarbonisation is currently more costly, as 2050 approaches.

In the UK, a similar cluster strategy is developing and research here has been focussed on a potential hydrogen cluster located in the Yorkshire & Humber region. This region is the most significant amongst the UK's six largest industrial clusters, in terms of energy use and greenhouse gas emissions, and there are opportunities to replace natural gas with hydrogen across a number of sectors, including glass manufacturing, the secondary steel industry, cement production and the lime sector. The rationale behind the development of a hydrogen cluster is that by first establishing projects which would supply a handful of large local industrial users, this may support a cost-effective hydrogen transition which can then be rolled out more broadly. There is political support in the Humber region for decarbonisation initiatives and it is hoped that by first utilising blue hydrogen, this will reduce the costs associated with the subsequent introduction of green hydrogen produced by using energy from offshore wind projects in the North Sea.

The broader international approach follows a similar vein. The International Energy Agency has recommended that industrial ports should become the "nerve centres" for the up-scaling of hydrogen technologies. The potential for cluster development around the North Sea, the North American Gulf Coast and China's Pacific coastline has been underlined.

Conclusion

Undoubtedly, the role that industrial and manufacturing processes will play in the energy transition will be key for the achievement of national and international climate change goals. Both blue and green hydrogen will have a role to play, with the scale and capital needs of the industrial sector making this an interesting proposition for those investors ready to move beyond R&D projects. The processes of today may need adapting and creating over the coming years, but hydrogen will play a role in unlocking complimentary technologies, such as carbon capture and storage, while also expanding the areas where it is currently deployed. With the marine and automotive landscape changing too, industrial sectors will determine just how deep and how far the low-carbon hydrogen revolution will reach.

Munir Hassan
Head of Energy
& Climate Change Group
T +44 20 7367 2046
E munir.hassan@
cms-cmno.com

Dalia Majumder-Russell
Partner, Energy
& Climate Change
T +44 20 7367 3634
E dalia.majumder-russell@
cms-cmno.com

Austria

Author:
Marco Selenic

Current status for hydrogen in Austria

Introduction

Austria has ambitious goals when it comes to renewable energy sources: 2030, the country wants to obtain its electricity supply completely from renewable energy sources and as a next step become climate-neutral by 2040. This means that by 2030, the annual electricity generation from renewable energy sources needs to be increased by 27 terawatt hours (TWh), 11TWh coming from photovoltaics, 10TWh from wind power, 5TWh from hydropower and 1TWh from biomass. According to the government programme, by 2030 Austria aims to produce 5,000GWh of green gas (including hydrogen).

It is clear that hydrogen will take an increasingly important role in achieving the ambitious climate goals. How important that role will be is of political discussions. In 2018, the Austrian government kicked off the development of an "Austrian Hydrogen Strategy", which was supposed to be spearheaded by the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology. Political turmoil led to a new government being elected with participation of the conservative Austrian People's Party and the Green Party. This led to an even stronger focus on renewable energy production. However, despite more ambitious climate goals, hydrogen has fallen somewhat behind on the political agenda.

The business community, however, is not deterred by the political hesitation. Like everywhere else in the world, there are more and more hydrogen projects surfacing. Currently approximately 180 companies in Austria deal with hydrogen technologies and interest is continuously increasing.[1] A few exemplary projects in the following fields are:

[1] Energieinstitut der Wirtschaft, Wasserstoff – Zentraler Baustein der Energiewende, p. 3.

Power to Gas	The "Renewable Gasfield" situated in Styria is one of the most advanced research projects in this context. This project pursues a holistic power-to-gas approach that generates green hydrogen from renewable electricity through electrolysis and combines two-stage catalytic methanation on a large scale for sustainable energy supply in the fields of energy, mobility and industry.[2]
Energy Storage	The project "Underground Sun Storage 2030" explores the safe, seasonal and large-volume storage of renewable energy in the form of hydrogen from solar and wind energy in underground gas reservoirs. Under the leadership of RAG Austria AG together with project partners such as Voestalpine and the WIVA P&G association underground storage possibilities will be researched under real conditions.[3] ADX, an Australian energy company that recently acquired former oil and gas fields in Lower Austria, currently also works on the use of depleted gas reservoirs suitable for hydrogen storage.[4] The project "HyWest", which is funded by the Climate and Energy Fund with EUR 9.2m, serves the exemplary development of a largely autonomous regional green hydrogen economy. The processes of cross-sectoral production, storage and application of green hydrogen are being researched. The aim of the project is to produce, methanise and feed green hydrogen and to use green hydrogen in industrial processes.[5]

[2] Renewable gasfield – WIVA P&G.
[3] Underground Sun Storage 2030: Sonnenenergie saisonal und großvolumig in Form von Wasserstoff speichern, vorhandene Infrastruktur nutzen | RAG Austria AG, 08.06.2021 (ots.at).
[4] PowerPoint Presentation (adx-energy.com)
[5] WIVA P&G HyWest: Regional Green Hydrogen Economy – WIVA P&G.

Production	UpHy II: In 2021, OMV and Kommunalkredit announced that they would invest EUR 25m in hydrogen production facilities. They are cooperatively building Austria's largest electrolysis plant at the OMV Schwechat refinery. The 10MW electrolyser will produce up to 1,500 metric tons of green hydrogen, thereby reducing CO_2 emissions by up to 15,000 metric tons. The goal of UpHy II is, on the one hand, to upscale green hydrogen for mobility and industry by investing in the green H2 value chain from production to electrolysis, trailer charging and bus filling station and, on the other hand, the development of novel measurement methods for gas quality and mass to meet regulatory requirements. Wien Energie, the regional Viennese energy provider, announced the foundation of the subsidiary "Wiener Wasserstoff GmbH" solely focusing on the development of hydrogen technologies including a 2.5MW electrolyseur. The medium-term goal is to become the hydrogen hub of the region.[6]
Mobility	The biggest Austrian energy company OMV AG and Post AG signed a letter of intent for the application of green hydrogen in heavy-duty transportation. The common goal is to advance commercial electromobility for heavy-duty transport in the field of hydrogen fuel cells in Austria and make it available. 2,000 fuel cell trucks that will be powered by green hydrogen shall be put into operation by 2030.

[6] Stadtwerke investieren 4,25 Mrd. in Klimaschutz – wien.ORF.at

	HyTrain: The "HyTrain" project aims to use Austrian know-how to develop the world's first hydrogen-powered narrow-gauge train to the point where it can be used in the mobility sector. This includes the generation, storage and refueling of the train with green hydrogen. The hydrogen powertrain will be tested at the Hydrogen Center Austria (**HyCentA**) test stand and then used in real operation with an electric railcar of the Zillertal Railway. The hydrogen train-system will be designed for high-performance train applications such as high-speed trains with high acceleration.[7] HyTruck: The project focuses on the development and testing of a zero-emission fuel cell powertrain for commercial vehicles. The goal is the development and simulation of a hydrogen tank system for commercial vehicles, as well as comprehensive technical, economic and ecological analyses.[8]

[7] HyTrain: Forschungsprojekt zu Wasserstoffzug– Testbetrieb auf der Zillertalbahn | Klima- und Energiefonds, 04.08.2020 (ots.at).
[8] HyTruck – Hydrogen Truck Austria – WIVA P&G.

Market prospects for hydrogen

The publication of the Austrian Hydrogen Strategy is still pending. A further rise in interest and investment activity can be expected once the strategy comes into force. In July 2021, the Austrian Parliament enacted the Renewable Energy Expansion Act ("REEA", "Erneuerbaren-Ausbau-Gesetz"). One major part of the REEA are investment grants in the amount of EUR 80m per year for the development of technologies for renewable gases including hydrogen. These investment grants are expected to have positive effects on development and investment actitivites.

The Austrian Climate and Energy Fund which is set up by the Austrian government to provide financial support to companies engaging in sustainable energy technologies and climate research, has supported (and continues to do so) numerous hydrogen related projects in Austria.[9]

There are several associations that deal with the market prospects of hydrogen, such as the WIVA P&G association. WIVA P&G is an association for the promotion of research and development in the fields of application, network and storage technologies of hydrogen and renewable gases as well as measures for the dissemination of these activities. The association supervises the "Hydrogen Initiative Showcase Region Austria Power & Gas" (in short "WIVA P&G"), which is also funded by the Climate and Energy Fund.

Even though hydrogen is not yet a priority on the political agenda, companies are strongly interested in the development of hydrogen technology and applications. Most Austrian energy providers have initiated the first hydrogen projects in recent years. Further, the Austrian economic chamber is pushing for an open approach to subsidising hydrogen technologies (not only limited to 100% green hydrogen).[10]

[9] https://www.klimafonds.gv.at/ueber-uns/.
[10] WKÖ-Kopf: Wasserstoff-Nutzung fördern, nicht behindern | SN.at

Challenges facing hydrogen projects

Lack of a national Hydrogen Strategy

As already mentioned, the Austrian federal government initiated a national hydrogen strategy in 2018. However, a final strategy has (despite several announcements) not been published yet. Austrian companies expect this strategy to provide guidelines at the national level for funding R&D and also large-scale demonstration projects in Austria.[11] In August 2021, the Austrian State Secretary for climate protection expressed strong support for investments in Austria for producing 100% clean hydrogen.[12] The lack of a strategy leads to the danger of Austria falling behind in several areas: amounts of hydrogen will be needed in industry, mobility, heat supply and stabilisation of the electricity grid and it will not be possible to cover the need with domestic sources only. Other countries have begun working on partnerships to secure supply sources, which Austria has not done yet.[13]

Legal Framework

Currently, there is no legal framework that exclusively deals with hydrogen. The laws governing the Austrian energy industry, the Electricity Industry and Organisation Act and the Gas Industry Act, also make hardly any reference to hydrogen-related technologies. For example, it has not yet been clarified whether the production of hydrogen falls under the industrial plant law (*Betriebsanlagenrecht*) of the Industrial Code or under the electricity laws of the Austrian states.

As described above, in July 2021, the Renewable Energy Expansion Act (**"REEA"**) was passed by the Austrian parliament. The REEA is the most important piece of legislation in the field of energy in Austria in decades. It was expected that hydrogen will play a major role in the REEA. However, only first steps have been taken in the form of the introduction of subsidies for the development of technologies for renewable gases, including the transformation of electricity into hydrogen. A total of EUR 40m in subsidies will be available for this purpose per year, with the aid being granted in the form of investment grants. Up to 45% of the costs for construction of each plant will be available. The subsidies can be higher, should the hydrogen be used for supporting the grid stability. Other Western European Countries have announced much bigger support schemes for the development of hydrogen technology and infrastructure.

[11] energy innovation austria, Issue 1/2020 (energieforschung.at)
[12] ÖVP-Staatssekretär Brunner zum Klimaschutz: "Drüberfahren ist nicht der richtige Weg" – Umwelt, Landwirtschaft & Klima – derStandard.at › Wirtschaft.
[13] Grüner Wasserstoff – der Stoff, aus dem Träume sind | DiePresse.com

Regulation of hydrogen

Legislation overall

Even though Austrian legislation is slowly advancing, there is no comprehensive set of regulations. Therefore, general provisions of public law and energy law must be used for the implementation of hydrogen projects.

The scope of the Gas Industry Act continues to be limited to natural gas or biogenic gases processed to natural gas quality. Other types of gas, such as hydrogen and synthetic natural gas, are therefore not explicitly covered by the current provisions of the Gas Industry Act. However, this could be remedied by Art. 1(2) of the Gas Directive 2009, the scope of which extends to other types of gas on a non-discriminatory basis. Since the Gas Industry Act falls short of EU law requirements in this respect and does not fully implement them, it can be argued that EU law is directly applicable.[14] In this sense, the Gas Industry Act can also be considered applicable to hydrogen.

Subsidies for hydrogen projects

As described above, one of the major new developments in hydrogen legislation is the subsidisation of electrolysis plants for the production of green hydrogen. The construction of an electrolysis plant for the conversion of electricity into hydrogen or synthetic gas with a minimum capacity of 1 megawatt (MW) can be subsidised by an investment grant if the plant is used exclusively for the production of renewable gases and is powered exclusively by renewable electricity. Funding is excluded for plants that are built and operated by grid operators or that add hydrogen to natural gas in the public gas grid. The investments are subsidised with up to 45% of the investment volume directly required for the construction of the plant (excluding land).

Generation of hydrogen

The Austrian legal system does not have any specific regulations on the construction and operation of a hydrogen production plant, nor does it provide for any specific licensing obligations for this type of plant. Therefore, the existing general licensing obligations in Austrian law must be examined for each hydrogen production plant on a case-by-case basis. As a commercial operating facility, a hydrogen production plant may regularly be subject to the Austrian Industry Act ("IA", "*Gewerbeordnung*"). Depending on the production capacity, the plant may be subject to the normal licensing procedure under the IA. Hydrogen production plants with a high production capacity may also be IPPC plants. Therefore, the competent authority has to assess the situation on a case-by-case basis, particularly for large hydrogen production plants that can potentially have a significant impact on the environment. In such cases, the comprehensive permit requirement under the Environmental Impact Assessment Act (or *Umweltverträglichkeitsprüfungsgesetz, UVP-G*) must be considered. According to the UVP-G, such plants are subject to an environmental impact assessment in which hydrogen is produced by chemical conversion in the order of 150,000/year.[15]

Storage of hydrogen

Regulations such as the Regulation dealing with the Prevention of Accidents in the Industry Sector (or *"Industrieunfallverordnung"*), the Explosion Protection Regulation 2015 (or *"Explosionsschutzverordnung 2015"*) and the Regulation on Flammable Liquids (or *"Verordnung über brennbare Flüssigkeiten"*) must be consulted when storing hydrogen. Necessary considerations will depend on the size of the facility being used.

[14] *De Bruyn,* Power to Gas – Eine rechtliche Analyse, Jahrbuch Energiewirtschaft 2017, 169.
[15] *Christoph Cudlik,* Ist das österreichische Anlagenrecht reif für Power-to-X-Anlagen? RdU-UT 2020/14, S. 63ff.

Transport and Distribution of hydrogen

The European Agreement concerning the International Carriage of Dangerous Goods by Road (**"ADR"**) regulates the transport of hydrogen, which is classified as a dangerous good under Annex A (Class 2) of the ADR. Drivers transporting hydrogen must be appropriately trained and vehicles must meet certain specifications required for hazardous cargoes. The Law on the Transportation of Dangerous Goods (*"Gefahrgutbeförderungsgesetz"*), the Law on Pressure Equipment (*"Druckgerätegesetz"*) and the Regulation on Explosion Protection (*"Explosionsschutzverordnung"*) also apply to the transport, design and manufacture of tanks being used to transport hydrogen.

Gas Grid regulation

The Austrian gas market is regulated by the public authority E-Control, whose task is to monitor and support the implementation of the liberalisation of the Austrian electricity and gas markets and, where necessary, to take regulatory action. E-control must be notified in advance of the commencement of a natural gas trader's activity. The regulatory authority shall publish a current list of such natural gas traders.

It must be considered that – unlike synthetic natural gas – hydrogen cannot be fed into the grid in its pure form. As a result, it must first be mixed with natural gas to form a natural gas-hydrogen mixture to achieve the required composition, so that damage to pipelines and customer plants can be prevented. It is therefore imperative that the gas being fed in complies with the relevant guidelines for the Gas and Water Industry and thus, is compatible with the grid. Until recently, the direct injection of hydrogen into the natural gas network was limited to a maximum of 4% by volume. With the new gas quality guideline G B210, which came into force on 1 June 2021, up to 10% hydrogen can be fed into the gas network.

Further, recent amendments to the Austrian Gas Industry Act specify that the Federal Minister for Climate Protection, the Environment, Energy, Mobility, Innovation and Technology, in alignment with the Federal Minister for Digitization and Economic Location, can set a maximum value for the technically permissible proportion of hydrogen in natural gas pipeline networks by ordinance.[16]

The Electricity Industry and Organisation Act, which was amended in the course of the new REEA package, now allows grid operators to operate power to gas plants to stabilise the electricity grid.

[16] Sec 133a GWG.

Regulatory bodies

Regulatory Body	Role
Municipality	The respective municipality makes the decisions on land use plans.
State (Bundesland)	The "Bundesland" is a one-stop-shop for the Environmental Impact Assessment.
Gas Connect Austria as Transmission System Operator ("TSO")	Gas Connect Austria is responsible for the safe operation of a high-pressure natural gas pipeline network. It is up to the transmission system operator to decide whether hydrogen can be injected into the gas grid.
AGGM Austrian Gas Grid Management AG	AGGM is the independent system operator of the Austrian gas network.
E-Control GmbH	E-Control monitors and supports the implementation of the liberalisation of the Austrian electricity and gas markets.

Upcoming developments

As described above, the most important development the Austrian hydrogen community and its stakeholders are waiting for is the publication of the Austrian Hydrogen Strategy.

The following cornerstones are expected to be part of the strategy:

- Developing hydrogen technology specifically for the economic and transport sectors to make Austria the leading hydrogen nation;
- Implementing a Climate Protection and Hydrogen Centre as a cluster for research, innovation and technology to position Austria as a pioneer in the field of renewable energy and support the Austrian export economy; and
- Austria:
  - the pioneer in electricity generation from renewable energies focusing on an anti-nuclear and anti-coal power agenda; and
  - an innovation leader in hydrogen technology.

Belgium

Author:
Youri Musschebroeck

Current status for hydrogen in Belgium

Introduction

There are no fewer than 613km of hydrogen pipelines in Belgium, with nodes around the ports of Ghent and Antwerp. This network reflects the high potential for hydrogen projects in Belgium.

Belgian authorities encourage the development of hydrogen projects through subsidies and other legislative initiatives. For example, many Belgian cities have introduced low-emission zones aimed at keeping the most polluting vehicles out of cities and promoting the use of low-carbon alternative solutions. On 16 July 2021, the Flemish government also approved a decree on zero-emission vehicles and vehicles powered by alternative fuels, which will not only allow the Flemish government to take (financial) incentives for the use of zero-emission vehicles (i.e. hydrogen vehicles), but also to develop a customised infrastructure.

Since 2009, demonstration projects have been developed within the framework of the *Interreg project Hydrogen Region Flanders-South Netherlands,* with Belgium and the Netherlands working closely together in a cross-border collaboration.[1] This project resulted in the first hydrogen stations using electrolysis in Flanders and the Netherlands, and the development, construction and demonstration of innovative hydrogen-based transport. Most of the hydrogen projects in Belgium focus on hydrogen in transport: including the development of hydrogen refuelling stations, hydrogen fuelled cars, buses, and (garbage) trucks.

The use of hydrogen as a large-scale renewable energy storage solution has also been proven to have technical and economic viability in Belgium.[2]

[1] https://www.waterstofnet.eu/_asset/_public/WaterstofNet_brochure_ENG.pdf
[2] https://www.don-quichote.eu/

Market prospects for hydrogen

There are significant prospects for growth over the coming years in Belgium. The total technical potential for green hydrogen in Flanders is estimated to be around 954kt by 2050.[3]

The Belgian recovery plan (as approved by the European Commission on 23 June 2021) has set a target for hydrogen production of 150MW by 2026. This is less ambitious in comparison to other countries such as Germany and the Netherlands, which plan projects for several gigawatts.

Concrete applications for the use of hydrogen, however, remain limited in the coming decades. There are two potential interesting applications:

— for a large number of industrial processes (fertilisers, plastics, oil and steel) hydrogen is indispensable as a raw material.
— carbon emissions from heavy and long-distance transport (such as aviation and shipping) could also be greatly reduced by the use of liquid fuels produced on the basis of hydrogen.[4]

There has been little M&A activity in the sector and relatedly, little by way of private financing to date. This is expected to change once the Belgian government clarifies the legal framework for hydrogen projects.

[3] https://www.energiesparen.be/sites/default/files/atoms/files/20191030-Vlaamse_prioriteiten_waterstof_vanuit_energetisch_perspectief.pdf
[4] https://www.energiesparen.be/sites/default/files/atoms/files/20191030-Vlaamse_prioriteiten_waterstof_vanuit_energetisch_perspectief.pdf

Challenges facing hydrogen projects

Reducing the cost and securing demand

As with many emerging technologies, the production and processing of low carbon hydrogen is more expensive than current processes for producing "grey" hydrogen. Accordingly, the development of hydrogen at scale is seen as a key requirement for reducing overall costs.

Given that the production of hydrogen in Belgium at present is entirely based on natural gas or coal, the greenhouse gases released when producing hydrogen are higher than the emissions avoided by using the hydrogen. It will therefore be a challenge to gradually start producing green hydrogen over the next few years through electrolysis using renewable energy.[5] Belgium will have to ensure that it has sufficient green electricity for this process.

Overcoming the current price uncertainties and lack of forecasted demand is key for developing successful hydrogen projects in Belgium. The certainty of long-term contracts is seen as critical for minimising some of the perceived risks.

Legislative framework gaps

In common with many other jurisdictions, Belgium does not have a well-defined legislative framework for hydrogen projects across various sectors. This creates a number of gaps and uncertainties which need to be addressed before the hydrogen economy can flourish.

Regulation of hydrogen

Legislation overall

There are different laws that specifically relate to hydrogen. These laws mostly regulate health and safety aspects of using hydrogen or the transport of it (please see more detail below).

In addition to these laws, there are other laws that do not specifically relate to hydrogen but should be taken into account. Some new legislative initiatives govern low-emission zones across the country (and, for example, specify that hydrogen fuelled vehicles are allowed to enter the relevant area).

Lastly, some hydrogen projects will require a permit. This may be the case when the project includes any of the following activities:

— the storage of gases (and therefore hydrogen);
— the physical treatment (compressing or relaxing) of gases;
— the filling of gases into movable containers,
— in addition, pursuant to the Royal Decree of 14 May 2002 on the transport permit for gaseous products and others by pipeline, a separate permit is needed for such transport by pipelines.

Urban planning regulations have been regionalised. When developing a hydrogen project that requires a building/environmental license, the applicable laws will differ in Flanders, Wallonia and Brussels.

[5] https://www.energiesparen.be/sites/default/files/atoms/files/Rapport-Vlaams-potentieel-groene-waterstof.pdf

Injection into the gas grid – blending hydrogen into the existing gas networks: regulation

At present, hydrogen is not interchangeable with natural gas in the Belgian networks. The possibilities of replacing gas with hydrogen in the natural gas distribution network in Belgium requires further research.

For the time being, research assumes that higher concentrations of hydrogen in the natural gas network require thorough renewal or modification of existing storage, transport and distribution infrastructure, as well as current consumption devices. To date, the competent authorities have not yet received any applications for the injection of hydrogen into the natural gas network.

However, the injection of a percentage of hydrogen into the natural gas grid and making the natural gas grid suitable for the transport of pure hydrogen are at the top of the Belgian hydrogen agenda.

Health and Safety laws

Hydrogen, like other gasses, is heavily regulated from a health and safety perspective, particularly due to its physical qualities. Hydrogen has a wide ignition range of 4 to 76%, has a low ignition energy (0.019MJ) and burns quickly.

The following directives and royal decrees are the most important initiatives in terms of health and safety measures related to hydrogen:

— *the Pressure Equipment Directive* (PED) (2014/68/EU) applies to the design, manufacture and conformity assessment of stationary pressure equipment with a maximum allowable pressure greater than 0.5bar. The directive entered into force on 20 July 2016 and is implemented in Belgian law via the royal decree of 11 July 2016;
— the *ATEX Directive* (2014/34) (implemented in Belgium via the royal decree of 16 April 2016) covers equipment and protective systems intended for use in potentially explosive atmospheres. The directive defines the essential health and safety requirements and conformity assessment procedures to be applied before products are placed on the EU market;
— the royal decree of 19 March 2017 includes the safety measures relating to the establishment and operation of installations for the transport of gaseous products and others by pipeline. This royal decree implements the law of 12 April 1965 on the transport of gaseous products and replaces all older royal decrees;
— the royal decree of 13 April 2019 regulates the standards that alternative fuels must meet (hydrogen used for road applications must for example conform with NBN EN 17124).

Transport of hydrogen regulation

The transport of hydrogen is also governed by the previously mentioned royal decree of 19 March 2017 and a royal decree of 14 May 2002 on the transport licence for gaseous products and others by pipeline.

[7] http://docs.vlaamsparlement.be/pfile?id=1380984

Regulatory bodies

There is no specific regulatory body which is responsible for the regulation of hydrogen projects. Instead, a number of regulators would have responsibilities depending on the activity in question.

Regulatory Body	Role
Local Authority / Town and Country Planning Authority	— Regulates the use of land — Undertakes environmental impact assessment
Minister for Energy	— Delivers a permit to build and operate pipelines for the transport of gaseous products
Fluxys	— Transports natural gas from the gas terminals to the distribution system operators and large industrial consumers
CREG (federal regulator)	— Supervises transparency and competition on the electricity and natural gas markets — Approves the transmission tariffs of Fluxys — Watches over consumer interests — Monitors whether the market situation is in the general interest and in line with general energy policy — Advises the authorities
The VREG (Flemish Regulator of the Electricity and Gas Market), the CWaPE (Commission Wallonne pour l'Energie) and BRUGEL (the Brussels energy regulator) (The regional regulators)	— The regional regulators are responsible for the organisation and functioning of the regional electricity and natural gas markets — They advise the regional authorities and monitor the application of the law

Upcoming developments

There have been a number of hydrogen projects in Belgium to date. WatersofNet (a non-profit association) is one of the most active organisations in terms of hydrogen projects. WatersofNet develops sustainable hydrogen projects and is active in international networks. Some of the projects in which they were recently involved are:

- Belgium signed a joint statement on 17 December 2020, together with 21 other EU Member States and Norway, announcing the official start of work on an **IPCEI hydrogen project** coordinated by Germany;
- **HyFLOW / Green Octopus:** a collaboration between large-scale green hydrogen producers, ports, gas companies and large-scale hydrogen customers;
- within the **EPOC project** (2018–2022) 14 Belgian research partners joined forces to create energy models. The aim of the EPOC 2030–2050 project is to find out the most cost-effective way to reduce greenhouse gases and guarantee the reliability of the energy supply;
- **Interreg Vlaanderen-Nederland** (European funded project – active since 2009 and still running as ***Waterregio 2.0***);
- in the field of hydrogen infrastructure:
  - Development and construction of two unique hydrogen filling stations, where hydrogen will be produced on site from green electricity: in Wilrijk the filling station will be linked to an incinerator, in Breda the filling station will be linked to solar energy.
  - Expansion of the existing hydrogen filling station on the Automotive Campus in Helmond to serve more demonstration applications.
  - Development and deployment of a mobile hydrogen filling station to facilitate demonstrations at various locations in the region;
- in the field of zero emission applications:
  - demonstration of Europe's largest fleet of 75 forklift trucks, using 'indoor' hydrogen refuelling;
  - development and demonstration of Europe's first large (40 tonne) hydrogen-powered truck;
  - the demonstration programme for garbage trucks, started in the previous Interreg project, will be continued in this Flanders and Southern Netherlands project.

Bulgaria

Authors:
Kostadin Sirleshtov
Borislava Piperkova

Current status for hydrogen in Bulgaria

Introduction

Hydrogen projects are in the mid to long-term pipeline of the Bulgarian energy policy. Hydrogen has been recognised as an area to be further developed under the Energy and Climate Integrated Plan of the Republic of Bulgaria for the period of 2021–2030 (the **"Integrated Plan"**). The Integrated Plan highlights significant opportunities for the development of hydrogen projects in transport and power generation, especially in the renewable energy projects sector.

The enthusiasm for the development of hydrogen in Bulgaria can be seen in several strategic documents, for example the Energy Strategy of the Republic of Bulgaria and the Innovation Strategy for Intelligent Specialisation. It is expected that later in 2021, the Bulgarian Ministry of Economy would prepare the updated Innovation Strategy for Smart Specialization 2021–2027 which is to cover some of the hydrogen usage aspects.

In addition to the above, the development of the hydrogen energy technologies on the territory of the Republic of Bulgaria has been analysed and assessed by the Fuel Cells and Hydrogen Joint Undertaking (**"JU"**) in close cooperation with the European Commission – DG Energy and with the assistance of Trinomics and LBST. As a result of those analysis, the JU has prepared and issued a report on the Opportunities for Hydrogen Energy Technologies considering the National Energy & Climate Plans (the **"Hydrogen Strategy"**).[1] The Hydrogen Strategy refers to two scenarios, where it compares the potential development by sectors.

All these documents indicate that most of the planned hydrogen projects are within the electricity and transportation sectors. There are also hydrogen producers operating in Bulgaria, including one in Bourgas which is owned by Lukoil, one of the biggest players in the Bulgarian fuel market. In this example, the hydrogen is produced in an oil refinery and, in time, could be converted to low-carbon hydrogen.

[1] https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20Bulgaria%20%28ID%209473033%29.pdf

Market prospects for hydrogen

Integrated Plan targets hydrogen projects

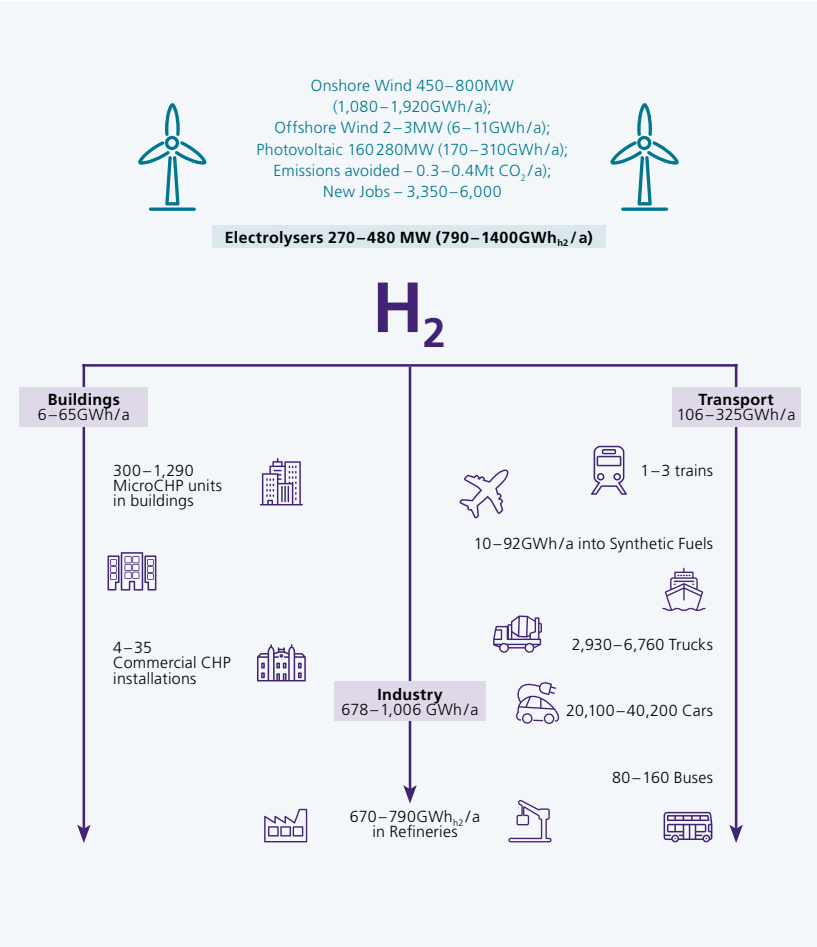
With regards to hydrogen, the Integrated Plan provides mainly for the development of the transportation sector in Bulgaria where the target is to introduce 32GWh of hydrogen fuelled vehicles by 2030. Currently, there are no hydrogen powered vehicles in the sector but the aim is that, by 2030, this figure will increase to 2.7%. Same figures and perspectives are mentioned in the Hydrogen Strategy.

It is expected that some of the projected production shall be by way "of Power to X" installations, where surplus solar and wind power generation will be used for the purposes of hydrogen production. It is forecasted that the consumption from such installations will reach 47GWh by 2030.

The Integrated Plan also states that Bulgaria shall invest approximately EUR 3.5m into hydrogen projects by 2030. Furthermore, Bulgaria is planning to develop hydrogen refuelling stations that will eventually have a total installed capacity of 20MW.

Hydrogen Strategy

The scenarios of hydrogen deployment in Bulgaria pursuant to the Hydrogen Strategy show a substantial potential.



According to the Hydrogen Strategy, the 'surplus' electricity production potential can be utilised by developing hydrogen with electrolysers using renewable electricity since to date Bulgaria has not developed its potential for exporting electricity production surpluses. The existence of nuclear power generation capacity in Bulgaria is also an opportunity for the development of the hydrogen sector since these can convert the surpluses into hydrogen while working at full load.

Currently Bulgaria has no salt cavern gas storage sites to be used for hydrogen storage. However, there is salt deposit in the eastern part that should be further explored whether suitable for hydrogen storage.

The strategy indicates opportunities for hydrogen demand in terms of decarbonisation in the sector of industry (e.g. high-temperature heat generation), heating and cooling and transport (road transport, rail sector).

As part of the positive incentives for the hydrogen development, the Hydrogen Strategy indicates the existence of hydrogen national association and the partial existence of hydrogen roadmap/strategy referring to the Strategy for Smart Specialization. However, the lack of national tax incentives and the lack of substantial greenhouse gas reduction measures play the role of contra-incentives.

The development of the hydrogen market may lead to meeting the GHG reduction targets by 2030 as well as to investments in the range of EUR 1.0 – 1.8bn.

Financial incentives

Since the market is still under development, there are no clear private financing options so far. However, given that the Energy from Renewable Sources Act (**"ERSA"**) provides for certificates of origin to be issued to producers of renewable energy, and obliges energy suppliers to purchase this renewable energy. Given the recent changes under the Energy Act, explicitly stating that the energy to be used for the production of green hydrogen shall be subject to certificate of origin, albeit at preferential prices, private investors may be encouraged into the sector.

Much like in other jurisdictions, commercial banks in Bulgaria are starting to opt out of financing carbon intensive, fossil fuel energy projects, choosing instead to provide debt financing to stakeholders investing in new, low carbon technologies, such as hydrogen projects. This will be important given that the infrastructure needed for the development of low carbon hydrogen projects is likely to involve significant capital expenditure (for example, for new pipelines and electrolysers).

Low carbon hydrogen production is currently expensive compared to the production of hydrogen from coal or methane gas, having not yet benefitted from the price reductions seen across other more mature low carbon technologies. Developers, therefore, will often need financial assistance beyond their own equity investment to support hydrogen projects. However, smaller developers are not always able to satisfy the conditions attached to bank financing. State support may, therefore, have a crucial role in funding hydrogen projects at least initially, especially for smaller developers. Such support will be needed until the cost of generation reaches market levels and becomes self-sustainable.

Challenges facing hydrogen projects

Legal framework gaps

The regulatory framework for hydrogen in Bulgaria is very brief. The February 2021 revision of the Bulgarian Energy Act provides for the very first legal definition of hydrogen as part of the green energy within the definition of "green hydrogen". The same draft provides that the producers of electricity from green hydrogen (from plants that are operational following 1 January 2021) shall not pay the 5% fee to the Bulgarian Fund for Security of the Energy System that is due by the other renewable energy sources producers. Other than those general provisions and the draft ruling on charging stations for hydrogen vehicles, there is currently no more detailed and specific legal framework in place. Instead, hydrogen production, transportation, storage and use falls within existing legislation for the production of other gases and general construction.

Since 7 of January 2021, a new ordinance No РД-02-20-2 dated 28 September 2020 on design, construction, exploitation, and control of hydrogen fuelling stations is effective, that also covers the applicable specifics of hydrogen storage in those cases.

Financial support and incentives

At present, there is a general lack of specific financial support for the introduction of hydrogen projects in the market, except for the certificates of origin. This is very much likely to change once the technology develops and with the phasing out of Bulgarian coal-fired baseload capacities.

Research and education

Except for the research made under the preparation of the Hydrogen Strategy, The Bulgarian Academy of Sciences (**"BAS"**) and Bulgaria's Technical University in Sofia have dedicated major efforts into researching the development of hydrogen production and its use in the transportation sector. The main areas of focus are charging stations and the storage of hydrogen. In February 2019, the Bulgarian Ministry of Education and Science announced that they would finance the National Scientific Program Low Carbon Energy for Transport and Households until 2022.[2] The programme aims to develop innovative methods in the use and storage of clean energy, in anticipation of implementing them across several Bulgarian municipalities, and will focus on:

— Renewable energy storage and transformation;
— Electric vehicles and hydrogen mobility; and
— Effective methods for carbon dioxide capture and utilisation.

Regulation of hydrogen

Specific legislation/ regulation

There is no specific legislation adopted in Bulgaria for the regulation of hydrogen projects, besides the two provisions noted at paragraphs *Specific legislation/ regulation* and the specifics in terms of fuelling stations as per the ordinance referred to under paragraph *Policy and government programmes*. The Energy Strategy of Bulgaria nor the Integrated Plan provide for the development of a specific framework. It is therefore likely that Bulgaria will follow EU regulations in the sector for any unregulated matters. Until then, existing laws relating to energy regulation will apply, such as the Energy Act, ERSA and the Spatial Development Act, which governs the construction of different types of projects.

Policy and government programmes

The Integrated Plan envisages the development of hydrogen projects in a strategic context. It is anticipated that practical steps under the Integrated Plan, such as the introduction of specific support mechanisms for financing, will be developed within the planned ten-year period up to 2030. The same is envisaged under the Hydrogen Strategy.

The hydrogen sector development is considered under the draft Development and Sustainability Plan as prepared by the Ministry Council of Bulgaria in February 2021. It is still subject amendment and approval. However, the referred plan provides for the development of hydrogen roadmap and infrastructure for transportation and supply of hydrogen.

[2] Scientists from BAS and higher education institutions are developing new methods for using and storing clean energy – Bulgarian Academy of Sciences

Primary legislation

Despite the fact that there is no specific legislation in this area, the Energy Act, RESA, and the Spatial Development Act, as well as certain secondary legislation, will apply as general rules governing the generation, connection and distribution, transportation, financing and the permitting process of hydrogen projects. As a result, under this legislation, hydrogen projects will be provided with priority access to the gas and electricity grids and awarded with certificates of origin for the electricity generated from hydrogen.

Regulation of hazardous activities

The most relevant acts regulating hazardous activities are:

— the Environmental Protection Act (**"EPA"**), together with its secondary legislation; and
— the Act on Providing Information on the Environment and its Protection, Public Participation in Environmental Protection and on Environmental Impact Assessments (**"EIA Act"**), which includes an obligation to conduct an environmental impact assessment in respect of a planned hydrogen project.

Transport, import and export of hydrogen

Since there are no dedicated regulatory solutions for hydrogen, the provisions applicable to gaseous fuels should be taken into account in this respect. Specific rules related to transportation of dangerous goods apply to road and railway transportation as provided for under the general EU legislation:

— the Agreement concerning the International Carriage of Dangerous Goods by Road (**"ADR"**); and
— the Regulation concerning the International Carriage of Dangerous Goods by Rail (**"RID"**).

Regulatory bodies

As there are no hydrogen-specific provisions, the general provisions concerning the investment process and exploitation of industrial installations and devices will apply to hydrogen.

The key regulatory bodies in relation to power generation projects are:

— The Energy and Water Regulatory Commission (**"EWRC"**) – the national regulatory agency that governs the licensing of installations for power generation; and
— Local authorities – governing the building and spatial planning processes in each municipality, which are vital for the installation of electricity or refuelling stations.

A number of regulators would have responsibilities depending on the activity in question.

Regulatory Body	Role
Energy and Water Regulatory Commission ("EWRC")	— Licensing of installations for power generation.
Energy and Water Regulatory Commission ("EWRC")	— Regulates the use of land; — Approves the construction processes; — Approves the construction and placement of fuelling stations.
Health & Safety Local Authority	— Assesses environmental impact; — Approves construction planning; — Approves use of hazardous goods.
Bulgartransgaz (Bulgarian Transmission System Operator ("TSO"))	— Regulates the gas network.

Upcoming developments

The **Integrated Plan** will be the key document in terms of regulating the potential development of the hydrogen sector in Bulgaria.

It is also expected that Bulgaria will adopt a new **Sustainable Energy Strategy** (a joint document covering both the former Energy and Energy Efficiency Strategies) where the future role of hydrogen will be outlined in a clear way.

Bulgaria will follow any developments at an EU level following the **Green Deal** and the overall focus on the transformation of the energy sector towards a carbon-neutral status.

As Bulgaria exceeded its 2020 targets in relation to developments in the renewable energy sector it is expected that, once hydrogen legislation and incentives are put in place, it could be among the leaders in the field, given Bulgaria's current dependency on fossil fuels, such as lignite, and its lack of other feasible alternatives.

In order to support the development of the hydrogen market in Bulgaria, the government shall undertake steps to:

— develop and prepare a roadmap;
— develop a strategy on the greenhouse gas reduction measures;
— develop some tax incentives;
— implement a specific regulatory framework to cover the different sector areas, where hydrogen is to be applied.

Chile

Authors:
Sebastián Barros
Tomás Barros

Current status for hydrogen in Chile

Introduction

Hydrogen is expected to have a substantial role over the coming decades in decarbonising the Chilean energy system. In 2019, the Chilean government announced that Chile would be carbon neutral by 2050.[1] However, at present, Chile is still at an early stage regarding hydrogen production due to technical barriers, an underdeveloped legal framework and a lack of clear financial support mechanisms.

In November 2020, the Chilean government published its *"National Green Hydrogen Strategy"* a public commitment that comes to show a growing public interest in developing a green hydrogen industry in Chile. Specifically, the government strategy emphasises the natural advantages to produce renewable energy in Chile and its consequently low cost, the lowest in the world according to the document, which makes green hydrogen-based energy sources an attractive alternative for the Chilean energy grid.[2]

At present, hydrogen production in Chile is still largely carried out by industrial gas producers and is primarily used in the refining industry (for hydrotreating, hydrocracking and desulphurisation), the food industry (in the manufacture of oils and margarines), the glass industry, the power generation industry (as a generator coolant), and in thermal and thermochemical treatments.[3] Every year, around 58,500 tons of hydrogen are produced in the country, 98% of which is used by refineries and the rest for the manufacture of glass and food.[4]

[1] More information available at: https://www.emol.com/noticias/Economia/2019/06/18/951626/Chile-y-su-meta-de-ser-carbono-neutral-El-ambicioso-camino-de-los-otros-paises-que-tambien-se-propusieron-serlo.html; and, https://news.bloomberglaw.com/environment-and-energy/chile-aims-for-first-green-hydrogen-production-by-end-of-2021
[2] More information available online at: https://energia.gob.cl/h2/
[3] More information available at: https://www.4echile.cl/4echile/wp-content/uploads/2018/04/LIBRO-TECNOLOGIAS-H2-Y-PERSPECTIVAS-CHILE.pdf
[4] More information available at: https://www.agenciase.org/2019/11/20/el-combustible-del-futuro-el-hidrogeno-verde-en-la-mira-de-chile-y-el-mundo/#:~:text=En%20Chile%2C%20actualmente%20se%20produce,combustibles%20f%C3%B3siles%20como%20gas%20natural.&text=Al%20a%C3%B1o%2C%20en%20el%20pa%C3%ADs,fabricaci%C3%B3n%20de%20vidrios%20y%20alimentos.

Public transport incentives

Hydrogen (specifically hydrogen fuel cells or similar) is seen as a potential solution for larger road vehicles in the Chilean public transport system.[5] The Ministry of Energy announced that the public transport system should shift in the short term towards natural gas and hydrogen fuel cell systems, both contributing to reducing the pollution caused by current diesel and gas transport fleets. In addition, if successful, this shift will include efforts with various public and private industry players to develop technologies that could be applicable in taxi fleets, buses and commercial fleets for the distribution of goods and services.

Use of hydrogen in industry

At present, Chilean industry uses hydrogen (mostly "grey" hydrogen) as a feedstock for several industrial processes. With the development of concentrated solar power plants (**"CSPs"**) and wind farm technology over the coming decade, this hydrogen could be obtained through electrolysis. Currently, there are two examples of low-scale pure hydrogen producers in the country:

— "INDURA Lirquén" is a green-hydrogen plant, located in southern Chile. Since 1996, it has been developing 99% pure green-hydrogen through electrolysis for the purpose of supplying hydrogen to local glass manufacturers.
— "ASU Indura Graneros" is a hydrogen plant, located in central Chile, which produces and supplies pure hydrogen to local industries.

Finally, a big market player in Chilean industry is Linde, which in 2006 initiated the operation of a grey hydrogen plant, located in Concón, Chile with a production capacity of 4,200kg/h. This hydrogen is supplied through a pipeline to the nearby oil refinery Empresa Nacional de Petróleo (**"ENAP"**), which has a hydrogen demand of 3,003kg/h. This hydrogen production plant uses steam reforming methane with a thermal efficiency of 85%. It also distributes around 4,500kg/month of hydrogen to external customers.[6]

[5] https://energia.gob.cl/electromovilidad/hidrogeno-verde
[6] https://www.4echile.cl/publicaciones/tecnologias-del-hidrogeno-y-perspectivas-para-chile-2019/

Use of hydrogen in mining sector

There have been some key advances in the implementation of hydrogen for use in fuel mining trucks. Overall, 25% of the total carbon footprint of local copper mines is produced by oil-based engines. In order to reduce Chile's carbon footprint and contribute to the production of "green-copper", Chile is promoting hydrogen fuelled mining trucks and other hydrogen fuelled industry support vehicles. Chilean public entity Corporación de Fomento a la Producción (**"CORFO"**)[7] also called for two public tenders to study the feasibility and implementation of two different technologies:

— dual powered hydrogen-diesel engines for mining trucks; and
— hydrogen fuel cell-powered mining trucks and support vehicles.
— Tenders were awarded in 2019.

In the case of the dual powered engines, the project was awarded to the technological consortium composed of: ALSET, the University of Santiago, Pontificia Catholic University of Chile, Japanese NTT DATA, Compañía Minera del Pacífico, BHP Chile, Anglo American Sur and ENGIE, amongst others. The purpose of this consortium was to develop a giant mining truck and demonstrate the technical and economic feasibility of mixing hydrogen with diesel. The total cost of this project is approximately USD 15,875,000, of which CORFO contributed USD 5,080,000 over the course of four years. The rest will be funded by the consortium.

Regarding the fuel cell-powered engines, the project was awarded to a second consortium composed of Federico Santa María University, Public Company Codelco, Collahuasi, Metalpar, Siemens, Engie, the National Mining Society, the National Hydrogen Center of Spain and LINDE. This project has a total cost of approximately USD 16,500,000, of which CORFO contributed USD 825,000. This project is being directed by local Federico Santa María Technical University where researchers have stated that they expect to be conducting the first in-plant tests for a hydrogen-powered mining vehicle by 2022.

Green hydrogen ambitions

Regarding green hydrogen production, on 18 October 2018, the World Energy Council identified Chile as the "hidden champion" in the race to develop a green hydrogen economy.

In light of the above, it is estimated that by 2050, revenues from exports of green hydrogen could represent 10% of the current Chilean GDP. Furthermore, the Ministry of Energy estimates that by 2050, 50% of the hydrogen production market in Japan and South Korea could be captured, as well as 20% in China.[8]

[7] https://www.corfo.cl/sites/Satellite?blobcol=urldata&blobkey=id&blobtable=MungoBlobs&blobwhere=1475166591633&ssbinary=true
[8] https://www.senado.cl/senadores-conocen-las-ventajas-del-denominado-combustible-del-futuro-el/senado/2020-06-26/103338.html

National Green Hydrogen Strategy

The National Green Hydrogen Strategy is a series of policies introduced by the Chilean government in October 2020 that aims to create a green hydrogen industry for Chile. Chilean government studies indicate that Chile will have the lowest green hydrogen production cost in the world to the point where, with a 160m ton yearly green hydrogen production potential, the Chilean government not only aims to produce green hydrogen to supply its local energy demand but also hopes to start exporting its energy to the rest of the world before the end of the decade.

The National Green Hydrogen Strategy is set up in a three-phased plan:

— **From 2020 to 2025.** The government plans to accelerate the deployment of green hydrogen in six prioritised applications in order to create local supply chains and acquire experience in the developing of the industry. Incentives for green hydrogen use and production will be aimed at: (1) oil refineries, (2) ammonia production, (3) mining haul trucks, (4) heavy-duty trucking, (5) long range buses, and (6) blending into gas grids (hydrogen injection into existing gas networks).
— **From 2025 to 2030 onwards.** The local government aims to leverage its growing local experience on green hydrogen production so that it can start exporting energy to other nations and by doing so becoming a key player in the energy export community.
— Finally, a **third phase** will exploit synergies and economies of scale to expand the local industry into a position in which Chile could become a global supplier of clean fuels with a special focus on the future use of ammonia in the shipping industry and synfuels in aviation.

The Chilean state has pledged it will become a facilitator, coordinator and promoter of green hydrogen projects in its quest to establish a new industry through a multisectoral effort in which both private and public sector play a key role. The public sector will intend to identify and lower legal, financial, technical and regulatory barriers. Private initiatives shall build upon these fundamentals to play a leading role in developing the technologies, business investments and projects required to scale up efficient and competitive local and export markets.

In the same line, the Chilean state has set up a policy to promote its domestic and export market for green hydrogen by: (i) launching funding rounds of up to 50 MUSD to support selected green hydrogen projects; (ii) establishing a public-private roundtable, to discuss the pathway for both carbon prices and taxes that may better reflect the negative externalities that fossil fuels produce; (iii) committing to bridge regulatory and standard gaps throughout the hydrogen production process to ensure safety standards and give assurances to investors; (iv) the establishment of an operational team to help developers in permitting and piloting processes for green hydrogen project developments; (v) integrally reviewing natural gas regulations and local infrastructure to promote the injection of green hydrogen quotas in the existing gas infrastructure therefore increasing the local demand for green hydrogen; and (iv) deploying a green diplomacy strategy to position itself internationally as a source of clean energy.

Market prospects for hydrogen

The hydrogen market in Chile is at an early stage and has significant prospect for growth over the coming years. The Ministry of Energy has advised that hydrogen will be a key enabler for Chile to meet its 2050 net zero goals.

Because of the nascent status of hydrogen projects, there has been limited M&A activity in the sector and as such, little by way of private financing to date. This is expected to change once the Chilean government clarifies the legal framework, as promised in the aforementioned National Green Hydrogen Strategy.

Notwithstanding the above, 2021 has already seen the emergence of some M&A operations. Among some of the most renowned projects are Green Hydrogen production ventures such as (i) "Haru Oni"in the Magallanes Region; (ii) a consortium between energy company Engie and mining research organisation Mining3 in order to incentivise decarbonisation in the mining industry through the use of green hydrogen; and (iii) "HyEx", a project that aims at implementing green hydrogen in the production of mining explosives.

Challenges facing hydrogen projects in Chile

Legislative framework gaps

In common with many other jurisdictions, Chile does not have a specific legislative framework for hydrogen projects across the various sectors. Therefore, it is important that new regulations are established to regulate the use of hydrogen in Chilean industry. There are a number of gaps and uncertainties that will need to be addressed before the hydrogen economy can truly flourish.

Financial support and incentives

The Chilean government supports the generation and use of alternative fuels generally and particularly hydrogen in the move to decarbonise the public transport system and the mining industry. This support is reflected in the decision of CORFO to financially support projects such as Hydra, which seeks to decarbonize the mining industry.[9] By the end of January 2021 the same public entity had received 18 letters of interest to develop green hydrogen projects from private investors. These letters are a response to a request for information solicited by CORFO that aimed at gathering information from private parties interested in developing green hydrogen projects. CORFO is currently studying the possible alternatives of public support that may be necessary for the projects that show to be most promising.

[9] https://www.corfo.cl/sites/Satellite?c=C_NoticiaNacional&cid=1476726420760&d=Touch&pagename=CorfoPortalPublico%2FC_NoticiaNacional%2FcorfoDetalleNoticiaNacionalWeb

However, according to a 2020 study by Deutsche Gesellschaft für Internationale Zusammenarbeit and 4E Chilean Renewable Energy Program and Electric Efficiency, Chile still requires a larger engagement from public and private funds in the development of the hydrogen sector across the board. The mentioned study states:

"…there are few climate finance options applicable to energy innovation projects in Chile. This implies a major challenge in improving business models, regulatory conditions and risk identification for this type of initiatives. This is relevant, especially considering that the spectrum of investors (concessional and non-concessional) interested in this type of low-carbon development projects is growing."[10]

Research and education efforts

Generally, there needs to be an increase in the amount of research that is conducted into hydrogen in order to fully understand the availability and applicability of the resource and the technology needed for its production.

Chilean regulation of hydrogen

Primary Legislation

In broad terms, hydrogen in Chile is classified as a dangerous substance and, according to NCh382.Of98: 2003, it belongs to the Class 2.1: "flammable gases". Therefore, the regulated activities are only those set out in the regulation. Namely, the following areas of activities are regulated:

— transport of hazardous substances in public roads;
— storage of hazardous substances; and
— possession of hazardous substances in the workplace.

The Ministry of Public Health regulates storage of dangerous substances (including flammable gasses), and basic sanitary and environmental conditions in the workplace pursuant to the following regulations:

— Supreme Decree N° 43 approves the regulation of storage of dangerous substances.[11] This regulatory decree is the most complete regulation on hydrogen in Chile. It explicitly refers to the storage of hydrogen and is the most comprehensive in terms of specific measures such as safety distances and maximum storage capacities. However, this supreme decree explicitly indicates that it does not apply to "liquid and gaseous fuels, used as energy resources", which "must be regulated by the Ministry of Economy, Development and Reconstruction".
— Supreme Decree N° 594 approves regulations on basic sanitary and environmental conditions in the workplace. It regulates hydrogen implicitly when dictating provisions for "flammable substances" and on fire safety measures; and
— Exempt Resolution N° 408 approves a list of dangerous substances to health. This exempt resolution introduces hydrogen as a "hazardous substance" in both compressed and liquid forms, however it has not been regulated by the Ministry of Economy, Development and Reconstruction.

[10] Full report available at: https://energia.gob.cl/sites/default/files/opciones_de_financiamiento_climatico_para_proyectos_innovadores_en_el_sector_energetico_en_chile.pdf

Transport regulation

The Ministry of Transport and Telecommunications regulates the transport of dangerous substances by road and their handling in port facilities, in the following regulations:

— Supreme Decree N° 298 regulates the transport of dangerous loads on streets and roads. It establishes general provisions for the transport of dangerous substances on public roads. However, it does not provide details or specific requirements for hydrogen or flammable gases transported in bulk. Nor does it contain provisions for the bulk transfer of flammable gases; and
— Resolution N° 96, which updates and modifies handling and storage regulations of dangerous cargoes in port facilities. It has mainly administrative provisions, product classifications and indications of what can be deposited in certain port areas. It also does not reference the transfer of flammable gases in bulk.

Health & Safety laws

The Ministry of Labour and Social Welfare has also issued a regulation on the prevention of occupational risks, which indirectly applies to hydrogen projects as it requires employers to have an internal regulation of safety and hygiene in the workplace, by means of Supreme Decree N° 40. This Supreme Decree approves regulation on professional risk prevention and requires employers to prepare and keep current safety and hygiene regulations, in addition to informing workers of the risks they run and training them to adequately face such risks. These provisions mandate to update the safety and hygiene regulations to include "hydrogen" whenever it is incorporated into a work task, in addition to informing and training workers

Mining sector laws

The National Service of Geology and Mining issued a Supreme Decree in 2004 which establishes mining safety regulations that could affect hydrogen indirectly. It does not refer to hydrogen directly, but this regulation allows the use of Liquefied Petroleum Gas (**"LPG"**) and Compressed Natural Gas (**"CNG"**) as a fuel for machinery in underground mines (under Article 129°), which suggests that they could also accept the use of hydrogen as a fuel.

Environmental laws

Regarding the environmental aspects of hydrogen, it is estimated that the current regulations issued by the Ministry of Environment, addresses projects related to the hydrogen value chain and guides environmental impact statement proceedings. The Ministry of Economy and the Ministry of Environment are analysing in detail the current regulations in relation to hydrogen in order to propose specialised legislation.

[11] Supreme Decree N° 43 is available online at: https://www.leychile.cl/Navegar?idNorma=1088802

Hydrogen-specific Regulation

Despite the lack of comprehensive regulation, small advances have been made aiming at creating broad regulation, a small change in Decree-Law 2,224[12] made in December 2020, granted sufficient powers to the Ministry of Energy so that it may directly regulate the hydrogen industry, which will be done on the basis of specific regulations on the subject.

In May 2020, a regulatory proposal funded by the Chilean Ministry of Energy and developed by the *Pontificia Universidad Católica de Chile* laid the groundwork for an eventual regulatory framework for the development of green hydrogen.[13]

Despite recent legal undertakings and proposals, the currently existing regulatory framework of hydrogen is still insufficient for all of its applications, since the eventual spread of the use of hydrogen requires updated, specific and detailed regulations, covering situations not dealt with by existing regulations.

Regulatory bodies

There is no specific regulatory body which is responsible for the regulation of hydrogen projects. Instead, a number of regulators have responsibilities depending on the activity in question.

Regulatory Body	Role
Municipal Authority	— Regulates the use of land
Superintendence of Health	— Usually has the inspection role of the hazardous substance authority in relation to storage
Labour Direction	— Regulates workplace hazards regarding storage and use
Superintendence of Environment	— Inspection of environmental compliance
Environmental Evaluation Service	— Undertakes Environmental Impact Assessments and all proceedings related.
Superintendence of Transport	— Usually has the inspection role of the hazardous substance authority in relation to transport.
Ministry of Energy	— As mentioned on p.56 under *Environment*, recent changes in law decree number 2.224 have made the Chilean Ministry of Energy the ultimate regulatory body and has granted them sufficient powers to regulate the industry.

[12] Decree Law 2.224 available at: https://www.bcn.cl/leychile/navegar?idNorma=6857

[13] Full proposal available online at: https://h2lac.org/wp-content/uploads/2020/10/Estudio_Propuesta-regulatoria-hidrogeno-Chile.pdf

Upcoming developments

As of 24 August 2021, nine months after the enactment of the Strategy, there are 60 green hydrogen projects in portfolio in Chile, mainly located in Antofagasta, Valpraiso, Biobío and Magallanes. It is advised that future projects should aim to be built in areas with low project congestion, considering the huge volume of projects currently being processed.[14] Some of the most relevant projects are the following:

- **Haru Oni:** a project currently in early construction and expected to initiate operations by 2022, led by companies such as Enel Green Power, Siemens Energy, Exxon Mobile, Global Thermostat and Porsche in the Magallanes Region. This project seeks to generate green hydrogen-based synthetic fuels (e-fuels) from wind power.
- **HYEX**: currently in early development and carried out by Engie and Enaex in the Antofagasta region. This project aims to generate green ammonia for the manufacture of explosives use in mining operations;[15]
- **HYDRA:** a project developed by CSIRO, Engie and Mining3, which seeks to validate the generation and use of hydrogen fuelled vehicles for electromobility in mining operations that is currently in its pilot phase;[16]
- **Enagas, Acciona Energia and GNL Quintero:** all key players in the Chilean energy industry, have partnered to develop a USD 30m green hydrogen generation plant for the generation of green hydrogen in the Chilean port city of Quintero.[17]

[14] https://www.globalcompliancenews.com/2021/09/24/chile-green-hydrogen-background-regulation-and-future-10092021/
[15] https://www.df.cl/noticias/empresas/energia/fiebre-por-el-hidrogeno-verde-empresas-comienzan-a-avanzar-en-proyectos/2021-08-19/101851.html
[16] https://www.energiaestrategica.com/estos-son-los-siete-proyectos-clave-en-hidrogeno-verde-del-sector-privado-en-chile/
[17] https://www.notimerica.com/economia/noticia-enagas-acciona-alian-impulsar-proyecto-hidrogeno-verde-chile-2565-millones-20210819160453.html

China

Author:
Vera Zhang

Current status for hydrogen in China

Introduction

In 2020, China's hydrogen production exceeded 25m tons, accounting for about one third of the world's total production. China has become the world's largest hydrogen energy producer and consumer. Production and sales of metal hydrogen storage materials have now surpassed Japan, and China is fast becoming the world's largest hydrogen storage material producer and retailer. China produces mainly "grey" hydrogen with "green" hydrogen accounting for a very small proportion (less than 1%). Although it is likely that fossil fuel-based hydrogen will continue to be the main form of hydrogen produced in China over the next decade, it is believed that after 2030, green hydrogen will gradually become the main. China has huge potential for hydrogen production from renewable energy and has been the world's largest investor in renewable energy for eight consecutive years.[1]

At present, China's hydrogen production is mainly in the fields of chemical industry and steel manufacturing, specifically in petrochemical, chemical industry and coking. Hydrogen is used mostly as a raw material to produce methanol, synthetic ammonia and other chemical products, with only a small portion used for industrial fuel.

Over the last decade, particularly since the "13th Five-Year Plan" was outlined in 2016, there has been an enormous push to develop hydrogen-powered vehicles in China. Hydrogen fuel cells are a key component of hydrogen-powered vehicles, and hydrogen refuelling stations are the necessary infrastructure required to support the application of hydrogen fuel cell vehicles (**"FCVs"**) in China. At present, the application of hydrogen is mainly within the promotion of hydrogen-powered vehicles and also as the main material for synthetic chemicals.

[1] https://www.dx2025.com/archives/136018.html

The National Alliance of Hydrogen and Fuel Cell (**"NAHFC"**) was launched in February 2018 with the aim of enhancing "the development of China's hydrogen sector in speed and quality". NAHFC is a government supported alliance that was jointly formed by a consortium of energy and automotive companies, including China Energy Investment Group and state-owned SAIC Motor, as well as several leading science and technology institutes. Several major international players from the energy industry are also members of NAHFC, including Air Liquide, Air Products and Linde. NAHFC acts as a platform to enable coordinated innovation, research and development of hydrogen and fuel cell projects, and as a thinktank to guide state policy.[2]

In August 2020, NAHFC worked alongside the Hydrogen Council to produce the "Path to Hydrogen Competitiveness – A Cost Perspective", a Chinese version of the Hydrogen Council's 2019 research report. The report highlighted that developments in technology, among other areas, will aim to assist in reducing the costs associated with hydrogen production and stated that this is an area in which China has much to offer.[3]

On 22 September 2020, at the United Nations General Assembly, China pledged to achieve carbon neutrality by 2060 and to reach its peak carbon dioxide emissions by 2030. In order to facilitate this, China aims to increase its nationally determined contributions and adopt more effective policies and measures. The continuous drop in the cost of hydrogen production from wind and solar power generation provides a potential decarbonisation path for industries that are most dependent on fossil fuel energy in economic activities, such as steel, heavy road freight, shipping and cement. China needs a long-term perspective to achieve its goal of net zero emissions in the future and solar, wind and hydrogen energy are all expected to be some of the most appropriate solutions. For the goal of carbon neutrality by 2060, China is expected to shift to a structure based on hydrogen production from renewable energy, anticipating clean energy to reach 80%.[4]

[2] http://www.h2cn.org/en/about.html#survey
[3] http://h2cn.org.cn/en/about.html#survey
[4] https://chuneng.bjx.com.cn/news/20210420/1148201.shtml

In April 2021, the "China Hydrogen Energy and Fuel Cell Industry White Paper 2020" (the **"White Paper 2020"**) released by NAHFC indicated that in the scenario of carbon peak in 2030, China's annual demand for hydrogen is expected to reach 37.15m tons, accounting for about 5% of the final energy consumption, the output of renewable hydrogen is estimated to be about 5m tons, and the installed capacity of electrolytic cell will be about 80GW.

In the scenario of carbon neutralisation in 2060, the annual demand for hydrogen in China is expected to increase to about 130m tons, accounting for about 20% of final energy consumption, and renewable energy production of hydrogen will be about 100m tons. It is anticipated that hydrogen will still be used most in the industrial field, which is about 77.94m tons, accounting for 60% of the total hydrogen demand; 40.51m tons of hydrogen will be used in transportation, 5.85m tons in construction, and 6m tons in power generation and power grid balance.[5]

Transport sector

Since 2017, the development of China's hydrogen-powered and FCV industry has been in full swing. Hydrogen fuel cells are mainly used in commercial vehicles, which have different application fields from pure electric vehicles. Although hydrogen FCVs are still in an early stage of research and development in China, it is expected that the next five to ten years will become a "golden era" for the industrialisation and rapid promotion of hydrogen FCVs.

At the end of 2019, more than 130 hydrogen-refuelling stations had been built or were under construction in China: 61 had been completed and 52 are in operation. China has initially formed industrial clusters and demonstration-application areas in the Beijing-Tianjin-Hebei area, Yangtze River Delta, Pearl River Delta, Shandong Peninsula and the central region. These are areas of highly concentrated industrial activity where the cost of hydrogen infrastructure can be shared between market participants. At present, there are nearly 4,000 vehicles of various types operating in the demonstration areas, such as fuel cell cars, trucks and buses.

Industry sector

China already has a recognised hydrogen energy industrial foundation. Currently, however, its production is mainly reliant on fossil fuels and hydrogen is predominantly used as a raw material for the synthesis of industrial chemicals. Unsurprisingly, the steel and chemical production industries consume the greatest amounts of hydrogen in China. Domestic hydrogen production from coal is the largest, reaching 21.24m tons, accounting for 63.54%, followed by industrial by-product hydrogen and hydrogen production from natural gas, with the output of 7.08m tons and 4.6m tons respectively, and the hydrogen production from electrolytic water is about 500,000 tons. Fossil fuels, such as coal, natural gas, and petroleum, account for almost 70%; hydrogen produced from industrial by-product gases accounts for about 30%; and hydrogen produced by electrolysis of water accounts for less than 1%. In terms of regional distribution, China's hydrogen production capacity is mainly concentrated in Northwest, North and East China, accounting for 75% in total. Among them, the capacity in Northwest China is 10.67m tons per year, in North China it is 10.21m tons per year, in East China it is 9.4m tons per year, in South China it is 4.99m tons per year, in Southwest China and Northeast China it is 3.35m tons per year and 1.95m tons per year respectively, accounting for 8.3% and 4.8% respectively.

[5] http://finance.cnr.cn/txcj/20210422/t20210422_525467869.shtml

Market prospects for hydrogen

It has been announced that, since 2017, Chinese investment into domestic hydrogen energy projects has exceeded CNY 250bn. In the first half of 2019, there were as many as 70 domestic investment projects in the field of hydrogen energy and fuel cells, including investments of some tens of billions of Yuan, and 50 projects with a public investment amount exceeding CNY 90bn.

In recent years, with the successive promulgation of national policies (which are discussed in more detail below), many large enterprises have entered the hydrogen energy market. These include many well-known state-owned enterprises such as CHN ENERGY, State Grid and China HuaNeng Group.

Many energy-related private companies are also aggressively expanding into the hydrogen-energy market, intending to occupy a strategic place in the future market. Among them is Meijin Energy Group (**"Meijin Energy"**), one of the most high-profile names in the oil and gas industry. In June 2019, Meijin Energy announced that it had signed the "Qingdao Meijin Hydrogen Energy Town Cooperation Framework Agreement" with Qingdao Municipal Bureau of Industry and Information Technology. Under the agreement, the town's total industrial land scale is planned to reach about 2,000mu (equivalent to 1.33 km^2) and will receive a total investment of CNY 10bn – the majority of which will be provided by Meijin Energy. The purpose of the agreement is to invest in hydrogen technologies, for example commercial new energy vehicles (**"NEVs"**), membrane electrodes, fuel cell stacks and systems, as well as providing support for scientific and technological innovation centres, fuel cell testing centres and the research and production of other projects. Furthermore, the agreement stated that Meijin Energy will establish a platform dedicated to the construction and operation of hydrogen energy infrastructure and initiate the launch of a hydrogen energy industry fund for investment into major projects in the industrial chain.

In July 2019, Meijin Energy also announced that it had used its own funds to increase Guangdong SinoSynergy Hydrogen Power Development Co., Ltd. (**"Synergy"**) capital by CNY 180m. Synergy have invested heavily in factories in the Yunfu Industry site, Guangdong Province, where they produced over 300 hydrogen-powered fuel cell-battery hybrid buses in 2018–2019.[6]

[6] https://www.mdpi.com/1996-1073/12/1/54

Furthermore, in August 2019, Meijin Energy and Jiaxing Transportation Investment Group Co., Ltd. signed the "Jiaxing Hydrogen energy infrastructure construction and hydrogen fuel vehicle demonstration operation platform cooperation agreement". The agreement stipulates that the two parties will cooperate, through the establishment of a joint venture company, in the construction of hydrogen energy infrastructure in Jiaxing, Zhejiang Province, and in the demonstration operation platform of hydrogen-powered vehicles.

On 19 January 2019, Shanghai Re-fire Energy Technology Co., Ltd. and the People's Government of Nanhai District, Foshan City, Guangdong Province formally signed a contract. The former will invest in the construction of a hydrogen energy industry base project in Danzao Town, Nanhai District. The purpose of the project is to set up several research and development bases that will focus on investigation into hydrogen fuel cells, hydrogen-powered FCVs and the related industries. The project is expected to have an annual output value of CNY 15bn. This follows another hydrogen-energy investment worth tens of billions of Yuan in Danzao Town; the Hydrogen Power (Foshan) R&D Centre and vehicle production project that was launched in 2017.

Following the announcement of the establishment of the hydrogen energy division in July 2021, GCL new energy (00451), a subsidiary of GCL group, officially announced the hydrogen energy development plan: the goal of blue hydrogen is to gradually expand the capacity to 4m tons of synthetic ammonia per year and supply 700,000 tons of blue hydrogen in China. The goal of green hydrogen is to build 100 comprehensive energy stations by 2025 to reach an annual capacity of 400,000 tons. In August 2021, Shenghui Technology (300423. SZ) announced the establishment of the Shenghui New Energy Co., Ltd. to invest in and layout core industries such as hydrogen energy storage.

In August 2021, Peng Huagang, Secretary General of the State-Owned Assets Supervision and Administration Commission (**"SASAC"**) of the State Council, said that more than one-third of the central enterprises are already in the layout of the whole industrial chain, including hydrogen production, hydrogen storage, hydrogenation and hydrogen consumption. The State Power Investment Corporation has simultaneously arranged the whole industrial chain of hydrogen production from renewable energy and fuel cell in the hydrogen energy industry. During the "14th Five-Year plan" period, Sinopec plans to lay out 1,000 hydrogenation stations or oil hydrogen joint construction stations. In addition, PetroChina officially established the Hydrogen Energy Research Institute in 2021.

Challenges facing hydrogen projects in China

High costs, difficulties in storage and lack of hydrogen infrastructure

Since hydrogen is a secondary energy source that is produced by using primary energy, and the costs of its storage, transportation, and production are high, people in China are sceptical as to whether hydrogen energy is economically viable.

Industry experts say that the current core technology and equipment related to China's hydrogen infrastructure require improvement, and a large amount of scientific and technological innovation and input are needed to reduce the cost of hydrogen energy. In addition, although the use of liquid hydrogen storage and transportation can reduce the cost of hydrogen, China's liquid hydrogen-related equipment manufacturing and industrialisation is in its early stages and it will take time for liquid hydrogen storage and transportation to be widely adopted.

Legislative framework gap

In common with many jurisdictions, China does not have a well-defined legislative framework for hydrogen projects across various sectors. This creates a number of gaps and uncertainties, which need to be addressed before the hydrogen economy is able to flourish.

Regulation of hydrogen

Legislation overall

China has not yet introduced specific or unified laws or administrative regulations on the use of hydrogen energy. The policy basis for the development of hydrogen energy utilisation in China is mainly founded on national industrial planning policies and local pilot regulations. Planning policies are discussed in more detail, below.

With regard to pilot regulations, 28 provinces have included the development of hydrogen energy in their provincial "14th Five-Year Plan for National Economic and Social Development and the Outline of Long-Term Goals for 2035"; ten provinces, including Guangdong and Shanxi, have included the development of hydrogen energy in their Government Work Reports in recent years. As well, provinces such as Shandong, Hebei and Zhejiang have released development plans for their local hydrogen energy industry. Additionally, many other provinces have formulated relevant policies to promote the development of the hydrogen energy industry that relate to the construction of hydrogen energy infrastructure, the manufacturing of key components and the supporting operation services. For example, the NEV industry action plan, issued by Shanxi Province in 2019, outlined plans to carry out hydrogen fuel vehicle projects in Taiyuan, Datong and other cities; Guangdong Province issued the "Implementation Plan for Accelerating the Development of Hydrogen Fuel Cell Vehicle Industry" in 2020, setting out the establishment of an independent, controllable and technologically advanced hydrogen fuel cell vehicle industry chain.

Policy and government programmes

The "13th Five-Year National Strategic Emerging Industry Development Plan" issued by the State Council in 2016 proposed to promote the development of on-board hydrogen storage systems and hydrogen preparation, storage, transportation and refuelling technologies, as well as to promote the construction of hydrogen refuelling stations.

The Government Work Report of the State Council 2019, states that there is a national mandate to "promote the construction of charging and hydrogen refuelling facilities". This is the first time that hydrogen energy has been included in a Government Work Report and reflects its growing importance in China.

In March 2020, the National Development and Reform Commission and the Ministry of Justice issued "Opinions on Accelerating the Establishment of Green Production and Consumption Laws and Policies", stating that the promotion of clean energy development requires the study and formulation of standards and supporting policies for new technologies, such as hydrogen and ocean energy.

In January 2021, National Development and Reform Commission promulgated the "Catalogue of Encouraged Industries in the Western Region". Among them, hydrogen processing and manufacturing, hydrogen energy fuel cell manufacturing, hydrogen transmission pipeline and hydrogenation station construction have been included in the catalogue of encouraged industries in Guizhou Province and Inner Mongolia Autonomous Region; hydrogen energy and other new energy and related device manufacturing industries and industrial operation services have been included in the catalogue of encouraged industries in Shanxi Province.

In February 2021, the State Council issued the "Guiding Opinions on Accelerating the Establishment and Improvement of the Green and Low-carbon Circular Development Economic Systems", which put forward to promote the green and low-carbon transformation of the energy system and develop hydrogen energy.

In March 2021, the National People's Congress approved the "Outline of the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035 for the People's Republic of China", stating that China plans to deploy a number of future industries in cutting-edge technology and industrial transformation fields such as hydrogen energy and energy storage.

Primary legislation

The draft Energy Law of the People's Republic of China, issued on 10 April 2020, highlighted various energy sources. However, unlike other secondary energy sources such as electrical power, thermal power and refined product oil, hydrogen was not listed separately, but was only categorised as "other new energy sources".[7] Therefore, the importance and potential of hydrogen is yet to be fully reflected in China's legislation. In any case, the inclusion of hydrogen energy in the energy category in the draft aims to promote the development of relevant industries. After being included in the energy category, it is expected to be easier for enterprises to obtain approval for the construction of hydrogenation stations, hydrogen production, storage and transportation.[8]

[7] Article 2(2) of *Energy Law of the People's Republic of China (Draft for Comments)*: Applicable Scope
The energy mentioned herein means various available energy resources that can be derived directly or through processing or conversion, including the primary energy sources like coal, crude oil, natural gas, coal bed methane, hydropower, nuclear energy, wind power, solar energy, geothermal energy and bio-energy, the secondary energy sources like electric power, thermal power and refined product oil, and other new energy sources and renewable energy sources.

[8] https://www.yicai.com/news/100588754.html

Generation related laws

According to the Regulations on the Safety Management of Hazardous Chemicals, hydrogen belongs on the hazardous chemicals list. Therefore, it is generally believed that the operators of hydrogen-production plants and hydrogen-refuelling stations should obtain hazardous chemical business licences. Such licences are issued by the safety production supervision and management department which is part of the Ministry of Emergency Management of PRC.

"China's Energy Development in the New Era" was published by the State Council in December 2020, stating that China will accelerate the development of hydrogen energy industry chain technology equipment such as green hydrogen production, storage, transportation and application, and promote the development of hydrogen energy fuel cell technology chain and hydrogen fuel cell vehicle industry chain.

On 19 April 2021, the National Energy Administration published "Guiding Opinions on Energy Work in 2021", proposing to carry out pilot demonstrations in the hydrogen energy industry, to deepen China-EU cooperation in energy technology innovation such as hydrogen energy, and to promote the implementation of a number of cooperative demonstration projects.

In terms of the standard setting, at present, China currently has 12 national standards and two industry standards in the field of hydrogen energy safety; four national standards, three industry standards, and one local standard in the field of gas quality testing; two national standards and three industry standards in the field of gas purification; 33 national standards in the field of hydrogen storage containers; 19 national standards in the field of transportation; eight national standards in the field of hydrogen refuelling stations; and eight national standards in the field of fuel cell systems.

Use in Transportation sector

The Ministry of Transport issued the "Inland Waterway Navigation Development Outline" in June 2020, indicating that it will study and promote the application of hydrogen energy within the industry.

Currently, the laws and regulations are vague on the qualifications required for the operation of hydrogen refuelling stations at national level. Therefore, some local governments have issued local normative documents on this. For example, Interim Provisions on the Safety Management of Hydrogen Refuelling Stations and Hydrogen Fuel Vehicles in Suzhou City (Draft for Solicitation of Comments) clearly stipulates that the production safety of hydrogen refuelling stations and hydrogen fuel vehicle operating units shall comply with the Work Safety Law, Administrative Regulations on the Safety of Hazardous Chemicals. The hydrogen refuelling station operating enterprises must apply for the PRC Mobile Pressure Vessel/Cylinder Filling Permit from the Administration for Market Regulation of the city where they are located before engaging in business activities. The site selection, design, construction, and safety management of hydrogen refuelling stations shall comply with current national standards.

It is worth noting that the competent authorities under the local regulations are also different. For example, in Shanghai, the Housing Urban-Rural Development Department was stipulated to be responsible for the management of hydrogen refuelling station operating licenses, as well as for the implementation of the issuance of interim operating licenses for hydrogen refuelling stations. In Dalian, it is a function of the Municipal Development and Reform Commission to promote the approval, construction and management of hydrogen refuelling stations.

In terms of construction specifications, the General Office of the Ministry of Housing and Urban-Rural Development released the national standards, Technical Specifications for Hydrogen Refuelling Stations (Partial Amendments) in March 2021 and Technical Standards for Automobile Refuelling and Hydrogen Refuelling Stations in June 2021. These standards stipulate technical requirements in the design, construction, and management of newly built, rebuilt and expanded hydrogen refuelling station projects.

Foreign Investment incentives

In terms of foreign investment, the "Catalogue of Industries Encouraging Foreign Investment (2020 Edition)" (the **"Catalogue"**) mentioned that various hydrogen energy industries will be included under the "foreign-investment encouraged" category. Among the industries to be included are the fuel production, storage, transportation, liquefaction, construction and operation of hydrogen refuelling stations, and hydrogen fuel cell manufacturing. The Catalogue is a government document that provides guidance on industries that are encouraged to seek investment – though it does not mean that foreign investment is required. Under the guidance, foreign investors interested in investing in hydrogen energy projects in China may enjoy preferential treatment, for example on taxation or security land rights.

Subsidies for hydrogen projects

On 23 April 2020, the Ministry of Finance, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, and the Development and Reform Commission jointly issued a notice adjusting current purchase subsidies for FCVs granting "rewards for compensation" to demonstration cities. The notice also stated that it should take about four years to establish the hydrogen energy and FCV industry chain. This timeframe has been estimated based on the currently high costs associated with producing hydrogen fuel cells, batteries and the long-distance transportation of hydrogen across the country.

Regulatory bodies

Hydrogen, gasoline, and natural gas (i.e., rich in methanol) are classed as hazardous chemicals in the "Catalogue of Hazardous Chemicals (2015 Edition)", due to their flammable nature. However, from an energy point of view, hydrogen does not yet have a dedicated regulatory department or corresponding classification system.

In April 2019, the State Council issued an opinion on implementing a division of labour among key work departments in the "Government Work Report". Instead of one central authority, the report recommended that various government departments should be responsible for: stabilising automobile consumption; continuing to implement preferential policies for the purchase of NEVs; and promoting the construction of charging and hydrogen refuelling facilities. Departments listed include the National Energy Administration, which is the competent authority for energy in China, and various other authorities which will each have a regulatory and supervisory role for different stages or processes, such as the production, storage or transportation of hydrogen.

Upcoming developments

In 2020, the Ministry of Education, the National Development and Reform Commission, and the National Energy Administration jointly issued the "Energy Storage Technology Professional Discipline Development Action Plan (2020–2024)", which will act as a roadmap for universities and other educational institutions. This plan notes that, in order to promote the hydrogen energy revolution in China, basic theoretical research at undergraduate, master and doctorate-level is needed over the coming years to develop highly efficient, low-cost energy storage systems. It is further noted that education and research should focus, in particular, on promoting compressed air energy storage, chemical-energy storage, new types of batteries, fuel cells, phase change energy and hydrogen storage.

The White Paper 2020 takes the "low-carbon and clean hydrogen supply system under the vision of carbon neutrality" as its main line. It puts forward the view that decarbonisation is the first driving force for the development of this round of hydrogen energy industry. It also predicts that in the context of carbon neutrality, the scale of hydrogen production from renewable energy is expected to reach 100m tons. With an installed capacity of 500GW of electrolysers, the reduction in hydrogen production from renewable energy alone is expected to reach 1.5bn tons/ year, accounting for about 13% of China's current total CO_2 emissions. In order to achieve the goal of carbon neutrality by 2060, China anticipates that hydrogen energy will play a key role in the entire system, and specifically heavy industry, medium and heavy transportation, and building heating industries that are difficult to decarbonise.[9]

[9] https://www.dx2025.com/archives/136018.html

According to the goals announced in the White Paper 2020, hydrogen energy looks to become an important part of China's energy system. It is predicted that by 2050, hydrogen energy will account for about 10% of its energy system, and the annual economic output value will exceed CNY 10tr. The popularisation and application of hydrogen energy is expected to be realised in the fields of transportation, industry, and more. The output of fuel cell vehicles is anticipated to reach 5.2m units/year, the capacity of stationary power generation devices will be 20,000 units/year, and the production capacity of fuel cell systems will be 5.5m units/year.[10]

The "Blue Book of China's Hydrogen Energy Industry Infrastructure Development", issued by the National Hydrogen Energy Standardization Technical Committee (SAC/TC309), clarifies that by 2030, 1,000 hydrogen refuelling stations and 1m hydrogen fuel cell vehicles will be built in China. This aims to drive the upstream infrastructure and fuel cell industry demand, thereby realising the development of the entire hydrogen energy industry chain.[11]

Regarding major renewable energy projects for the "14th Five-Year Plan", the State Hydropower and Electricity Institute recently issued a notice stating that new energy power generation and hydrogen energy integration development projects are able to participate in the application process. It is expected that state-owned enterprises, such as China HuaNeng Group, China Datang Corporation and China Three Gorges Corporation, will apply to develop hydrogen energy projects.

On 1 February 2021, the Ministry of Science and Technology of PRC released "Soliciting opinions on the 2021 project application guidelines for 18 key special projects including the 'Hydrogen Energy Technology' in 'The 14th Five-Year Plan' National Key R&D Program". It is planned to focus on the four technical directions of green hydrogen energy production and scale transfer system, hydrogen energy safe storage and rapid transmission and distribution system, hydrogen energy convenient upgrading and high-efficiency power system, and comprehensive demonstration of "hydrogen into thousands of homes", and 19 guiding tasks will be launched.

In April 2021, the world's largest green hydrogen production project from electrolysed water, Baofeng Energy's National Comprehensive Demonstration Project for Hydrogen Production from Solar Energy Electrolysis, was put into operation in Ningxia. The project uses solar water electrolysis to produce green hydrogen and green oxygen, and directly supplies the chemical system to replace fossil energy to produce high-end chemical products. It directly reduces nearly 400,000 tons of standard coal and reduces CO_2 emissions by about 700,000 tons per year.

[10] https://www.qianzhan.com/analyst/detail/220/210617-7e452a9b.html
[11] https://auto.sina.com.cn/news/hy/2021-09-02/detail-iktzqtyt3542665.shtml

Colombia

Authors:
Álvaro Josué Yáñez
María Lucía Amador
María Paula Sandoval

Current status for hydrogen in Colombia

Introduction

The hydrogen industry is emerging in Colombia, as it is expected to be one of the most relevant low-carbon alternative energy solutions in the following decades. In general terms, the Colombian energy sector expects hydrogen to play a substantial role as part of the energy transition programme,[1] contributing to the goal set by the Colombian Nationally Determined Contributions (**"NDC"**) of reducing 51% of its greenhouse gas (**"GHG"**) emissions by 2030 compared to 2015.[2]

Currently, no hydrogen projects are being developed in Colombia, even though different stakeholders are considering the jurisdiction for investing and forming the hydrogen industry. The state-owned company Empresa Colombiana de Petróleos (**"ECOPETROL"**) uses grey hydrogen for some processes inside its refineries and oversees a green hydrogen pilot project for reducing emissions in its refineries.[3]

According to Colombia's National Energy Plan 2020–2050 (**"PEN"**), the Ministry of Mines and Energy and the Unit of Energy Mining Planning (**"UPME"**) have committed to a clean energy transition. Colombia is one of the Latin-American leaders in energy transition, having set a range target of 2,400MW of renewable energy capacity by 2022, diversifying the energy matrix with clean energy sources. According to the PEN, renewable energy is expected to be the principal energy source in Colombia by 2050. This is also counting on the hydrogen industry developments.[4] By 2050, Colombia is expecting to have a significant green hydrogen production from renewables.[5]

[1] More information is available in https://www.minenergia.gov.co/libro-transicion-energetica
[2] For more information:
(i) https://www.minenergia.gov.co/documents/10192/24309752/21261021_Plan_Modifica+el+Plan+Integral+de+Gestión+del+Cambio+Climático+-+Sector+Minero+Energético.pdf/dbb68213-3ac3-48fb-9638-08ab42e74e83#:~:text=La%20meta%20de%20reducción%20de,estratégicas%20y%20sus%20respectivas%20acciones9, page 5
(ii) https://www.minenergia.gov.co/documents/10180/23517/15333066739365700Presentación+PIGCCME.pdf
[3] https://investincolombia.com.co/es/articulos-y-herramientas/articulos/hidrogeno-verde-una-alternativa-para-el-futuro-de-la-energia-en-colombia, https://www.bnamericas.com/es/noticias/colombia-publica-anteproyecto-para-impulsar-el-hidrogeno-con-inversion-de-us2500mn
[4] http://www.upme.gov.co/docs/pen/pen_idearioenergetico2050.pdf
[5] https://www.minenergia.gov.co/documents/10192/24302627/Hoja+de+Ruta+H2+Colombia_Borrador.pdf

Hydrogen as an Alternative Energy Solution

Earlier in the year, the Colombian government, in partnership with multilateral organisations and research institutes, started to develop a route to establish principally:

— initiatives and activities to be developed in the short (two years), medium (five years) and long term (ten years);
— potential hydrogen exportations;
— a legal framework;
— incentives for the different stages of the hydrogen chain; and
— private investment, (the **"Hydrogen Route"**).

Market Prospects for hydrogen

The hydrogen market in Colombia is at an early stage but has significant prospects for growth. As part of the Hydrogen Route, it is anticipated that, in the near future, opportunities will come mainly in the form of pilot projects by state-owned companies such as ECOPETROL and Grupo de Energía de Bogota (**"GEB"**), as Colombia oversees hydrogen as a low-carbon alternative energy solution which is capable of being one of the Colombian principal energy sources by 2050, increasing the fulfilment of the rural energy needs.[6]

Currently, Colombia does not have large-scale facilities for mass hydrogen production, nor the tough, high-pressure, insulated fuel tanks required for large-scale hydrogen storage. Instead, the Colombian government is evaluating the possibility of using the local gas infrastructure and facilities to overcome large-scale facility issues, as Colombia expects to export green and blue hydrogen.[7]

As the hydrogen industry in Colombia is nascent, there are currently no records of M&A or project financing activity. In addition, stakeholders continue to monitor the hydrogen industry as the state-owned companies' pilot projects evolve.

Challenges facing hydrogen projects

Absence of Legislative framework

Like many other jurisdictions, Colombia does not yet have a well-defined legislative framework regulating hydrogen. Even though, last year, Bill No. 371 of 2020 (Senate), which promotes the production and use of green hydrogen in different industries, was presented to the National Congress.

Given the emerging status of hydrogen as a low-carbon energy alternative, it is crucial that new regulations cover all hydrogen types as a hydrogen chain to regulate the use of hydrogen in Colombia. However, many gaps in the energy sector will need to be addressed before the hydrogen framework is determined.[8]

[6] https://www.ocensa.com.co/Paginas/Los-planes-de-GEB-y-Ecopetrol-con-el-hidr%C3%B3geno.aspx
[7] https://www.larepublica.co/analisis/jose-david-name-507206/atencion-a-la-emergente-industria-del-hidrogeno-verde-3113532
[8] E.g., gas reservoirs.

Commercial Viability of hydrogen projects

As many different countries' economies consider the hydrogen industry as part of the strategy to reduce GHG emissions, one of the key challenges for its development involves the production, refurbishment, and transportation of hydrogen, with the high costs and difficulties in achieving economies of scale.[9]

Colombia's principal source in the electric generation matrix is hydric, providing clean and efficient energy generation in terms of costs. This clean generation may imply a lower environmental pressure to develop green hydrogen projects in Colombia than in other jurisdictions, especially regarding energy costs.

Regulation of hydrogen

As mentioned above, Colombia does not have a specific or well-defined legislative framework that regulates hydrogen-based projects. Instead, and until a specific regulation is issued, hydrogen projects may be governed (on applicable grounds) by the existing legislative framework for natural gas and renewable energy projects. The most relevant laws are:

[9] https://www.asuntoslegales.com.co/analisis/jose-luis-palacios-verswyvel-3000911/el-hidrogeno-en-el-sector-electrico-colombiano-3155970

— Decree 1609 of 2002, regarding the land transportation of hazardous materials and waste;
— Law 1715 of 2014, which promotes renewables integration to the National Energy System;
— Decree 570 of 2018, which establishes public policy guidelines for long-term power generation projects;
— CONPES 3934, relating to public policy for green development (energy matrix diversification); and
— Law 2099 of 2021, regarding the energy transition framework.

The Colombian gas market is regulated by the Energy and Gas Regulatory Commission (Comisión de Regulación de Energía y Gas (**"CREG"**)), a government body for the national regulation of the mining-energy sector.

The Colombian Ministry of Mines and Energy, CREG, and UPME, are crucial for the further development of hydrogen projects. They lead, regulate, and coordinate efforts in the field of natural gas and renewable energies. Earlier this year, the Ministry of Mines and Energy started to promote the implementation of the Hydrogen Route.

Regulatory bodies

Colombia does not have one regulatory body which exclusively regulates hydrogen projects. Instead, as hydrogen falls under the existing regulation of the gas and electricity markets, the responsible bodies that may be involved are:

Regulatory Body	Role
Energy	— Ministry of Mines and Energy — Energy and Gas Regulatory Commission (*Comisión de Regulación de Energía y Gas* – CREG) — Mining-Energy Planning Unit (*Unidad de Planeación Minero-Energética* – UPME) — National Hydrocarbons Agency – ANH
Transportation	— Ministry of Transport — Superintendence of Transport.
Environmental instruments	— Ministry of the Environment and Natural Resources — National Environmental Licensing Agency (*Agencia Nacional de Licencias Ambientales* – ANLA) — Superintendence of Health

Upcoming Developments

Regarding Colombia's commitment to reduce GHG emissions and be one of the energy transition leaders in Latin-America, the National Congress may enact the green hydrogen law. The government may start regulating and promoting hydrogen projects in the following years.

The Hydrogen Route expects:

— a 1GW of electrolysis capacity by 2030; and
— an adoption of hydrogen vehicles.

As mentioned before, there are currently no low-carbon hydrogen projects in Colombia. Even though green hydrogen pilot projects are expected to start by 2022.

— **ECOPETROL** would develop a hydrogen pilot project of 50KW by electrolysis. This pilot would take place in Cartagena's Refinery and would be operating by the first quarter of 2022.[10] It is also evaluating 17 further hydrogen projects, including pilots for its Barrancabermeja refinery. These would require about USD 200m – 300m in investment,[11] as part of Colombia's goal of developing hydrogen energy options.
— **Promigas** is developing two hydrogen pilots in the northern part of the country, with one operating by 2022. It is also studying four different market segments:

  - distributed generation;
  - decentralized production;
  - mix gas pipelines; and
  - mobility.[12]

— Transportadora de Gas Internacional (**"TGI"**) is expecting to soon present its pilot in the next weeks regarding GEB's clean energy policies.[13]

10 https://www.portafolio.co/economia/infraestructura/empresas-que-haran-piloto-de-hidrogeno-en-colombia-557104
11 https://www.argusmedia.com/en/news/2259875-colombias-ecopetrol-eyes-18-hydrogen-projects
12 https://www.bloomberglinea.com.co/2021/10/06/colombia-alista-pilotos-de-hidrogeno-verde-en-sectores-de-gas-e-hidrocarburos/
13 https://www.tgi.com.co/

Czech Republic

Authors:
Lukas Janicek
Lukas Reichmann
Lukas Vymola

Current status for hydrogen in Czech Republic

Introduction

In the Czech Republic, the potential benefits of using hydrogen have been recognised particularly in the transportation sector. However, the actual development of dedicated hydrogen projects to date has been limited. The Czech government's current policy framework takes the development of hydrogen technologies into account and there are several hydrogen-based projects in the pipeline.

In July 2021, the Czech government approved the Czech Hydrogen Strategy for 2021–2050 (the **"CHS"**). The CHS is based on the EU Hydrogen Strategy for a Climate-neutral Europe. The CHS introduced four target areas on which the Czech Republic shall focus:

— production of low carbon hydrogen;
— utilisation of the low carbon hydrogen;
— transport and storage of hydrogen; and
— development of new hydrogen technologies.

The CHS is further divided into three phases:

Hydrogen mobility Phase 1: 2021–2025

The priority for Phase 1 is the use of hydrogen in clean mobility. "Island solutions" are likely to emerge, because hydrogen transport infrastructure will not yet be fully developed. Therefore, integrated projects under which hydrogen production and consumption will be jointly addressed will likely be the most attractive project types during this phase. Gas grid is expected to begin with testing the blending of hydrogen with methane gas. In connection with the use of methane gas to produce hydrogen, it will be necessary to make the carbon capture and utilisation (**"CCU"**) and carbon capture and storage technologies more effective, which are currently very limited in the Czech Republic.

Hydrogen mobility Phase 2: 2026 – 2030

Operational verification of how hydrogen can be used in industrial processes is expected to begin during Phase 2. The scale of this phase depends mainly on the success of the development of systems for the pyrolysis decomposition of organic waste and natural gas, and on the construction of large local solar or wind power plants connected to electrolysers. Planning of the efficient modes of transport will also be necessary to stimulate hydrogen demand. Due to the energy requirements of industry and the lack of low carbon sources of electricity, the Czech Republic is expected to be a net importer of hydrogen as it is today with respect to natural gas and oil. Separately, the testing of hydrogen supply for domestic consumption should begin in parallel during this phase.

Hydrogen mobility Phase 3: 2031 – 2050

It is expected that during Phase 3 the transport of hydrogen by pipeline/grid will be fully established without the need for subsidies. This is on the basis that there will likely already be established hydrogen producers and consumers by this phase. At this stage, hydrogen should also be used commercially in industrial processes.

Use in Energy & Industrial sectors

There are a number of companies in the Czech Republic developing and providing a variety of hydrogen production methods and technology for use in the energy sector. One such company is ÚJV Řež, a. s., which is a member of the Czech energy group headed by ČEZ, a. s. This company has developed and offers to potential customers hydrogen energy storage systems which are capable of serving as back-up power sources, stabilising power supplied to the grid from renewable sources, or facilitating the operations of energy self-sufficient facilities/buildings.

Currently, hydrogen is used predominantly in refining, chemical and steel production.

Use in Transport Sector

The transportation industry is the cornerstone of the hydrogen economy in the Czech Republic and a number of hydrogen initiatives focus on the use of hydrogen in the transport sector. The Czech government has adopted a National Action Plan for Clean Mobility (the **"NAP CM"**), which was last updated in 2019. The NAP CM expressly deals with the use of hydrogen in transportation and sets out specific hydrogen related goals with targets to be met in 2025 and 2030.

The NAP CM identifies the development of hydrogen bus transportation in the Czech Republic as a priority of the hydrogen mobility plan and sets a target of putting 95 hydrogen buses into operation by 2025, and to have 870 buses by 2030.

ÚJV Řež, a. s., a Nuclear Research Institute, has developed and put into operation a pilot transportation project involving a city bus with triple hybrid electric drive and hydrogen fuel cells (called **"TriHyBus"**) along with a hydrogen fuelling station in the town of Neratovice. The bus has been successfully operating on the Neratovice city line for the last five years.

UNIPETROL RPA, s. r. o., which belongs to the PKN Orlen Group and operates the BENZINA chain of fuelling stations, announced in 2019 the implementation of a pilot project of three hydrogen fuelling stations in 2020. There is also an ongoing project to establish a cross-border hydrogen fuelled bus connection between Prague and Berlin.

Market prospects for hydrogen

Focus on hydrogen use for transport

The NAP CM states that in order to attain the country's ambitious goals relating to the roll out of hydrogen bus transportation, an overall investment of approximately CZK 2.4bn (around EUR 92m) from both private and public sources will be required. In respect of public funding, the action plan takes into account the significance of EU-sourced funds as well as the "Modernisation Fund", a new fund to be established with the purpose of supporting the modernisation of energy systems in Central and Eastern Europe. The NAP CM states that a key factor in achieving this goal is the cost of hydrogen. Costs of hydrogen fuelled buses are forecast to continue decreasing in the future which will help the Czech Republic meet these targets.

In addition to public transportation, the NAP CM sets the goal of achieving between 40,000–50,000 hydrogen fuelled cars in the Czech Republic by 2030. It is recognised that this goal is ambitious and there are several key factors which will need to be addressed in order to achieve it. Firstly, direct financial subsidies for hydrogen fuelled cars will need to be established (such as those that exist for battery powered electric vehicles). The NAP CM also notes that public procurement is an important factor in the potential hydrogen car market development, given the large number of cars purchased and operated by the public sector. The NAP CM predicts that in order to attain this goal, overall investment from both private and public sources will need to reach approximately CZK 28bn (around EUR 1bn). Once again, a key factor in achieving this goal is the continuing decline in the price of hydrogen vehicles.

The NAP CM also includes a general objective to increase the share of hydrogen fuelled transportation goods vehicles. The action plan specifies that it will be necessary to set up a specific subsidy scheme to increase the share of hydrogen fuelled transportation goods vehicles. No specific time frame has yet been announced for this.

The NAP CM recognises that, in order to achieve these goals, the development of a sufficient network of hydrogen fuelling stations is crucial. The action plan estimates that it would be adequate to construct approximately 80 fuelling stations in the Czech Republic by 2030 (16 of these will need to be constructed by 2025). The overall cost of constructing these stations is estimated to be approximately CZK 3.5bn (around EUR 134m).

Initiatives for hydrogen developments

There are also a number of regional initiatives in the Czech Republic relating to the development of hydrogen technology. For example, in 2019, the region of Ústí and Labem along with UNIPETROL, a. s. (a PKN Orlen Group company) assembled a group of 17 public and private entities (including regional municipalities Ústí nad Labem, Děčín, Most, and private companies AIR PRODUCTS spol. s. r. o., Linde Material Handling Česká republika s. r. o., by-product ÚJV Řež, a. s.) to sign a memorandum on partnership and cooperation in the development and use of hydrogen (produced as an industrial by-product) as a clean source of energy. The goal of this initiative is to support the use of hydrogen in the local industry. The initiative anticipates that hydrogen will be produced, distributed and widely used in the transport sector in the region as well. UNIPETROL, a. s., currently the largest producer of grey hydrogen in the Czech Republic, also aims to start production of green hydrogen to be used in transport in Poland, the Czech Republic and Slovakia by 2030, and plans to bolster cooperation with significant market players in these countries.

The Moravian-Silesian Region has also announced a plan (inspired by some western European cities) to create a "Hydrogen Valley". This region is known for its coal mines and its steel industry, which are responsible for high levels of carbon emissions. This initiative represents a shift in the approach towards energy sources in the region. It is anticipated that within five years the region will introduce hydrogen fuelled public transport, and that the funding required will be largely provided by the EU (in particular, by The Fuel Cells and Hydrogen Joint Undertaking (the **"FCH JU"**)).

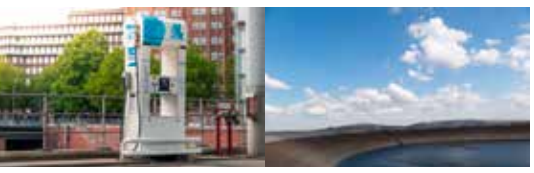
Challenges facing hydrogen projects

Legal framework overall

Regulatory shortcomings are a key barrier to greater development of hydrogen projects in the Czech Republic. This issue is also identified in the CHS. Some of the potential regulatory issues involve a lack of regulation concerning:

- the parking of hydrogen fuelled cars indoors e.g. in underground car parks, which has been identified as possibly requiring additional safety measures;
- the injection, transport, distribution, and use of hydrogen;
- the procedure of obtaining regulatory permissions for the construction of hydrogen infrastructure; and
- the implementation of current internationally standard norms relating to services of hydrogen fuelled cars within the Czech legislative framework.

In the absence of sufficient regulation, hydrogen developers must rely on existing energy and planning legislation, as well as on laws regulating the production, transport, use, and storage of gases generally.



Financial support and incentives gaps

Despite the existence of various general national funding programmes which may potentially be used for financing hydrogen projects, the absence of a specific hydrogen fund represents a key challenge facing potential hydrogen projects and the development of the hydrogen economy in the Czech Republic. The NAP CM points out that some areas (e.g. transportation of goods) require more direct subsidy programmes for their development, rather than the general funding programmes that are currently available. There are, however, financing possibilities from EU programmes (e.g. the FCH JU) and it is expected that some of the newly established financial sources for funding energy transition (e.g. the Modernisation Fund) will also be used for financing hydrogen projects.

No tax exemptions from the transport tax are currently available for hydrogen fuelled cars, although there are such exemptions for electric cars.

Research and education efforts

According to the CHS and NAP CM, although many hydrogen technologies are ready for introduction into the market, further research and development of the technologies is crucial for their adaptation for practical utilisation. The main areas where further research and development is likely to be needed are:

— applied research;
— pilot and demo projects;
— long term support of hydrogen mobility (also within "Hydrogen Valley" projects); and
— research for preparation of the legislative framework and for development of technical norms.

International collaboration in the area of hydrogen technologies is essential for Czech companies and research centres.

Regulation of hydrogen

Primary legislation

Legislation applicable to hydrogen projects in the Czech Republic is fragmented. There is no dedicated act relating to the use or commercialisation of hydrogen in the Czech Republic. Indeed, hydrogen has only been recognised as an alternative fuel since 2017 under the Czech Act no. 311/2006 Coll., on Fuel Substances, as amended. Therefore, the application of hydrogen will dictate the rules that stakeholders have to follow (such as rules applying to vehicle fuels or rules applying to energy supply). Given these rules have not been drafted with hydrogen in mind, they may not be suitable for the development and implementation of hydrogen technology. The laws which would apply to hydrogen projects will depend on the means of production, management, disposal, and use of hydrogen, thus including laws such as the Energy Act, Chemical Act, Act on Protection of Public Health, Health and Safety regulations, transport regulations, and legislation relating to the management of dangerous gases.

There are certain sources of primary legislation which make reference to the use of hydrogen, including:

— Act no. 13/1997 Coll., on road infrastructure, as amended, which exempts hydrogen fuelled vehicles from certain fees;
— Act no. 56/2001 Coll., on conditions of traffic on road infrastructure, as amended, setting up certain rules on number plates of electric and hydrogen fuelled vehicles; and
— Act no. 201/2012 Coll., on the protection of the environment, as amended, which includes hydrogen under the definition of fuel substances.

Secondary legislation and other legal documents

Relevant secondary legislation includes Ministerial Decree no. 268/2009 Coll., on technical requirements of constructions, as amended, which addresses to a limited extent the technical requirements of hydrogen fuelling stations. There is also the Ministerial Decree no. 341/2014 Coll., on technical capability and technical conditions of transport vehicles, as amended, which provides for the reconstruction of a hydrogen fuelled vehicle.

Policy and government programmes

The most recent government policy relevant for hydrogen is the Czech Hydrogen Strategy, namely, the CHS (discussed above).

There is a national action plan for clean mobility in place which also covers the use of hydrogen in transportation – namely, the NAP CM (discussed above).

There are a number of general national funding programmes which can be used for financing hydrogen projects (e.g. programmes **"OP Doprava"** and **"Restart"** administered by the Ministry of Transport and by the Ministry of Environment).

Regulatory bodies

Since there are no hydrogen-specific provisions in Czech legislation, acts which include general provisions concerning the investment process and exploitation of industrial installations and devices apply to hydrogen projects.

In respect of licensing, given there are no specific hydrogen licensing regulations in place, the generic licences covering specific activities will be applicable to hydrogen production and processing. For instance, the production of hydrogen as a fuel in transport is likely to be covered under specific trade licences for the production, processing and distribution of fuel substances. Trade licenses in the Czech Republic are issued by the Trade Licence Office. There is also no special licence for energy storage, hence activities such as energy accumulation would likely fall under the electricity production licence. Energy licences in the Czech Republic are issued by the Energy Regulatory Office.

Upcoming developments

It can be expected that investment in the area of hydrogen technologies will increase in the upcoming years. With regards to the ambitious goals set out in the NAP CM, and taking into consideration the CHS as well as the initiatives of certain regional municipalities in the Czech Republic, these investments will be made primarily in the transportation sector with the aim of decreasing the carbon footprint of this sector.

While there are several projects being discussed, many of these are not yet sufficiently developed. At this stage, the main project of note is the Usti-nad-Labem hydrogen station.

In February 2020, the city of Usti-nad-Labem announced the construction of its first hydrogen station. Construction has been planned to start in 2021 and will be funded under the **Operational Program "Transport"**. The total funding is expected to be CZK 31m, with completion of the station initially expected by the end of 2022[1] in the latest, but this completion will probably be delayed. The city also intends to invest in a fleet of hydrogen buses.[2]

ČEZ, a.s. intends to focus on production of green hydrogen from renewable energy sources and has announced that it plans to develop six electrolyser projects with a total capacity of 10MW by 2025. Such green hydrogen is expected to be primarily used in the transport sector.

In addition, two Czech investment entities (ForH2Energy and Hydrogen1) are cooperating together on the "H2 Triangle" project, which involves the creation of a hydrogen research centre with a total combined investment of CZK 600m. It has been reported that the project, which is to be located in the region of Ústí and Labem, has been selected for inclusion in the list of eleven strategic projects that will seek funding of approximately 50% of the overall investment from the EU Just Transition Fund next year. In the first phase of the project, the intention is to build a 4MW electrolyser for hydrogen production using electricity from a photovoltaic power plant (to be constructed as part of the project). It has been reported that this first phase could be completed by 2024. A research centre will also be developed which focuses on both hydrogen fuel cells and electrolysers.

Significant investment in hydrogen technology has been announced also by ORLEN Unipetrol, a Czech petrochemical company belonging to the PKN Orlen Group. It has been reported that ORLEN Unipetrol plans to produce 990 tonnes of hydrogen per year by 2025. It is anticipated that this hydrogen will also be produced by a 26MW electrolyser using electricity generated by a new 52MW photovoltaic power plant.

[1] https://www.world-today-news.com/the-first-carrier-in-the-czech-republic-has-chosen-a-supplier-of-hydrogen-buses-solaris-will-ride-in-usti/
The first carrier in the Czech Republic has chosen a supplier of hydrogen buses. Solaris will ride in Ústí - World Today News (world-today-news.com)

[2] https://www.themayor.eu/en/a/view/usti-nad-labem-will-build-its-first-hydrogen-station-4579
Green transport transformation for Usti-nad-Labem | TheMayor.EU

France

Authors:
Aurore-Emmanuelle Rubio
Christophe Barthélemy
Julie Guillemet

Current status for hydrogen in France

Introduction

In France, Law No 2015-992 of 17 August 2015, relating to the Energy Transition for a Green Growth, provided in its Article 121 that the Government shall establish a "development plan for the storage of renewable energies using decarbonated hydrogen" aiming, firstly, at encouraging hydrogen mobility through the development of fuel cells and hydrogen distribution infrastructures, and secondly, at adapting regulations to allow the power-to-gas business.

On 1 June 2018, the Minister for Energy presented the hydrogen plan, which has three main objectives:

— "greening" hydrogen for industrial use;
— using hydrogen for mobility to complement the battery sector; and
— stabilising energy networks.

Law No 2019-1147 of 8 November 2019 on Energy and Climate added the objectives of a low carbon hydrogen rate of 10% by 2023, and between 20% and 40% by 2030.[1] The Parliament also empowered the Government to take measures through law-decrees in order to "define the terminology of the different types of hydrogen according to the energy source used for its production", "to allow the production, transport, storage and traceability of hydrogen", and "to define a support framework applicable to low-carbon hydrogen".[2] Finally, this law instituted a system of guarantees of origin for hydrogen of renewable origin;[3] these provisions were however repealed and replaced.

After a public consultation from 8 January to 2 February 2021, the Law-Decree No 2021-167 of 17 February 2021 relating to hydrogen[4] was published in the *Journal Officiel* on 18 February 2021. It created a Book VIII in the Energy Code, entitled "Provisions relating to hydrogen". The Law-Decree provides several clarifications on the legal framework for hydrogen (see below *Challenges facing hydrogen projects in France*).

[1] Article L. 100-4, I, indent 10°, of the Energy Code
[2] Article 52 of the Energy and Climate law
[3] Article L. 447-1 of the Energy Code
[4] https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000043148001/

In addition, the Multiannual Energy Program (the **"PPE"**), published on 23 April 2020, approved by Decree No 2020-456 of 21 April 2020, with deadlines in 2023 and 2028, foresees an increase in the financial support for the hydrogen sector. The Government is determined to promote the development of green hydrogen in France. For instance, it has not waited for the publication of the Law-Decree to encourage motorway concessionaires to install hydrogen refuelling stations, as soon as the car fleet has reached a certain threshold of hydrogen vehicles.[5]

Use in Energy & Industry sectors

GRTgaz, a subsidiary of ENGIE and the main gas TSO, has set up the "Jupiter 1000" project to demonstrate the feasibility of the power-to-gas process on an industrial scale. The project will also test the injection of hydrogen and synthetic methane into its transmission network through a 1MW hydrogen production facility, a methanation unit to convert the hydrogen produced into synthetic gas, and an industrial CO_2 capture unit for methanation. This project was approved by the French energy regulator (the **"CRE"**)[6] in 2015.[7]

GRTgaz announced in May 2020 that it was initiating another project in collaboration with CREOS: **the MosaHYc project**. These two companies will create a hydrogen network linking Germany and France. The purpose of this agreement between the two gas transmission system operators is to make a 70km hydrogen transport infrastructure accessible by adopting existing gas infrastructures.[8]

Hydrogène de France and Teréga will develop a HyGéo pilot project to set out solutions for significant hydrogen energy storage.[9] This project aims to study the underground storage of energy using hydrogen obtained by electrolysis of water. This non-polluting hydrogen will be stored in an abandoned geological cavity previously used for hydrocarbon storage. Using fuel cells technology, the stored hydrogen will then be used to produce electricity back.

GRDF's tender for a "power-to-gas" demonstrator. Launched on 29 October 2020, it aims to test the injection of synthetic methane into the network from hydrogen produced by electrolysis and CO_2 from a biomethane production site. GRDF is proposing to contribute EUR 1.25m to the project over the duration of the experiment.[10] The three award winners selected are:

- the Hycaunais project, led by Storengy and developed in Saint-Florentin: linked to a methanation site already connected to the network, this project will make it possible to use hydrogen for green mobility and to produce synthetic methane by biological methanation. This project should demonstrate the advantages of power-to-gas as a flexibility service for the electricity network;
- the Perpignan pumping storage power plant, supported by the Perpignan Méditerranée metropolis: the project is based on the water treatment activity of the wastewater treatment plant, which already generates green gas (biomethane), and will set up a biological methanation process to recover its CO_2 with hydrogen delivered from the hydrogen hub in Port-la-Nouvelle; and
- the Pau Lescar pumping storage power plant is a project carried out by the Pau Béarn Pyrénées agglomeration community. The methanation part is integrated into the project to develop a methanation unit on the site, which should facilitate its financing, while allowing savings on wastewater treatment.

5 Article D. 122-46-1 of the Road Code
6 https://www.jupiter1000.eu/
7 https://www.cre.fr/Documents/Deliberations/Approbation/programme-investissements-2015-grtgaz
8 https://www.h2-mobile.fr/actus/mosahyc-grtgaz-creos-lancent-reseau-europeen-transport-hydrogene/
9 https://www2.terega.fr/fileadmin/presse/CP_FR/2020/CP-Terega-Hygeo.pdf
10 https://www.grdf.fr/institutionnel/actualite/newsroom/liste/communiques-presse/laureats-power-to-gas

Transportation sector

Hydrogen is a technology competing with electric batteries and other chief fuels. Its cost is still very high compared to its competitors. This challenge is the reason why regions are heavily investing in hydrogen projects. For example, the Auvergne Rhône Alpes region has invested in a project to build 14 hydrogen recharging stations. This is the "Zero Emission Valley" project. The Pays-de-la-Loire region recently set aside a budget of EUR 100m to invest in hydrogen projects until 2030.

In order to encourage green investments, the French Environment and Energy Management Agency (**"ADEME"**) is responsible for encouraging "the development of clean technologies and savings".[11] It thus encourages the development of hydrogen and fuel cells by issuing tenders for projects, which, if successful, would qualify for a State subsidy. The tenders to date have included:[12]

- Call for projects "Ecosystems of hydrogen mobility", 3 May 2019;
- Call for projects "Support for the emergence of hydrogen mobility in the railway sector", 21 January 2020;
- Call for projects "Innovative projects of European or national scope on the design, production and use of hydrogen systems", 23 January 2020;
- Call for projects "Technology bricks and hydrogen demonstrators", 13 October 2020;[13] and
- Call for projects "Territorial ecosystems", 13 October 2020.[14]

[11] Article L. 131-3, 5° of the Environmental Code
[12] smartgrids-cre.fr
[13] https://agirpourlatransition.ademe.fr/entreprises/dispositif-aide/20201013/inodemo-h22020-176
[14] https://agirpourlatransition.ademe.fr/entreprises/dispositif-aide/20201013/ecosysh22020-165

Market prospects for hydrogen

The potential of hydrogen to boost the economy is recognised in France. Both State and local authorities have expressed an interest in developing this new technology. The use of hydrogen as an alternative fuel for mobility and as an energy storage technology are currently one of the main areas of research and development in France.

To date, hydrogen has developed further for mobility. However, the injection of hydrogen into networks is still at the research and development stage. More generally, hydrogen technology is still in the early stages of development in France.

There have also been a number of mergers and acquisitions in the sector. For example, EDF created a subsidiary in 2020 dedicated to industry and mobility, Hynamics, and took a minority stake in the French company McPhy, a designer and manufacturer of hydrogen equipment. Another example: Michelin and Faurecia took the joint and equal control of Symbio, a fuel cell manufacturer created in 2010, whose plant is located near Lyon.

Currently, the projects are mainly financed by public bodies. However, it is likely that investors and banks will participate in the near future.[15]

Finally, several gas system operators, including GRTgaz which operates in nine EU Member States, proposed a European "hydrogen backbone". GRTgaz and Térega participate in the project. The work carried out by these TSOs has shown that existing gas networks can be adapted to transport hydrogen at an affordable cost. The emergence of a hydrogen network in the mid-2020s to reach by 2030 a first set (totalling 6,800km) of pipeline is considered possible. If achieved, it will link the different European hydrogen valleys. For 2040, a 23,000km hydrogen network is envisaged, i.e. the European "hydrogen backbone", consisting of 75% of existing converted natural gas pipelines supplemented by 25% of new hydrogen pipelines.[16]

Challenges facing hydrogen projects

Legal framework gaps

Since the publication of the Law-Decree No 2021-167 of 17 February 2021, the regulations concerning the use of hydrogen in the mobility sector have developed for the injection of hydrogen into the gas networks.

The major stake is the development of projects by the network operators regulated by the Energy Regulator, CRE, since these operators essentially depend upon the grid tariffs.

The sale of hydrogen is not regulated,[17] and a producer is allowed to sell renewable gas to a natural gas supplier without a licence.[18]

15 French industrialists in the starting blocks, Les Echos, 9 July 2020
16 https://www.terega.fr/newsroom/nos-actualites/terega-et-dix-autres-transporteurs-de-gaz-presentent-leur-plan-hydrogene-dans-le-cadre-de-la-strategie-europeenne
17 Article L. 851-1 of the Energy Code.
18 Article L. 445-2 of the Energy Code.

The Law-Decree No 2021-167 of 17 February 2021 made some significant changes to the legal framework:

— *Definitions of the different types of hydrogen:* First of all, "renewable hydrogen" is produced with electricity generated from renewable energy, such as wind or solar, below a specified threshold of CO_2/kg; it can be produced with an electrolyser.[19] Secondly, "low-carbon hydrogen" is defined as hydrogen produced from other energy sources below a threshold, like nuclear energy, with the threshold defined by a ministerial order. Finally, "carbon-based hydrogen" corresponds to the gas currently used in industry.
— *Self-consumption of hydrogen:* The Law-Decree has a chapter dedicated to the self-consumption of hydrogen in the Energy Code. The legal regime for hydrogen self-consumption is based on the individual and collective self-consumption regime, provided that it emits in the electricity sector. To be self-consumed, hydrogen must be produced and consumed on the same site by one or more producers and one or more consumers who are linked together within a single legal entity, possibly with a storage period.[20]
— *The mechanisms of guarantees and traceability for the production of renewable and low-carbon hydrogen:* The Law-Decree establishes two traceability systems for hydrogen, so that its low-carbon or renewable nature can be ascertained by the buyer, or so that the buyer is informed that the purchase of a guarantee constitutes a support for green energy. A traceability mechanism and a guarantee of origin system have been put in place; in both cases, one guarantee is issued for each megawatt-hour of energy.
— The system of *guarantees of origin* is inspired by the existing mechanisms for electricity from renewable energy sources[21] and biogas.[22] A guarantee of origin is issued for each megawatt-hour produced.[23] The guarantee of origin is issued to certify the origin of the renewable or low-carbon hydrogen, either when it is likely that it will be mixed with another type of hydrogen or gas, or if the guarantee issued at the time of its production is likely to be sold independently from the hydrogen produced. The guarantee proves that one megawatt-hour of hydrogen with this character has been produced.
— A *traceability guarantee* proves one megawatt-hour of hydrogen with a low-carbon or renewable character, not mixed with another type of hydrogen or gas, has been physically delivered to the buyer or final consumer.[24] A traceability guarantee cannot be sold independently from the corresponding hydrogen.
— *Guarantees of origin* of renewable and low-carbon hydrogen from other Member States may be assimilated to French guarantees of origin provided they meet a similar level of requirements. These special provisions for guarantees of origin from other Member States have been applicable since 30 June 2021.
— *The public support mechanism for hydrogen production:* The cost of low-carbon or renewable hydrogen production, notably by electrolysis, is higher than that for carbon-based hydrogen. The Government has therefore established a support mechanism for green hydrogen production. This mechanism takes the form of either an operating aid, or a combination of financial aid to investment and operating aid.[25]

[19] Article L. 811-1, second indent, of the Energy Code
[20] Article L. 813-2 of the Energy Code
[21] Articles L. 314-14 to L. 314-17 of the Energy Code
[22] Articles L. 445-3 and following of the Energy Code
[23] Article L. 821-3 of the Energy Code
[24] Article L. 821-3 of the Energy Code
[25] Article L. 812-2 of the Energy Code

— *Hydrogen injection into natural gas networks:* The hydrogen produced can be transported via new infrastructures dedicated to the transport and storage of hydrogen[26] or by being injected into the existing natural gas networks.[27] The Law-Decree amended articles L. 431-6-4 and L. 432-14 of the Energy Code to extend the obligations of natural gas network operators regarding hydrogen transportation. In this respect, the operators will have to ensure the safety conditions of goods and people, in addition to the proper functioning and balancing of the networks.
— The implementing regulations of the Law-Decree should be published during the course of 2021 to set out the details of this new legal regime.

Financial support and incentives

The Government has decided to significantly accelerate its investments in the development of low-carbon hydrogen. The Government announced that EUR 7bn will be invested before the end of 2030 according to the National Strategy for the Development of Low-Carbon Hydrogen published on 8 September 2020, including EUR 2bn before the end of 2022 for the framework of the COVID-19 "Recovery Plan".

This strategy targets three priorities that combine technological development and ecological transition:

— the decarbonation of industry to help achieve carbon neutrality in 2050, by developing a French hydrogen industry;
— the development of hydrogen-powered heavy mobility; and
— support for research, innovation, and skills development.

The objective of this strategy is to accelerate the technological mastery in order to industrialise hydrogen and enable a significant reduction in production costs.

As with renewable electricity, to avoid accumulating multiple State aids, the guarantees of origin generated by the production of renewable or low-carbon hydrogen in facilities benefitting from State aid (CfDs) belong to the State, which sells them via auctions. The municipalities which consume such gas can however be granted these guarantees for free, insofar as the gas is produced in their territory, and the amount of guarantees correspond to their consumption. These provisions relating to the guarantees of origin associated with the production of installations benefiting from State aid apply only to installations commissioning after 31 December 2023.

Research and education efforts

Lhyfe has joined forces with CEA Tech, the European consortium marine energy alliance, and the IRD in three R&D partnerships dedicated to the deployment at sea of green hydrogen production by electrolysis using electricity produced by offshore wind turbines.[28]

Network operators such as GRTgaz and GRDF, respectively the main French gas TSO and DSO, are also very active in hydrogen research and development, in particular by participating in pilot projects.

[26] Articles L. 831-1 and following of the Energy Code
[27] Articles L. 431-6-4 and L. 432-14 of the Energy Code
[28] https://www.industrie-techno.com/article/lhyfe-avance-vers-un-hydrogene-vert-produit-en-mer-avec-trois-partenariats-r-d.61076

Regulation of hydrogen

Specific legislation / regulation

The legal regime for hydrogen is enshrined in the Law-Decree No 2021-167 of 17 February 2021 relating to hydrogen, in application of the Mobility Orientation Law No 2019-1428 of 24 December 2019, which allows cities to create hydrogen refuelling infrastructures for vehicles and boats. The Law-Decree relating to hydrogen is the first text in France to establish a legal regime for hydrogen. As set out in paragraph *Legal framework* above, this text mainly defines the different legal categories of hydrogen, its traceability in the networks, and the public support mechanism to develop the sector.

However, the implementing regulations for the Law-Decree are still to be published.

Policy and Governmental programmes

The Government presented its Hydrogen Plan, named "National strategy for the development of carbon-free hydrogen in France" in September 2020, partly influenced by the global COVID-19 "Recovery Plan" (this is discussed in more detail below).

As set out in paragraph *Legal framework* above, the legal regime for hydrogen is enshrined in Law-Decree No 2021-167 of 17 February 2021 relating to hydrogen.

Generation
Hydrogen production is divided into three categories (renewable hydrogen, low-carbon hydrogen, and carbon-based hydrogen). Renewable and low-carbon hydrogen producers will be eligible for public support mechanisms. The conditions and modalities of this public support mechanism are yet to be defined by the Minister in charge of Energy.

Production and recharging facilities are subject to environmental regulations specific to "classified facilities for the protection of environment" (known under the French acronym "ICPE").

Connection and distribution
According to the Energy Code, it is mandatory to conclude a contract for being connected to the public gas network either for a generation facility, or for a consumption site, and the distribution network operator prior informs the user of the conditions relating to the connection of his installation. The activity of the DSOs is regulated and controlled by the regulator. GRDF, a subsidiary of ENGIE, is by far the main DSO in mainland France (there are no gas networks either in Corsica, or in overseas territories).

Transportation
The Mobility Orientation Law of 24 December 2019 mainly provides a framework for refuelling stations for private vehicles, buses, and ships.

Since the publication of the Law-Decree No 2021-167 of 17 February 2021, the hydrogen produced in France can be blended with methane gas and injected into the existing natural gas networks.

In addition, the Law-Decree extends the tasks of natural gas system operators to the injection of hydrogen. In this respect, the network operators must ensure the safety conditions of goods and people and ensure the proper functioning and balancing of the networks.

Any investment or extension of the scope of activity of natural gas network operators is regulated and must be approved by the CRE in accordance with Articles L. 453-2 and L. 453-6 of the Energy Code.

Primary legislation

Financing
Subsidies are awarded by a State-owned public body (ADEME) in response to tenders for projects. To date, the regulator has not launched yet any call for tenders to develop hydrogen projects; this option would allow operators to benefit from funding by the taxpayer.

In its Deliberation No 2020-231 of 24 September 2020 on the draft Law-Decree regarding hydrogen, the CRE specified that it was not in favour of setting up a support mechanism for renewable hydrogen distinct from that for low-carbon hydrogen because the production of renewable energy already benefits from a public support mechanism for the production of electricity. In addition, the regulator stated its support for the production of hydrogen with electricity generated from nuclear power plants.

The Law-Decree No 2021-167 of 17 February 2021, however, provides for public support mechanisms for renewable and low-carbon hydrogen production projects.[29] This public support mechanism takes the form of either operating aid (OPEX) or a combination of financial support for investment (OPEX) and operating aid (CAPEX). The duration of the aid is up to 20 years.[30]

A Decree must specify the terms of application of these public support mechanisms and thus allow the launch of the first calls for tenders by the CRE.

Permitting process
Hydrogen production and fuelling station construction projects are subject to the regulations for environmentally classified facilities (ICPE).

Secondary legislation and other legal documents

The Multiannual Energy Programme (PPE), approved by Decree No 2020-456 of 21 April 2020, determines the objectives for the development of hydrogen until 2028.

France's future hydrogen plan should make it possible to draw up a financing plan to develop hydrogen in the coming years.

Regulation of hazardous activities

The main laws here are: the Environmental Code (with *inter alia* the regulation on the environmentally classified installations, or ICPE), the General Code of Local Authorities (which for instance gives powers to local authorities to build and operate supply stations) and, more broadly, the Law on Energy Transition of 17 August 2015 and the Mobility Orientation Law of 24 December 2019.

Transport, import and export of hydrogen

To date, there are no specific regulations for the transport, import and export of hydrogen.

[29] Article L. 812-1 of the Energy Code
[30] Article L. 812-4, last indent, of the Energy Code

Regulatory bodies

The Law-Decree No 2021-167 of 17 February 2021 relating to hydrogen, the general provisions on the development and construction of renewable energy apply.

The Energy Regulator, CRE, controls the investments made by the network operators. For the time being, investments only concern experimental and research and development projects.

The Transport Regulator (the **"ART"**) has no jurisdiction over hydrogen projects: the CRE is the sole competent regulator.

Upcoming developments

On 8 September 2020, the French Government published its new Hydrogen Plan titled "National strategy for the development of carbon-free hydrogen in France", which takes into account the global COVID-19 "Recovery Plan" aimed at progressively removing the consequences of national lockdowns.

The purpose of the Hydrogen Plan is to make France "the carbon-free leader for tomorrow", according to the Minister for Economy. In order to do so, EUR 7.2bn shall be invested in this sector to: firstly, decarbonise the industry through cost-effective water electrolysis, with long term targets, such as saving 6m tonnes of CO_2 by 2030 and to reach carbon neutrality by 2050; secondly, support research and development, *inter alia* to make green hydrogen profitable; and thirdly, develop a "heavy mobility" using hydrogen as fuel (in trucks, trains, buses, planes) by utilising fuel cells.

Additionally, the Government hopes that this effort will directly create between 50,000 and 150,000 jobs.

The Hydrogen Plan includes measures, such as:
- Install enough electrolysers to make a significant contribution to the decarbonisation of the economy with a production capacity of 6.5GW carbon-free hydrogen through electrolysis;
- Conversion of land transport (passengers and goods) to hydrogen technologies, for example hydrogen-powered river shuttles and ships;
- Promote the emergence of a French electrolysis sector;
- Decarbonise industry by replacing carbonated hydrogen; and
- Calls for large-scale regional projects, aimed at pooling uses, to accelerate the deployment of professional hydrogen mobility (e.g. call of tenders for a "Territorial hydrogen hub").

[31] https://www.ecologie.gouv.fr/installation-du-conseil-national-lhydrogene

On 11 January 2021, the Government announced the formation of the National Hydrogen Council[31] to ensure the effective implementation of the National Strategy for the Development of Low-Carbon Hydrogen. The role of this Council is to structure exchanges between the State and the stakeholders in the implementation of the strategy, particularly the industrial sectors, and to measure the progress of the planned actions in order to identify any obstacles.

The Law to combat climate change and strengthen resilience to its effects, voted on 20 July 2021 and signed on 22 August 2021 (known as the **"Climate and Resilience Law"**), which was published in the *Journal Officiel* on 24 August 2021, allows local authorities to participate in the development of hydrogen, notably to develop, operate or delegate the development and operation of hydrogen facilities in the same way as renewable energy projects in accordance with Article L. 2224-32 of the General Code of Local Authorities.[32]

Similarly, municipalities and their groupings will be able to participate in the capital of a public limited company or a simplified joint stock company whose corporate purpose is the production of renewable or low-carbon hydrogen in the same way as companies whose corporate purpose is the production of renewable energy in accordance with Article L. 2253-1, 2nd intend of the General Code of Local Authorities.[33]

Moreover, for hydrogen installation projects selected by calls for tender and benefiting from a public support mechanism, the Administration may waive the need to organise a competitive bidding procedure for occupation of the public domain in accordance with the exemptions provided for in Article L. 2122-1-3-1 of the General Code of Local Authorities.[34]

Finally, the regulatory texts implementing the Law-decree No 2021-167 of 17 February 2021 relating to hydrogen are expected by the end of 2021 to particularly specify the public support mechanism for hydrogen and the two traceability mechanisms for hydrogen in the networks (guarantees of origin and traceability).

[32] Article 88, 1°, c) of the Climate and Resilience Law
[33] Article 88, 2°, a) of the Climate and Resilience Law
[34] Article 87, III, 1° of the Climate and Resilience Law.

Germany

Author:
Friedrich von Burchard

Current status for hydrogen in Germany

Hydrogen in the German Energy Market

The aim of Germany's energy transition is to replace nuclear and conventional fuels with renewable energy. At present renewable fuels account for 43% of the German electricity mix (as at the end of 2019).[1] Hydrogen is playing an increasingly important role in this energy transition. This has been particularly highlighted by the announcement of the National Hydrogen Strategy by the German Government in June 2020 as described in more detail below.

Domestic hydrogen consumption currently amounts to 55TWh. Hydrogen is used mainly in industrial processes, such as the production of basic chemicals like ammonia and methanol, as well as in the petrochemical sector. Most of the hydrogen used in industry is grey hydrogen produced from natural gas, whilst only 7% of current demand is provided by green hydrogen from electrolysis.

By 2030 hydrogen demand is expected to increase considerably, particularly in the industrial sector for use with chemicals, petrochemicals, and steel. In addition, growing demand is expected in the transportation sector.

Projects in development

A large number of projects for the establishment of a hydrogen economy have been launched, including the following:

The AquaVentus project was initiated in 2020 by industry players such as RWE, Shell, Siemens Gamesa, Vattenfall and Northland Power. The project comprises offshore wind farms with a total capacity of 10GW by 2035 to produce 1m mt tons of green hydrogen. They shall be built initially offshore the German island of Helgoland and in the further course of the project at the Dogger Bank sandbank by 2035. From the electrolysis plants the green hydrogen shall be transported via a dedicated pipeline system to Helgoland and in the final stages of the project further on to the German mainland (AquaDuctus).

The GET H2 initiative plans to implement several projects in Germany encompassing the production, transport and storage of green hydrogen. It has been launched by a variety of industrial companies and infrastructure providers such as BASF, RWE, BP, Thyssenkrupp, Uniper and OGE. By 2030, the partners envisage to build a hydrogen backbone transmission network from Lingen in Northern Germany

[1] https://www.bundesregierung.de/breg-de/themen/energiewende/energiewende-im-ueberblick-229564

to the central German Ruhr region and from the Dutch border to the East to Salzgitter.

The H2 Mobility initiative has been established by players such as Linde, Air Liquide, Shell, Daimler, Hyundai and TotalEnergies. The aim is to build a German-wide network of hydrogen fuelling stations. The first goal is to operate 100 stations in Germany for cars and smaller commercial vehicles. Further extension of the infrastructure network is envisaged in line with growing demand.

Gas transmission operators Gasunie Deutschland and Thyssengas in cooperation with electricity transmission system operator TenneT TSO are planning a 100MW power-to-gas pilot project in Lower Saxony (project "Element Eins"). It is scheduled to become operational in 2022. By converting renewable electricity into gas, the plant will create new opportunities for the storage of renewable energies. The project aims to achieve a comprehensive coupling of the energy, transport and industrial sectors. Gas that has been produced from renewable electricity will be transported from the North Sea to Central Germany through existing gas pipelines. Moreover, it could be made available to the transportation sector through hydrogen fuelling stations and to industrial consumers through storage caverns. Although the Federal Network Agency (**"BNetzA"**) has declined to include the investment in the incentive regulation scheme, investors have decided to pursue the project nonetheless.

Amprion and OGE are planning a major power-to-gas plant in Northern Germany (project "Hybridge") to convert renewable electricity into green hydrogen. Amprion is to build a 100MW electrolyser while OGE is to convert an existing gas pipeline into a pure hydrogen pipeline. The partners expect the project costs to be around EUR 150m. Like Element Eins, BNetzA declined to permit financing this project under regulated conditions.

The WESTKÜSTE 100 project in northern Germany is being led by companies from different sectors such as EDF Germany, Holcim Germany, OGE, Ørsted and Thyssenkrupp Industrial Solutions. The project is aimed at producing green hydrogen from electricity generated from offshore wind, and recovering the waste heat produced. The green hydrogen will be used to produce aircraft fuels or will be fed into a new hydrogen grid, which will connect the refinery, the hydrogen storage facility, a hydrogen fuelling station and the existing municipal natural gas grid. Within the initial five-year project period, an electrolysis plant with a capacity of 30MW is to be installed. It is also anticipated that the project could be scaled up to include, for example, an electrolysis plant of 700MW capacity with the electricity generated by an offshore wind farm.

Together with partners such as ONTRAS and Uniper, VNG Gasspeicher is planning the construction of an electrolysis plant with a capacity of up to 40 MW for the conversion of green electricity from a wind farm specially built for the project into green hydrogen ("Energiepark Bad Lauchstädt"). The hydrogen produced will be stored in a dedicated salt cavern, fed into the existing network and supplied to the chemical industry, the transportation sector and for urban energy supply. A special feature of the project is the large-scale storage of hydrogen. The planned salt cavern would be the first cavern in the world to store green hydrogen and would be specially equipped for the storage of up to 50m m^3 of hydrogen.

Gas Transmission Network

The German TSOs have proposed a "hydrogen starter network 2030" as published in their proposal of the Gas Network Development Plan 2020–2030 (**"NDP"**). According to the plan, the first converted pipelines shall, as early as at the end of 2022, provide the core of a nationwide hydrogen network, which will gradually evolve and expand until 2030. The starter network with a length of more than 1,200km shall connect demand centres in North Rhine-Westphalia and Lower Saxony with green hydrogen production projects in Northern Germany. By 2030, the starter network shall primarily consist of pipeline conversions, while only about 100km will be newly built dedicated hydrogen pipelines. There are plans for a first interconnection point for imports via the Netherlands as well. Investments of around EUR 290mn are expected by the end of 2025 to build the starter network, with a total of EUR 660m worth of investment expected by the end of 2030.

BNetzA has rejected the inclusion of hydrogen pipelines in the NDP 2020–2030 based on the argument that existing German law does not allow for the inclusion of hydrogen networks in the planning procedure of the gas network. The regulatory approval of hydrogen pipes, however, is provided for in the amended Energy Act on a case-by-case basis *(see below)*.

OGE has signed a network connection and use contract with an onshore wind farm ("Bürgerwindpark") in Northern Germany, allowing hydrogen to be blended into the gas network. The hydrogen comes from a community wind farm with a total capacity of 67.2MW. As part of a site expansion, the wind farm will be equipped with a 2MW electrolyser to convert the renewable electricity into hydrogen which is then fed into the gas pipeline system.

Industry Sector

The Carbon2Chem project explores how industrial gases from steel production can be used to create valuable primary products for fuels, plastics, or fertilisers. The chemical processes involved require the use of hydrogen, which is to be produced from green energy by way of electrolysis. The Carbon2Chem approach is expected to make 20m tons of the German steel industry's annual CO_2 emissions economically exploitable in future. This represents 10% of the annual CO_2 emissions from German industrial processes and the manufacturing industry. The German Federal Ministry of Education and Research is funding the project with more than EUR 60m. The partners involved intend to invest more than EUR 100m by 2025.

Transport Sector

Transport applications play an important role in the future German hydrogen economy, although they are still in early stages. Hydrogen-based mobility is seen as an alternative option for those applications where using electricity directly is not reasonable or technically feasible. Hydrogen could be applied in a wide range of sectors such as local public passenger transport, heavy-duty road transport and commercial vehicles. The introduction of fuel cell vehicles can also complement battery-powered electric mobility. In certain areas, hydrogen may also provide an alternative for cars. If hydrogen is to be used in road transport, refuelling infrastructure must be expanded. As of January 2020, there were 87 refuelling stations in Germany. An expansion by 15 stations per year is envisaged to accommodate the increased use of hydrogen in transport *(see above)*.

Power Generation using hydrogen

Uniper and General Electric (**"GE"**) signed an agreement in June 2020 aiming at a long-term collaboration of the decarbonisation of Uniper's gas-fired power plants and natural gas storage facilities. GE's Gas Power business and Uniper will explore, assess, and develop technology options for decarbonisation. The agreement aims at producing a detailed decarbonisation roadmap. This roadmap is to develop an assessment of potential upgrades and R&D programs needed to drive decarbonisation, including increasing the use of emissions-friendly hydrogen in GE gas turbines and compressors in Uniper's power plants and gas storage facilities across Europe.

Market prospects for hydrogen

Areas of Growth

Areas of growth and resulting market prospects are defined in the National Hydrogen Strategy published by the German Government in June 2020, as discussed in more detail below.

Funding and incentives

Although the hydrogen market in Germany is still in early stages there is already a well-established history of public funding. The funding from the Federal Ministry for Economic Affairs and Energy for research and development in the field of fuel cell and hydrogen technologies is tied into the "National Hydrogen and Fuel Cell Technology Innovation Programme" (**"NIP"**) which was launched in 2006. The programme is being continued as the Government's NIP2 programme (**"NIP2"**) in the 2016–2025 period. Up to 2016 the Federal Government provided funding amounting to EUR 700m in total. From 2016 – 2026 public funding will amount to EUR 1.4bn. In June 2020, the Government adopted a "package for the future" which makes available another EUR 7bn for speeding up the market rollout of hydrogen technology in Germany and another EUR 2bn for fostering international partnerships.

The NIP2 programme builds on the maturity of technology and market availability attained in the first generation of equipment. In view of the forthcoming market launch phase, the aim is to ensure that the national activities of science, industry and government continue to take place under a common umbrella. The intention is to continue developing innovations in hydrogen and fuel cell technologies which are not yet ready for market, to build up the appropriate infrastructure and to use appropriate instruments and measures to support the placing on the market of technologies which are on the cusp of a market launch.

M&A Activity

Because of the nascent status of the hydrogen projects there has been little M&A activity in the sector. This may change in the medium term once the current projects and the National Hydrogen Strategy are implemented by market players.

Challenges facing hydrogen projects

Legal and Regulatory Framework

As in other jurisdictions, the legal and regulatory framework for hydrogen is not yet comprehensive. As described in more detail below, the German Parliament passed an amendment to the Energy Act which contains new provisions for the regulation of hydrogen networks. These new rules are, however, only of a transitional nature. It is to be expected that hydrogen network regulation will evolve further alongside the development of European law. A framework for carbon capture and storage necessary for the market launch of "blue" hydrogen is lacking completely. Technical rules e.g. for the increased blending of hydrogen into the natural gas grid are still under consideration.

Incentives needed

As outlined above, over the past few years the funding from the German Government for research and development in the field of hydrogen was substantive. According to the National Hydrogen Strategy, Germany now has the chance to play a key role in international competition for the development and export of hydrogen and Power-to-X technologies. The broad-based community of German stakeholders in the hydrogen technology field, with their substantive international connections, will not only be a key factor for the successful market ramp-up of hydrogen technologies in Germany, but will also improve the opportunities of German firms in this forward-looking market. The manufacture of components for the generation, use and supply of hydrogen will contribute to regional value creation and strengthen the companies active in these fields.[2]

Other than the existing market for grey hydrogen mainly in industrial applications, there is no market for green hydrogen as of today in Germany. Given the fact that the production of green hydrogen is still far more expensive than grey hydrogen, the market launch of green hydrogen is largely dependent on incentives for its production and use. Potential incentive mechanisms range from tax measures, quota regulations, changes in the emissions trading scheme and feed-in tariffs, to exemption from transportation and storage tariffs.

It is still discussed whether green hydrogen will be the only option for Germany or whether at least for a transitional period blue hydrogen could pave the way for a hydrogen economy. Because of the large quantities of grey hydrogen already used in industry, blue hydrogen is seen as a potential transitional substitute to enable a shift towards a lower-carbon intensive hydrogen economy. Against this background, the German Government underlines the fundamental role of green hydrogen in the energy transition, whilst acknowledging a transitional role for blue hydrogen.

Regulation of hydrogen

Construction of Hydrogen Production Facilities Laws

The construction and operation of a hydrogen production facility such as a power-to-gas plant requires the execution of an authorisation procedure pursuant to the Federal Immission Control Act. This encompasses a preliminary audit under the Environmental Impact Assessment Act. The requirements of the Hazardous Incident Ordinance also have to be fulfilled.

[2] https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/die-nationale-wasserstoffstrategie.html

Regulation of Hydrogen Networks

On 24 July 2021 the German Parliament passed an amendment to the Energy Act which contains new provisions for the regulation of hydrogen networks. The purpose of the amendment to the Energy Act is to gradually build up a hydrogen infrastructure in Germany. According to section 112b of the Energy Act the provisions are intended as a transitional solution until corresponding European guidelines are available. The EU Commission has announced that it will present proposals on this by the end of 2021. Implementation into German law is expected from 2025 onwards.

So far there are only a few hydrogen pipelines in Germany which are not regulated as they are direct pipelines used for industrial purposes. According to the explanatory notes on the legislation, in view of this, there is no intention to subject existing or future hydrogen pipelines to mandatory regulation. Instead, this decision is to be left up to the pipeline operators. However, the German government presumes that as more and more interconnected hydrogen networks are developed, there will be a need to subject them to comprehensive regulation.

The amendment to the Energy Act provides for the following framework conditions:

— In the definition of the term "energy" in section 3 no. 14 of the Energy Act, hydrogen is categorised as an independent energy carrier alongside gas. However, this only applies to pure hydrogen pipelines. For the blending of hydrogen into the natural gas network, the existing legal framework continues to apply on the basis of which hydrogen produced by electrolysis falls under the definition of gas.

— According to section 3 no. 39a of the Energy Act, a hydrogen network is a network for the purpose of supplying customers with hydrogen which, in terms of its size, is not designed from the outset to supply specific customers or customers which are specifiable at the time when the network is constructed but which is, in principle, open for the supply of all customers. Industrial pipelines which connect a generation plant with dedicated individual consumption sites are therefore not covered by the Energy Act by their very definition. Section 39b of the Energy Act defines hydrogen storage facilities.

— Section 28j of the Energy Act gives operators of existing networks and newly constructed networks a unique and irrevocable right to choose whether they want to be subject to the newly introduced regulation of hydrogen networks or not. This also applies to the conversion of natural gas pipelines to hydrogen. The right to choose applies to the operator in general and not to individual pipelines. Those who choose not to be regulated will not be covered by the requirements regarding network access, tariffication and unbundling as explained below.

— According to section 28n of the Energy Act, network operators are required to grant access and connection to their hydrogen networks based on the principle of negotiated network access. The standardised contracts for regulated network access to the natural gas network, which have been continuously developed since 2006, therefore do not apply. Whether a corresponding uniform contractual practice will nevertheless emerge remains to be seen.

— Section 28o of the Energy Act provides for cost-based tariffication which is largely in line with the current legal situation. The conditions and tariffs must be reasonable, non-discriminatory and transparent. Application of the Ordinance on the Incentive Regulation of Energy Supply Networks is not planned but is not completely ruled out. This is logical as benchmarking between network operators would not make sense in the beginning with only few operators to compare. A prerequisite for cost recognition is a positive needs assessment of the hydrogen infrastructure in accordance with section 28p of the Energy Act.

— According to section 28k of the Energy Act, the operators of hydrogen networks must carry out separate accounting and bookkeeping for their networks (unbundling of accounts). This serves to avoid cross-subsidisation and discrimination. Particularly in the case of simultaneous operation of gas transmission networks, the aim is to prevent costs for the hydrogen infrastructure being included in the transmission tariffs.

— In accordance with section 28m of the Energy Act, hydrogen network operators may not construct, operate or own facilities for the production, storage or distribution of hydrogen. The requirements on informational unbundling also apply. Legal unbundling in the sense that the operator of a hydrogen network must be separated from an energy supply company in terms of its legal form is not prescribed.

— Section 113a of the Energy Act regulates the transfer and continued application of rights of way and easements for gas pipelines. Under this provision, these also apply to the operation of these pipelines with hydrogen. This is intended to facilitate the transition from gas pipelines to hydrogen.

— Transmission system operators can identify pipelines that could be converted to hydrogen in the framework of the Gas Network Development Plan in accordance with section 113b of the Energy Act. It must be ensured in this respect that the remaining network can meet the capacity requirements.

— Last but not least, an independent Network Development Plan is to be drawn up for the hydrogen networks. The target year for this is 2035. This rejects the idea of joint network planning with the natural gas network.

— Already the draft amendment to the Energy Act met with sharp opposition from the associations of network operators. The separation between the natural gas and hydrogen networks was criticised as an obstacle to rapidly and efficiently developing a hydrogen infrastructure. Separate tariffication, in which the network tariffs for hydrogen would have to be significantly subsidised in the start-up phase, would lead to higher network tariffs overall. The argument that separation would avoid cross-subsidisation, which is questionable under EU law, is not convincing, they said. Network user associations, on the other hand, welcomed the idea of separate tariffication saying that natural gas customers should not pay for the development of hydrogen networks which are primarily for industrial applications.

— Whether a transitional solution with a right to choose for the network operators as provided for by the amendment is actually sensible is questionable. The amendment itself presumes that full regulation will be necessary in the medium term. The artificial separation of the natural gas network from the hydrogen network is not convincing either. In the future hydrogen will take over the role of natural gas. The gas network therefore needs to be transformed into a hydrogen network. We can expect that the conversion of existing gas pipelines will be the vital backbone of the future hydrogen network. This will be operated by the existing network operators. In view of this, it is not clear why natural gas and hydrogen networks should remain separate for a transitional period.

— Finally, the amendment paints a colourful picture of network access to hydrogen networks. In the case of unregulated network operators, there is network access, if any, on the basis of the general legal provisions. The conditions are completely unclear. At regulated network operators, negotiated network access applies which had to give way to regulated access to gas networks 15 years ago. Finally, when hydrogen is fed into the natural gas network, regulated network access on the basis of the Energy Act applies with conditions that are standardised down to the very last detail.

Regulatory bodies

There is no specific regulatory body which is responsible for the regulation of hydrogen projects. As far as hydrogen falls under the existing regulation of the gas and electricity markets the Federal Network Agency, BNetzA, is the competent authority on a federal level.

Upcoming developments

The National Hydrogen Strategy

In June 2020, after long discussions the German Government announced the National Hydrogen Strategy.[3] According to the overarching principle of the Strategy, security of supply, affordability and environmental compatibility need to be combined with innovative and smart climate action in order for the energy transition to be successful. This means that the fossil fuels currently used need to be replaced by alternative options. This applies in particular to gaseous and liquid energy sources, which will continue to be an integral part of Germany's energy supply. Against this backdrop, hydrogen will play a key role in enhancing and completing the energy transition. The first step to be taken to speed up the rollout of hydrogen technology is establishing a strong and sustainable domestic market for the production and use of hydrogen in Germany.

The cornerstones of the strategy are as follows:

— The German Government expects that around 90 to 110TWh of hydrogen will be needed by 2030. In order to cover part of this demand, Germany plans to establish up to 5GW of generation capacity including the offshore and onshore energy generation facilities needed for this. This corresponds to 14TWh of green hydrogen production and will require 20TWh of renewables-based electricity. An additional 5GW of capacity is to be added, if possible, by 2035 and no later than 2040.

— A domestic market for the production and use of hydrogen has to be established. If hydrogen is to have long-term prospects, capacities for generating electricity from renewables (particularly wind power and photovoltaics) must be systematically improved. The introduction of CO_2 pricing for fossil fuels used in transport and the heating sector is an important element to support green hydrogen production and will be complemented by a reduction of the EEG surcharge.

[3] For details see https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/die-nationale-wasserstoffstrategie.html

— The industrial sector is well-placed to become one of main factors speeding up the market rollout of hydrogen and a global pioneer for hydrogen technology. It is estimated that more than 80TWh of hydrogen would be needed to make German steel production CO_2-neutral by 2050. Around 22TWh of green hydrogen would be needed for German refinery and ammonia production to switch to hydrogen. The switch to hydrogen in the industrial sector will be supported by providing funding for investments in electrolysers. Furthermore, a new pilot programme entitled "Carbon Contracts for Difference" is due to be launched which targets the steel and chemical industries with their process-related emissions. Under this programme, the German Government will guarantee funding amounting to the difference between the actual cost of avoiding emissions/a project-based contractually agreed carbon price per amount of greenhouse gas emissions avoided, and the ETS prices for the construction and operation of decarbonisation technologies to achieve greenhouse gas neutrality

— Transport applications offer great potential for hydrogen uses. Hydrogen-based or power-to-gas based mobility can be an alternative option for those applications where using electricity directly is not reasonable or technically feasible. In the long-term, air and maritime transport in particular will develop a demand for carbon-neutral fuels which can be supplied in the form of hydrogen-based energy sources from power-to-gas processes. In air transport as well as coastal and inland navigation, fuel cells and battery-powered drives may also be an option for certain mobility needs.

— Even after the efficiency and electrification potentials for process heat generation and the building sector have been harnessed, there will continue to be long-term demand for gaseous fuels. In the long run, hydrogen and its downstream products can help in various ways to decarbonise parts of the heat market. For the period from 2020–2024, up to EUR 700m can also be used for funding fuel-cell heating systems.

— The German Government has appointed a National Hydrogen Council. The Council is made up of 26 high-level experts from business, science, and civil society who are not part of the public sector. The task of the National Hydrogen Council is to advise and support the State Secretaries' Committee through proposals and recommendations for action in implementing and enhancing the Hydrogen Strategy.

Climate Change Act

The requirement to boost the production and use of hydrogen is mainly determined by climate change policy and legislation. In that respect Germany has taken a huge step forward by the adoption of an amendment to the Climate Change Act on 24 June 2021.

— At the heart of the amended Climate Change Act is Germany's aim of achieving climate neutrality by 2045 and the specification of binding targets on the way there for the 2020s and 2030s. Until now, the goal was greenhouse gas neutrality by 2050. The interim target for 2030 has been raised from the current level of 55% to 65% greenhouse gas reductions compared with 1990 levels. A new interim 88% reduction target will also apply for 2040.

— The Climate Change Act continues the system of annualised permissible emission levels for individual sectors for the 2020s and in some cases lowers them significantly. The energy sector and industry will bear the lion's share of the additional reduction by 2030. The energy sector will be allowed to emit only 108 instead of 175m tonnes of CO_2 in 2030, with industry allowed 118 instead of 140m tonnes of CO_2. The reduction in the energy industry's CO_2 budgets compared with the previously planned emissions volume is thus just under 40%, and the reduction for industry is about 16 %. The increase in target cuts for other sectors is much less drastic. The Act also provides for specific annual targets for cuts until 2040. However, a decision on the specific share of the individual sectors will only be made once the course has been set at the European level in 2024. The reduction targets until 2045 will be set by law in 2032. As an incentive, the German federal government has announced an immediate programme with an additional volume of up to EUR 8bn.

— The amendment of the German Climate Change Act will significantly raise the bar for reduction targets, specifically for the energy sector and for industry in particular. It is no exaggeration to describe the effects as fundamental. The energy industry has a central role to play in the implementation of climate action targets. The German coal compromise with its coal phase-out by 2038 will probably not survive the Climate Change Act 2021. Renewables must therefore be rapidly expanded, much faster than at current trends. This applies in particular to offshore and onshore wind power as well as photovoltaics. Converting industrial production processes to hydrogen, which needs to happen in the steel industry for example, is also important. Even assuming that 10% of demand for green hydrogen can be met in Germany, there is still a huge gap that will have to be filled by imports. Moreover, the production of green hydrogen is still in its infancy. Achieving the reduction targets by 2030 will not be possible without blue hydrogen. The issue of CO_2 capture and storage will therefore also need to be addressed in Germany if demand cannot be met with imported blue hydrogen alone.

Italy

Author:
Matteo Ciminelli

Current status for hydrogen in Italy

Introduction

According to the Integrated National Energy and Climate Plan (**"PNIEC"**), published in December 2019 by the Ministry of Economic Development together with the Ministry of the Environment and the Ministry of Infrastructure and Transport, one of the primary objectives Italy is aiming to achieve by 2030 is the reduction of around 30% of national greenhouse gas emissions. With this in mind, hydrogen is considered as having a key role in reaching this goal as a result of its unique chemical and physical attributes, and specifically because hydrogen can be produced by renewable energy sources and can be stored and transported like a gas or liquid.

In November 2020, the Ministry of Economic Development published the "Italian Hydrogen Strategy: preliminary guidelines" (the **"Hydrogen Strategy"**). This document sets a medium and a long-term objective, according to which the national energy consumption is expected to consist of 2% hydrogen by 2030 and 20% by 2050. The Hydrogen Strategy also identifies the sectors that will be crucial for the use and development of the hydrogen, such as public transportation, chemicals and refining.

The key role of hydrogen in the context of the national energy transition has been further confirmed by the National Recovery and Resilience Plan (**"NRRP"**), transmitted by the Italian Government to the European Commission on 30 April 2021 and approved by the European Commission on 13 July 2021. The NRRP is part of the Next Generation EU programme, namely the EUR 750bn recovery package, consisting of grants and loans, set up by the European Union in response to the COVID-19 pandemic crisis. The NRRP, whose total value is equal to EUR 191.5bn, has been conceived based on three strategic pillars:

— digitalisation and innovation,
— ecological transition, and
— social inclusion.

In the context of the ecological transition, paramount importance has been given to renewable energy, hydrogen and sustainable mobility.

Currently, hydrogen is mostly used in chemical and metallurgical industries in Italy. It is commonly obtained through a thermochemical process called "steam methane reforming" which consists in the conversion of fossil fuels (e.g. coal and natural gas) into "grey" hydrogen. This produces high CO_2 emissions and other pollutants; therefore, in order to reduce such emissions, both "blue" and "green" hydrogen should be considered as alternatives.

To date, in Italy only a small share of the hydrogen production originates from electrolysis to create green hydrogen. However, an increasing interest in green hydrogen is expected over the coming years thanks to the progressive reduction in the cost of renewable power and electrolysers.

In Italy, the transition to green hydrogen would be facilitated by two additional key factors, namely: 1) a higher availability of renewables than in other European countries and 2) the existence of several pipelines connecting northern Africa to Southern Italy which could be used to import hydrogen at a lower cost. Green hydrogen is therefore now considered as a game changer for Italy's energy transition. More generally, a recent study conducted in 2019 by specialists in the energy sector has confirmed this by showing that hydrogen has the potential to provide almost one quarter of all national energy consumption by 2050.

There are significant opportunities for the use of hydrogen in many sectors, such as in buildings, industry, transportation and the entire energy supply and storage chain. More specifically, green hydrogen could be used as chemical product to decarbonise refining and high-heat processes of the steel, petrochemical, and mining industries. Green hydrogen could also serve as a storage system for the electricity surplus produced by renewable sources and as a fuel for public and private transportation.

Use in industry

In 2019, SNAM S.p.A (**"SNAM"**), one of Italy's leading energy infrastructure operators, launched a project called **"SNAMTEC"**, worth approximately EUR 850m, aimed at increasing energy efficiency, reducing pollutant gas emissions and promoting innovation in the energy sector. Among the initiatives included in SNAMTEC project, SNAM launched a trial that took place in the Campania Region consisting of the introduction of a quota of 5% of hydrogen in the energy mix for a period of a month. The trial proved that the introduction of even a small portion of hydrogen in the energy mix would allow a substantial reduction in carbon dioxide emissions.

In March 2019, ENI, one of the most important Italian energy companies engaged in the exploitation, production, refining, and sale of oil, gas, electricity, and chemicals, signed an agreement with the National Consortium for the Collection, Recycling, and Recovery of Plastic Packaging (**"COREPLA"**), to develop a research project aimed at producing hydrogen and high-quality biofuels from non-recyclable plastic packaging waste.

ENI and NextChem, the Maire Tecnimont Group's subsidiary for green chemistry, have entered into several partnership agreements to conduct engineering studies with the aim of developing and building new waste-to-hydrogen and waste-to-methanol production plants in Taranto, Venice, and Livorno. These plants will be crucial for a massive reduction of pollutant gases and for achieving Italian decarbonisation targets.

Transportation with hydrogen fuel

In June 2020, Alstom, a leading company in the construction of trains and railway infrastructure, signed an agreement with SNAM where, for the first time, hydrogen fuelled trains will be introduced in the Italian rail network. These trains will be equipped with fuel cells which will convert the hydrogen into electricity with no greenhouse gas emissions. The first hydrogen fuelled trains are expected to run in the Lombardy region from 2023.

In June 2019, ENI announced the launch of a new partnership with Toyota for the planning of a new hydrogen refuelling station in the Lombardy Region. ENI has specified that the hydrogen that will be sold in the refuelling station will be completely green as it will be produced only through the electrolysis process.

In September 2019, another partnership was signed between ENI, Toyota and the Municipality of Venice to evaluate the construction of a hydrogen refuelling station. The refuelling station will mark a concrete step forward in promoting the circulation of public and private hydrogen powered vehicles.

Energy storage and power generation using hydrogen

In January 2019, Enel Green Power, Enel Group's subsidiary involved in the generation, distribution, and supply of renewable energy, and the Municipality of Lipari entered into an agreement for the building of a new photovoltaic plant on the Island of Stromboli. The new plant will be equipped with an innovative energy storage system that will store the excess solar energy produced in the form of hydrogen and will convert it back into electricity during periods of maximum consumption. This storage system will avoid the risks related to non-programmable renewable energy sources ensuring the availability of electricity.

In April 2019, the National Agency for New Technologies, Energy, and Sustainable Economic Development (**"ENEA"**) and the Società Gasdotti Italia (**"SGI"**), an Italian Company that offers the service of transportation of natural gas, signed a framework agreement to develop a "Power to Gas" pilot project, consisting in one or more electrolysers directly connected to an electricity grid or to a renewable energy system converting the overproduced electricity into hydrogen. The hydrogen can then be used for several purposes, e.g. as gaseous fuel in industry and transport sectors; as a chemical component to be added to CO_2 to obtain methane; or as reserve energy to be stored for underproduction periods.

Market prospects for hydrogen

Compared with other energy sources, the hydrogen market is still at an early stage in Italy. Nevertheless, it is at the heart of the Italian new green deal given its huge potential in terms of decarbonisation and exploitation of renewable energy. In recent years, the Italian government and private companies have invested in research and innovative projects to boost the development of new hydrogen-related technologies. Italy is one of the leading countries in Europe in terms of research in hydrogen sector, with 128 projects financed by the European Commission in the period 2008–2017, involving over 80 Italian beneficiaries and mobilising over EUR 90m funding.

It is expected that, in the medium-long term, the economic and environmental potential of hydrogen will be crucial in the following areas:

— Decarbonisation of hard-to-abate sectors, such as private and public transport, building heating and the production of fertilisers and petrochemicals;
— Integration of renewables by using electrolysers to convert surplus electricity in hydrogen. The development of this technology will be crucial to improve large-scale energy storage systems and to make the electricity grid more stable;
— Implementation of more efficient energy storage and distribution systems; and
— Promotion of sustainable mobility through incentives for vehicles fuelled by hydrogen.

Currently, ENI and SNAM are the main players involved in hydrogen projects. However, it is expected that in the next few years many other private and state-owned companies will operate in the hydrogen market. The growing interest in hydrogen sector, proved by the recent increasing public investments in hydrogen technology research, is also likely to attract strategic investments from private equity funds as well as from other public and private investors. Potentially, there is a wide range of private financing options that my apply to hydrogen projects, such as green bonds (i.e. minibonds linked to energy projects with a positive impact on the environment) and project financing.

Challenges facing hydrogen projects

Legal framework gaps

The Italian legal framework regulating hydrogen production, operation and connection is rather fragmented and often this has proven to be a barrier to the development of new projects. For instance, although the authorisation process related to hydrogen production and storage is set at a national level, the local public authorities may ask for different requirements with regard to the land use. Such divergence may lead to uncertainty in terms of project financing and timing.

Another relevant issue is the lack of a clear distinction, in terms of authorisation procedures, between:

— the production of hydrogen for industrial use obtained through reforming process and
— the production of green hydrogen obtained through electrolysis process.

The Italian environmental authorities do not differentiate between these two processes with the result of imposing the same level of restrictions even though the electrolysis is more similar to an electrical reaction rather than a chemical process like reforming. Therefore, a specific legislation for hydrogen production by electrolysis is highly desirable in order to simplify the authorisation procedure and encourage investments in this low-carbon sector.

Financial support and incentives

To date, most of the hydrogen projects in Italy have been financed by private and state-owned companies. Nevertheless, it is worth noting that there are other national and European financial support schemes which have been already implemented or are in the process of being defined.

At European level, the Next Generation EU programme is undoubtedly one of the most impressive financial supports in recent decades. The NRRP, which allowed Italy to benefit from the European funding, has allocated approximately EUR 23bn to promote and develop the green transition with the main goals of improving the sustainability and resilience of the economic system and ensuring a fair and inclusive environmental transition. With specific reference to hydrogen, the NRRP has allocated around EUR 3bn to pursue the following objectives:

— developing flagship projects for the use of hydrogen in hard-to-abate industrial sectors, starting with the steel industry;
— promoting the creation of "hydrogen valleys", especially on brownfield sites;
— allowing – through the building of new recharging stations – the use of hydrogen in heavy transport and in non-electrifiable railway sections;
— supporting research and promoting all necessary legislative reforms to facilitate the use, transport, and distribution of hydrogen.

Still also at the European level, in March 2020, the Clean Hydrogen Alliance (the **"Alliance"**) was set up as part of the new European industrial strategy. The Alliance's main task is the promotion and solicitation of investments in hydrogen projects. It is estimated that, at European level, the hydrogen sector will benefit from investments of EUR 430bn until 2030.

An interesting outlook on hydrogen market investments is also offered by the Hydrogen Roadmap, a report issued in January 2019 by the Fuel Cells and Hydrogen Joint Undertaking ("FCH JU"), a public-private partnership, of which the European Commission is a member, supporting research and technological development in fuel cells and hydrogen energy technologies. The roadmap makes an accurate analysis of the investments to be made until 2030, distinguishing them on the basis of the technologies to be developed (e.g. fuel cells vehicles, industry heat equipment and new production facilities along the value chain).

At a national level, it has been estimated that the investments required to achieve the new green deal objectives set out in the PNIEC should reach the quota of EUR 50bn up to 2030.These investments are expected to lead to a GDP growth of 0.5% each year and to contribute to the creation of more than 5m jobs in the green economy sector. With specific reference to hydrogen, the Hydrogen Strategy has forecasted that up to EUR 10bn will be required in order to foster the deployment of hydrogen and achieve the medium and long-term goals set at national level. This sum includes:

— investments required for hydrogen production: EUR 5–7bn;
— investments in hydrogen distribution and consumption facilities (hydrogen trains, refuelling stations, etc.): EUR 2–3bn;
— investments in research and development: EUR 1bn.

It is expected that up to half of these investments could be supported by ad hoc national and European resources and funds (e.g. the Next Generation EU program and the Mission Innovation project, among others).

Regulation of hydrogen

Specific legislation / regulation

On 23 October 2018, the Ministry of Interior Affairs jointly with the Ministry of Infrastructures and Transport issued a Ministerial Decree on "Technical rules of fire prevention for design, construction and operation of hydrogen distribution facilities for automotive vehicles" (the **"Decree"**). Compared to the previous ministerial decree of 2006 regulating the same matter, the Decree has overcome some of the regulatory barriers that affected the construction and operating of hydrogen plants during previous years. For the first time, the Decree has introduced the distinction between the reforming and electrolysis processes, as the past decree considered hydrogen as an industrial chemical produced only through fossil sources. Nonetheless, to date, the production of hydrogen in Italy is considered to be an industrial activity both when it takes place through steam reformation method or electrolysis. This means that restrictive measures in terms of land use, including zone prohibitions, apply irrespective of the production method adopted.

Within the Italian regulatory framework, the Decree is the only specific legislation relating to hydrogen production and operating. Thus, other general provisions, mostly referring to gas and other fossil fuels are applicable.

Policy and government programmes

In 2019, the Ministry of Economic Development approved a "three-year electrical research plan". The plan, applicable for the period 2019–2021, aims at fostering the research and the development of new technologies that could improve the national electricity system. The plan discusses new ways to covert renewable power into hydrogen and more efficient hydrogen storage systems.

Italy is a participant of the "Mission Innovation" project, a global initiative of 24 countries and the European Commission. The main goals of the project are doubling private and public investments in clean energy and fostering international collaboration to reinvigorate and accelerate global clean energy innovation. More specifically, among other initiatives, Italy joined the Renewable and Clean Hydrogen Innovation Challenge which is a multinational research program aiming to accelerate the development of hydrogen market by improving key technologies at production, storage and distribution level.

Generation related regulation

In Italy, the production of hydrogen, both through the reforming or electrolysis process, requires the obtainment of the Integrated Environmental Authorisation (**"AIA"**) by the Ministry of the Environment and Protection of Land and Sea. This authorisation is granted following an administrative procedure whereby the concerned authorities examine the project and evaluate its potential environmental risks. Moreover, according to the Ministerial Decree dated 23 October 2018, the components of a hydrogen production plant must comply with specific standards and the producer is bound to detailed maintenance duties.

Regulation of connections to the grid

With regard to the connection of electrolysers to the electricity national grid (Power to Gas facilities) , there are no specific laws or regulations regulating this. Therefore, the Italian Unified Text for Active Connections ("*Testo Integrato delle Connessioni Attive*" or **"TICA"**) issued in 2008 by the Italian Regulatory Authority for Electricity Gas and Water (**"AEEG"**, the former ARERA) contains the rules applicable to high, medium and low voltage connections to the power grid. A specific regulation applying only to Power to Gas facilities is needed given the specific and complex technology used for the process of conversion from electricity energy to hydrogen.

Regulation of hazardous activities

Pursuant to the Ministerial Decree of 23 October 2018, an applicant wishing to build a new hydrogen production plant must accurately indicate the place where the plant is expected to be built so that the local authorities can assess compatibility with the Land Use Plan. Afterwards, the local Fire Department provides an assessment with regard to safety and fire prevention. Depending on location of the proposed plant, other Regional authorities might have to be consulted, e.g. the Regional Environmental Protection Agency (*"Agenzia Regionale Protezione Ambiente"* or **"ARPA"**) and the regional technical committee (*"Comitato Tecnico Regionale"* or **"CTR"**). Moreover, the Decree makes a list of all potentially hazardous activities and provides for the relevant required safety measures that must be implemented.

Transport, import and export of hydrogen

Since there are no specific national rules relating to hydrogen transport, Italy has implemented the last European ADR regulation, which relates to regulation concerning the international carriage of dangerous goods by road. Hydrogen is included among the dangerous materials classified as a flammable gas.

The same can be said of the regulation of import-export activities. As no specific law has been implemented to regulate the hydrogen trade with other countries, it can be argued that the same regulatory framework applying to the trade of natural gas also applies to hydrogen. More specifically, according to the Legislative Decree No. 164, dated 23 May 2000, gas import activity is subject to a specific licence issued by the Ministry of Economic Development. To obtain such a licence, the applicant must:

— possess the technical and financial capacity appropriate for the import activities;
— provide adequate information and guarantees regarding the origin of the natural gas; and
— prove the safety of the system to be used for transport

Regulatory bodies

Regulatory Body	Role
Local Public Authorities and regulatory bodies (Regions, Municipalities, ARPA, Others) Local Fire Department	— Regulates the use of the land; — Assess the compatibility of the project with the Land Use Plan; — Assesses the safety of the plant and any relevant fire risks.
Ministry of the Environment and Protection of Land and Sea	— Grants the Integrated Environmental Authorisation
Ministry of Economic Development	— Regulates import/export activities
Ministry of Economic Development ARERA (the Italian Regulatory Authority for Energy Networks and Environment)	— Regulates new pipelines and decommissioning — Regulates the gas network, including fees

Upcoming developments

The guidelines set out in the PNIEC and in the PNNR will drive Italian energy policy over the next few decades.

The Ministry of Economic Development has announced that, in compliance with the PNIEC, the Italian Government will launch a program aimed at developing and fostering the hydrogen industry and its value chain, thus making the industry more appealing to operators and investors. The objective is to strengthen the position of Italy in the European hydrogen market and to make progress in the country's energy transition. In this, the NRRP has stressed the importance of a legislative reform regulating:

— technical standards on production, transport, storage and use of hydrogen;
— administrative simplification measures for the construction of small-scale green hydrogen production plants and
— measures to allow the building of hydrogen refuelling stations at motorway service areas, logistic warehouses, ports etc. by means of specific agreements between the Ministry for Ecological Transition and the Ministry of Infrastructures and Sustainable Mobility.

The Ministry of Economic Development is currently considering the comments made by market players and trade associations on the preliminary hydrogen strategy guidelines before proceeding with the publication of the final program.

Also, during 2021, the Ministry of Economic Development, jointly with the Ministry for Ecological Transition, met several times with market players to discuss the potentials for hydrogen and its implications on the decarbonisation process. Following these sessions, a new study was submitted in July 2021 to the abovementioned Ministries and is currently under review. This study analyses trends and costs related to the technologies to be implemented in "hard to abate" sectors.

Japan

Authors:
Miho Niunoya
Mihoko Shima
Kimiharu Masaki

Current status for hydrogen in Japan

Development of Hydrogen in Japan

Japan is one of the further advanced countries in relation to developing hydrogen projects and has the advantage of having a designated government policy supporting the uptake of hydrogen, coupled with a public acceptance of hydrogen projects in the domestic-energy mix.

Japan is now in the third wave of hydrogen. The first wave was in the early 1990s, the second wave was in early 2000s, and the third wave started around 2015. In pursuit of finding a way to be independent from the fossil fuel produced in the Middle East and recognising both Japan's limited domestic energy resources as well as a desire to decarbonise its energy mix, Japan made a deliberate choice to develop a hydrogen-based society in the 1990s.

Significantly, in 2002, the Japanese government enacted the *"Basic Act on Energy Policy"* and has been formulating and updating a *"Basic Energy Plan"* every three years since its first publication. Subsequently, in 2008, the *"Cool Earth – Energy Innovation Technology Plan"* was announced to promote technological innovation and deregulation in the promotion of fuel cell vehicles (**"FCV"**) and hydrogen refuelling stations. In 2000s, the Japanese government and industries focused on popularising FCV, with the view to stimulating a decrease in the price of FCV and improving the effectiveness of hydrogen refuelling stations.

In 2011, Japan was affected by the Great East Japan Earthquake and the nuclear accident at the Fukushima Daiichi Nuclear Power Station. These disasters accelerated the government's efforts to realise a hydrogen-based society. The government announced the *"4th Strategic Energy Plan"* which was substantially adjusted from the 3rd Strategic Energy Plan. In the same year, the government compiled the *"Strategic Roadmap for Hydrogen and Fuel Cells"* (the **"Roadmap"**) to implement the *"4th Strategic Energy Plan"*. The plans were further bolstered by the Paris Agreement in December 2015. As a result, 2015 is known as the *"First Year of Hydrogen"* in Japan.

Recent Efforts by Government

In 2017, the government formulated the *"Basic Hydrogen Strategy"* (the **"Strategy"**). Japan has set a long-term goal that, by 2050, CO_2 emissions will be reduced by 80% from 2013 levels; the Strategy sets out an action plan for the period up to 2030. In response to the *"5th Strategic Energy Plan"* formulated in 2018, the Roadmap was revised for the third time. Japan's current hydrogen programme is based mainly on the Strategy and the latest Roadmap.

In October 2018, Japan held the world's first *"Hydrogen Energy Ministerial Meeting"* (**"HEM"**) under the main theme of *"Realisation of a Hydrogen-Based Society"* and, as a result, the *"Tokyo Statement"* was released. In 2019, the second HEM was held, with approximately 600 participants from 35 countries, regions and organisations attending. The third HEM was held online on 14 October 2020 to share the efforts and progress of each country to realise the hydrogen-based society.

Japan has also entered into memorandums of agreement with New Zealand, Argentina, and the Netherlands, among others, regarding cooperation for the realisation of a hydrogen-based society. For example, in the memorandum which was entered into between Japan and New Zealand, both countries agreed to cooperate on the exchange of information and personnel, developing technology, and establishing an international supply chain, among other things.

In Q3 of 2020, Japan decided to take a significant step towards a decarbonised society. First, on 26 October, 2020, the government declared *"Carbon Neutrality by 2050"*. Following this, the government published the *"Green Growth Strategy Through Achieving Carbon Neutrality in 2050"* on 25 December 2020 (revised in June 2021), which states that Japan aims to introduce up to 3m tonnes of hydrogen before 2030 and up to 20m tonnes before 2050. The Act on Promotion of Global Warming Countermeasures was also revised on 26 May 2021 in response to the 2050 Carbon Neutral Declaration. On 21 July 2021, the draft of the 6th Strategic Energy Plan was published, which states that Japan aims to increase the percentage of renewable energy sources in its domestic energy mix from 22–24% to 36–38% for FY 2030, and includes hydrogen and ammonia as energy sources for the first time to account for one percent of all energy sources. The draft refers to the establishment of the international hydrogen supply chain, development of innovative hydrogen production technologies, reduction in the cost of hydrogen supply, and other specific measures.

Japan is now rapidly developing hydrogen power generators and establishing a hydrogen supply chain; it is a leader amongst industrialised nations on how to integrate hydrogen technologies into the energy, transport, and industrial sectors.

Supply Chain efforts

In Japan, where natural resources are scarce, hydrogen is attracting attention as a low-carbon alternative to fossil fuels. In order to promote the utilisation of hydrogen, it is essential to reduce the cost for procuring and supplying hydrogen.

As a measure to reduce the cost of hydrogen supply, two methods are considered promising: one approach is the combining of low-cost unused energy from overseas with Carbon Capture and Storage (**"CCS"**), and the other is procuring a large amount of hydrogen from low-cost renewable energy overseas. To achieve this, the goal in the Strategy is to build a comprehensive international supply chain in the manufacture, storage, transport and use of hydrogen. Specifically, Japan aims to procure approximately 300,000 tonnes of hydrogen per year at approximately 30 JPY/Nm^3 by around 2030, and in the future, to procure it at reduced cost of 20 JPY/Nm^3.

Further, the above *"Green Growth Strategy Through Achieving Carbon Neutrality in 2050"* considers hydrogen to be a key technology for achieving carbon neutrality. It summarises future initiatives for; (i) hydrogen utilisation, (ii) transportation and storage of hydrogen (liquefied hydrogen carriers, etc.), and (iii) hydrogen production (water electrolysers, etc.).

In Japan, various pilots are being carried out to develop an international hydrogen supply chain. For example:

— A project is underway to extract hydrogen from brown coal, of which there are large reserves in Australia, and liquefy it to transport it to Japan by sea. In December 2019, the world's first liquefied hydrogen carrier *"Suiso Frontier"* was launched and will be utilised in a demonstration experiment where hydrogen produced in Australia will be transported to Japan by the end of March 2022. In Kobe, where the hydrogen will be received, a 2500m^3 tank became operational in June 2020.
— Another project is underway in Brunei to extract hydrogen (as methylcyclohexane (**"MCH"**)), using the organic hydride method from unused gas, and transport it to Japan. In December 2019, hydrogen produced in Brunei arrived in Japan for the first time. As such, the domestic policy agenda is to combine the surplus fossil fuels from overseas and use these to produce *"blue"* hydrogen – by capturing the carbon dioxide using CCUS technologies – alongside the establishment of international supply chains for Japan's hydrogen.
— In Japan, transportation of hydrogen in the form of (i) liquid hydrogen, (ii) MCH, and (iii) ammonia is expected. The transported hydrogen in the form of MCH is now used as fuel for thermal power plants. Currently, hydrogen, as an import, is undergoing verification testing and results of this study are expected in due course.

In anticipation of a large amount of renewable energy coming onto the grid in the coming years, attention is being focused on power to gas (**"P2G"**) technology, which uses electrical power (produced from renewable sources) to produce a gaseous fuel (hydrogen) and then store it. Improvement of water electrolysis technology is necessary for the commercialisation of P2G technology.

In March 2020, the world's largest (10MW) renewable hydrogen production facility *"Fukushima Hydrogen Energy Research Field* (**"FH2R"**)" was opened in Namie Town, in the Fukushima Prefecture. FH2R has achieved positive results in demonstration experiments.

In addition to renewable energy, the utilisation of unused local resources, such as waste plastics and sewage sludge, is being considered as a low-carbon hydrogen supply source.

Transport sector developments

According to the Strategy, the goal is to have:

— 40,000 FCVs by 2020, 200,000 FCVs by 2025 and 800,000 FCVs by 2030;
— 100 fuel-cell buses by 2020 and 1,200 fuel-cell buses by 2030; and
— 500 fuel-cell forklifts by 2020 and 10,000 fuel-cell forklifts by 2030.

In addition, Japan is developing and commercialising fuel-cell trucks and shifting passenger vessels to fuel-cell powered vehicles. At the end of the 2019 financial year, 3,757 passenger FCVs were in use in Japan.

FCV Business policy of each Japanese car manufacturer:

— In terms of passenger cars, Toyota Motor Corporation (**"Toyota"**) started lease sales of FCVs to Japanese government departments for business and industrial use, in December 2002. After years of further technical developments, Toyota began retail sales in December 2014 and released a brand-new model FCV in December 2020.
— In February 2021, Toyota announced its development of an FC module that packages a fuel-cell (FC) system into a compact module, and distribution of the FC modules starting from the spring of 2021. These modules are expected to be applied in FC products for various uses such as in mobility, including in trucks, buses, trains, and vessels, as well as in stationary generators.
— Toyota is also carrying out research and development of a hydrogen vehicle (not an FCV, which is one model of EV, but a vehicle equipped with an internal combustion engine (**"ICE"**) fuelled by hydrogen in place of gasoline) and participated in a 24 hour endurance race with its hydrogen vehicle in May 2021.
— By contrast, in June 2018, the corporate affiliation between Nissan Motor and Renault of France froze the commercialisation of FCVs that was being jointly developed with Daimler and Ford Motor. In December 2020, Honda started lease-only sales of its FCV on the same date as Toyota but declared in June 2021 that it would discontinue the production of FCVs at the end of 2021 due to poor sales. Honda will continue its joint development of FCVs with General Motors (GM) of the United States, but it will mainly focus on commercial cars, indicating that Honda will withdraw from the development of passenger FCVs.

Fuel-cell commercial cars

— Due to poor sales of passenger FCVs, there is unlikely to be any new car manufacturers aiming to enter the Japanese FCV market with passenger cars. Popularisation of FCVs is likely to be limited to commercial vehicles such as buses and trucks running between fixed terminals.
— As for fixed-route buses, Toyota first put a fuel cell hybrid vehicle (**"FCHV"**) into practical use in the 2000s. Fuel-cell buses were developed in the 2010s and mass-marketed for sale in March 2018. The metropolitan government of Tokyo, which engages in bus business in the city, has introduced 84 fuel-cell buses as of December 2020. There remains various hurdles to overcome, such as: high vehicle pricing (five times that of a conventional type of bus), improvement in performance, durability and reliability, cost reduction technology and establishment of mass production technology, reduction of operational costs, and deployment of stable filling facilities.

— In January 2020, Honda and Isuzu Motors Ltd. agreed to conduct joint research on fuel cell trucks. In March 2020, Toyota and Hino Motors, Ltd. agreed to jointly develop a heavy-duty fuel cell truck, and to proceed with initiatives towards its practical use through verification tests and other means. Mitsubishi Fuso Truck and Bus Corporation announced its vision to make all new vehicles for the Japanese market CO_2 neutral by the year 2039. In line with this vision, it aims to start the series production of fuel-cell trucks by the late 2020s.
— Toyota also announced, in June 2018, that together with Seven-Eleven Japan Co. Ltd., they will be conducting a joint project to reduce CO_2 emissions by introducing a newly developed small fuel cell truck in the distribution process, aiming to achieve zero emissions of substances of concern including CO_2.

Fuel-cell trains
JR East, the East Japan Railway Company, signed an agreement with Toyota in September 2018 for a comprehensive business partnership, focusing on the use of hydrogen, and has been cooperating with Toyota to introduce fuel cell technology to railway vehicles. JR East is aiming to complete a hybrid vehicle test car, that uses hydrogen as fuel, and is preparing to start a demonstration test on an operating route in 2021.

Fuel-cell vessels
As decarbonisation gains momentum, the efforts in the shipping industry to reduce greenhouse gases are also progressing. The draft Strategic Energy Plan states that Japan will promote technological development of zero emission vessels using alternative fuels such as hydrogen and ammonia, and aims to start demonstration experiments by 2025, achieve commercial operation of zero emission vessels earlier than its initial target of 2028, and bring about further popularisation of zero emission vessels in 2030.

Fuel-cell aircraft
In addition to electrification technology, hydrogen fuel looks set to be leveraged in the field of aviation in order to reduce carbon emissions.

Hydrogen power generation

The Strategy aims to commercialise hydrogen power generation by 2030. At present, the necessary conditions for introducing hydrogen co-combustion power generation into existing thermal power plants is being clarified. As for the hydrogen co-generation system, the aim is to achieve power generation efficiency of 27% by 2020–2021. As stated above, the draft 6th Strategic Energy Plan sets the percentage of hydrogen and ammonia in the energy mix at 1% for FY 2030.

However, to fully introduce hydrogen power generation, it will be necessary to reduce the cost of hydrogen procurement by developing a hydrogen supply chain. The government aims to decrease the cost of hydrogen for power generation to 30JPY/N^3 by the time hydrogen power generation has been commercialised in 2030, and 20 JPY/N^3 in 2050.

Use of fuel cells

Household fuel cells (solid oxide fuel cells (**"SOFC"**), known locally as **"ENE-FARM"**), were introduced to the market in 2009 before anywhere else in the world. ENE-FARM produces power and heat for use in the home, from hydrogen derived from city gas or liquefied petroleum gas (**"LPG"**) and oxygen derived from the air. At the end of January 2019, approximately 274,000 units were in use; the aim is to further reduce costs and 5.3m units will be introduced by 2030.

As for industrial fuel cells, phosphoric acid fuel cells (**"PAFC"**) and SOFCs have respectively been on the market since 1998 and 2013, with 20 kW-class SOFCs expected to be put on the market soon. Currently, efforts are being made to increase power generation efficiency, and to reduce system prices and power generation costs by 2025.

Use at the Tokyo Olympic and Paralympic Games

At the 2020 Tokyo Olympic and Paralympic Games (**"Tokyo 2020 Games"**) held in the summer of 2021, for the first time in Olympic and Paralympic history, hydrogen was used as fuel for the torch and part of the torch relay. The hydrogen produced in the FH2R, mentioned above, was also used as fuel for the torch. Toyota provided approximately 500 FCVs for use in the Tokyo 2020 Games. As a worldwide partner of the Olympic and Paralympic Games, Toyota supported the Tokyo 2020 Games with its full suite of electric vehicles, including FCVs and fuel-cell buses. The operation of the Games was also supported by fuel-cell forklifts manufactured by Toyota Industries.

Market prospects for hydrogen

General market prospects

As described above, FCVs and fuel-cell trucks are already in use in the transportation sector. As of August 2021, there are 154 hydrogen refuelling stations in Japan. In addition, the household fuel cell ENE-FARM, is widely used due to a subsidy system from the government. However, in other fields, the hydrogen use in Japan has not yet reached commercial production or is still in the pilot stage.

Given that the current supply chain and power generation projects are mostly the pilots being led and subsided by the Japanese government, there has been limited private sector involvement so far. The scale of business of hydrogen mobility options is still small and would need to grow in order to attract more private sector investment. In the field of ENE-FARM, major electronic manufacturers and gas companies are involved, but thus far there has been limited M&A activity. Major companies procure finance through ordinary corporate finance and other products and services concerning hydrogen are still at the pre-commercial-stage. This is expected to change as the projects reach further stages of maturity.

Non-Fossil Fuel Energy Value Trading Market

In May 2018, the Non-Fossil Fuel Energy Value Trading Market was established at the Japan Electric Power Exchange (**"JEPX"**). This is a green certificates market where non-fossil fuel energy power producers sell *"non-fossil fuel energy certificates"*, which evidence to energy retailers in the market that electric power was generated without using fossil fuel sources. The certificates can be traded separately from actual electricity.

In 2021, the system was changed, the market was split into two, namely (i) a market for trading certificates to satisfy the obligations of the Act on Sophisticated Methods of Energy Supply Structures, and (ii) the Renewable Energy Value Trading Market. Market (i) trades only non-FIT, non-fossil fuel energy certificates (certificates of non-fossil fuel energy generated from sources other than FIT energy sources), which are sold to energy retailers. On the other hand, market (ii) only trades FIT non-fossil fuel energy certificates (certificates of non-fossil fuel energy generated from FIT energy sources), which may be sold not only to energy retailers, but also to consumers. Trading for market (i) started in the end of August 2021 and trading for market (ii) is scheduled to start from November 2021. It is expected that hydrogen energy sources will be traded in market (i) in the future.

Challenges facing hydrogen projects

Supply chain issues

At present, the cost of hydrogen at stations in Japan is approximately 100 JPY/Nm^3, which is relatively high. In order to improve this, it will be necessary to:

— further study the development of an international supply chain to diversify procurement,
— develop water electrolysis technology with higher efficiency and durability along with other technologies; and
— expand domestic hydrogen demand.

Transport-related challenges

FCV vehicle prices

— The number of components in FCVs is larger than in electric vehicles (**"EV"**), and the cost of individual devices and components is also high. In addition, production capacity is limited because it requires manual manufacturing by skilled workers. As of December 2015, only a few cars could be produced per day, unlike the significantly greater volumes that can be manufactured as ICE vehicles or EVs.
— In the latest revision of the *"Strategic Roadmap for Hydrogen and Fuel Cells"* (the **"2018 Roadmap"**), the current price of a passenger car type FCV is priced in the seven million yen (JPY 7m) range, which is three million yen (JPY 3m) more expensive than a hybrid vehicle (**"HV"**). The price of a fixed-route bus is one hundred and fifty million yen (JPY 150m).

To achieve the target use, the 2018 Roadmap aims to reduce the price difference between passenger car-type FCVs and HVs to seven hundred thousand yen (JPY 700,000) and to lower the price of fuel-cell buses to fifty two million, five hundred thousand yen (JPY 52.5m) by 2025, by reducing the FCV system cost.

Running cost of FCVs
For HVs and plug-in hybrid cars (**"PHV"**), consumers can benefit from the low cost of energy compared to ICE vehicles. FCVs have almost the same cruising range as petrol cars, but the cost of hydrogen fuel is more expensive than petrol, so its value is not directly visible to consumers. Therefore, the popularisation of FCVs is closely related to the reduction of hydrogen production cost.

Hydrogen stations
The lack of refuelling infrastructure will prevent the popularisation of FCVs. This, in turn, deters vehicle manufacturers from introducing new passenger FCVs. The draft Strategic Energy Plan, in view of the popularisation of fuel-cell cars, buses, and trucks, seeks to create 1,000 hydrogen stations by 2030 at optimal locations, taking into consideration the flow of people and logistics, tackle regulatory reform, and create hydrogen stations for commercial vehicles such as buses and trucks, including refuelling facilities dedicated for certain business places.

Hydrogen aircraft
In September 2020, Airbus announced its goal to introduce hydrogen aircraft by 2035. Japanese airlines are also expected to promote development of core technologies such as liquefied hydrogen storage tanks and engine combustors for hydrogen aircraft that will be necessary for introducing hydrogen aircraft after 2035. In August 2021, the government also started discussions with private companies towards the improvement of airport facilities for storing hydrogen and refuelling aircraft with hydrogen.

Low carbon hydrogen standards

Japan aims to use *"green"* hydrogen in power generation and other industrial uses of hydrogen in the future. At present, the government is examining the replacement of existing fuels and raw materials with green hydrogen and the associated costs for various industrial processes.

The combination with CCS is necessary in order to produce *"blue"* hydrogen from coal or natural gas, and a large-scale demonstration experiment of CCS has been conducted in Tomakomai, Hokkaido since 2012. This verified that the technology can be put into practice by 2020. The government aims to commercialize the technology by 2030.

In addition, to promote the uptake of green hydrogen, the construction of a scheme to enable trading of the environmental value of hydrogen is being considered. For example, the utilisation of the existing *"J-credit Scheme"* (the system used for certifying the reduction and absorption of greenhouse gas emissions) and the *"Act on the Rational Use of Energy"* are under consideration. Utilisation of the *"Non-fossil Fuel Energy Value Trading Market"*, described above, is also expected as a promising option.

Regulation of hydrogen

Current status of hydrogen regulations

There are no laws specific to the use of hydrogen yet. Currently, hydrogen is regulated as a type of high-pressure gas. With respect to hydrogen gas, the High Pressure Gas Safety Act, which regulates the safety of high pressure gas, plays a central role. For example, in order to manufacture and/or store hydrogen, permission from or notification to the prefectural governor is required, with specific requirements being based on the amount of production and/or storage.

In addition, hydrogen must be transported in a manner that meets the technical standards stipulated in the High Pressure Gas Safety Act. However, various regulations such as construction-related regulations and environmental regulations are also applicable. Major regulations are discussed below.

Manufacturing and storage regulations

The installation of hydrogen production and storage facilities is subject to various strict safety regulations due to the flammable nature of hydrogen.

— The High Pressure Gas Safety Act requires permission from, or notification to, prefectural governors depending on the processing capacity of hydrogen production facilities and storage facilities.
— The Ministerial Ordinance on the Arrangement of Facility Districts for New Business Facilities etc. in Special Disaster Prevention Areas of Petroleum Industrial Complexes, etc. stipulates that, when hydrogen production facilities, for example, are to be established, they must be divided into production facility districts, storage facility districts, incoming and outgoing facility districts. It is also stipulated that a road of a specified width must be interposed, in accordance with the area of production facility districts and storage facility districts.
— The Regulation on Safety of General High Pressure Gas provides technical regulations to ensure that hydrogen is not retained in the rooms where hydrogen production facilities, storage containers and consumption facilities are installed, in case of hydrogen leakage.
— The Regulation on Safety of General High Pressure Gas sets detailed regulations on the temperature and the location of storage containers in relation to their storage.

Environmental and health regulations

Since reformers for hydrogen production and fuel cells are regarded as gas generators, notification to local governments and the periodic measurement of soot, smoke and NOx are required under the Regulation for Enforcement of the Air Pollution Control Act.

Under the Noise Regulation Act and the Vibration Regulation Act, if a facility installed at a factory or workplace is classified as a specified facility that generates significant noise and vibration, an application must be submitted to the relevant local government. In addition, since the regulation criteria differs for each municipality, it is necessary to confirm the local criteria.

Regulations concerning transportation of hydrogen

Transportation of hydrogen gas by truck, tank lorry, etc., is subject to the High Pressure Gas Safety Act, the Road Vehicle Act and other regulations which stipulate technical standards, such as vehicle loading methods, transportation methods and safety measures for containers.

The Road Act prohibits or restricts the passage of vehicles loaded with dangerous substances having explosive or flammable qualities in underwater tunnels.

Regulations concerning hydrogen stations

Hydrogen refuelling stations play an important role in the use and popularisation of hydrogen vehicles. Regulations on the installation of hydrogen stations are outlined below:

— The technical standards for hydrogen refuelling stations are, essentially, in line with those applicable to high pressure gas production facilities under the High Pressure Gas Safety Act. However, more stringent technical standards are included to protect consumers.
— The Building Standards Act limits the areas where hydrogen refuelling stations can be installed.
— Rules on dangerous goods regulate the location and structure of equipment installed in hydrogen refuelling stations, such as compressors, accumulators and dispensers.
— When a hydrogen refuelling station is installed at a gas station, it is necessary to comply with the safety measures prescribed in the Fire Services Act and the High Pressure Gas Safety Act.

The government is tackling deregulation for hydrogen stations for the popularisation of hydrogen cars, and by August 2020, it had revised related ministerial orders to allow unmanned operation of hydrogen stations through remote monitoring, and is proceeding with deregulation to promote the improvement of hydrogen stations.

Regulatory bodies

Regulatory Body	Role
Industrial and Product Safety Policy Group, Commerce and Information Policy Bureau, Ministry of Economy, Trade and Industry	— Administers the High Pressure Gas Safety Act
Water and Air Environment Bureau, Ministry of Environment	— Administers the Air Pollution Control Act, Noise Regulation Act, and the Vibration Regulation Act
Ministry of Land, Infrastructure and Transport and Tourism	— Administers the Road Vehicle Act, the Road Act and the Building Standards Act
Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications	— Administers the Fire Services Act
Each prefecture	— Handles permission and notification under the High Pressure Gas Safety Act

Upcoming developments

Planned supply chain studies

The feasibility studies of supply chains from Russia, South America and the Middle East is underway, in addition to Australia and Brunei where demonstration experiments are ongoing.

Construction of hydrogen society model areas

"Fukushima New Energy Society Initiative": the Fukushima Prefecture suffered great damage from the Great East Japan Earthquake in 2011, as well as from the subsequent tsunami and nuclear power plant accident. In the Fukushima Prefecture, a project named *"Fukushima New Energy Society Initiative"* is underway to create a model for a new energy society. One of the aims of this plan is the utilisation of hydrogen derived from renewable energy. The hydrogen produced in the Fukushima Hydrogen Energy Research Field is utilised in various hydrogen mobility and factories, in order to build an integrated supply chain in the Fukushima Prefecture and build a model area for a hydrogen-based society. The hydrogen produced here was used for the Tokyo 2020 Olympic and Paralympic Games, in 2021.

"Smart City Kobe Initiative": Kobe City aims to build a large-scale hydrogen energy supply chain that uses overseas unused energy to produce, store, and transport (by sea) liquefied hydrogen, to be discharged at Kobe Port for transportation and use. The Demonstration Project for Establishment of Mass Hydrogen Marine Transportation Supply Chain Derived from Unused Brown Coal, described above, is part of this initiative. Electricity and heat generated from a hydrogen power generation system, that uses a gas turbine fueled by hydrogen, will be supplied to neighbouring public facilities.

Initiatives in the Aichi Prefecture: Since 2019, 10 private companies, including energy, petrochemical and automobile companies, have been studying the possibility of large-scale hydrogen utilisation in the Chubu region, and established the *"Chubu Region Hydrogen Utilization Council"* in March 2020 in cooperation with the Aichi Prefecture.

Developments in transportation

The Japanese government positioned FCVs as key to popularising hydrogen in Japan. However, in the automobile industry the uptake of FCVs has not progressed as expected.

Nevertheless, as global automotive demand switches from ICE to fuel-cell vehicles, hydrogen power vehicles may have a great role. This will be particularly true where there are requirements that are difficult to satisfy through the use of existing lithium ion secondary batteries, for example forklifts used in warehouses where exhaust fumes cannot be emitted, and drones.

The Railway Technical Research Institute is also considering resuming the development of fuel-cell trains that began in the 2000s but which did not attract enough attention at that time in Japan.

Mexico

Authors:
Derek Woodhouse
Luis Fernández
Sofía Taracena
Gabriel Salinas

Current status for hydrogen in Mexico

Introduction

Hydrogen penetration in Mexico in both projects and regulation is scarce. As is the case for most energy transition matters, Mexico has had a scientific approach rather than a practical one. In 1999, Mexican professionals and academics founded the *Sociedad Mexicana del Hidrógeno* (**"SMH"**), which organises an annual Technical Congress on hydrogen. The limited experience with hydrogen produced through electrolysis in Mexico has been conducted by members of SMH, who are the principal players in this field.

In 2016, the SMH published the National Hydrogen Plan, which is neither an official nor a binding plan, but it intends to identify key technologies, products, and markets for the development of hydrogen. Also in 2016, the Mexican Ministry of Energy (*Secretaría de Energía*) together with the Mexican Council for Science and Technology (or *Consejo Nacional de Ciencia y Tecnología*) granted funds to develop a prototype for a zero-emission electric vehicle powered by hydrogen fuel cells. This project was successfully developed by the National Institute of Electricity and Clean Energy (or *Instituto Nacional de Electricidad y Energías Limpias* **"INEEL"**) along with other research entities, however, there has been no further development.

On the market side, in 2017, PEMEX established an alliance with Linde, a global industrial gas and engineering group. The purpose of the alliance was to obtain a long-term supply of hydrogen for the Francisco I. Madero refinery in Ciudad Madero, Tamaulipas State, but in terms of the Annual Report according to Section 13 Or 15 (D) of the Securities Exchange Act of 1934 for 2018, such alliance was terminated.

Moreover, in 2017, Air Liquide México, S. de R.L. de C.V. (**"Air Liquide"**), a company dedicated to the production and distribution of gases such as nitrogen, hydrogen, and oxygen, announced its acquisition of the hydrogen production business unit of Pemex Transformación Industrial, S.A. de C.V., for USD 59m (around EUR 50m). Under the terms of the agreement, Air Liquide was to supply hydrogen to PEMEX's Miguel Hidalgo refinery, based in Tula de Allende, Hidalgo State, for 20 years.

The intention is for Air Liquide to operate the existing hydrogen plant at the Miguel Hidalgo refinery. In February 2018, PEMEX executed the plant's performance and stabilization tests, which was an important milestone under the agreement with Air Liquide. Up to date of publication, the agreement with Air Liquide is still in force; however, the repurchase of the plant by PEMEX is being sought to economise production costs.

In addition, in April 2018, PEMEX entered into a long-term agreement with Linde AG for the supply of hydrogen to their Madero refinery. In July 2018, PEMEX signed several agreements related to the supply of hydrogen to its Cadereyta refinery. However, some of the conditions required by these agreements were not met, and these were subsequently terminated. In 2018, PEMEX continued to experience shortages in the supply of hydrogen to their refineries, which has contributed to their operational difficulties. PEMEX intends to address the operational difficulties in their refineries through its plan for the rehabilitation of the National Refining System.

To foster hydrogen development, the *Asociación Mexicana de Hidrógeno* (**"AMH"**) was formally launched in 2021, bringing together more than 30 energy companies. AMH aims to work with authorities to develop a national hydrogen plan.

Hydrogen was singled out for the first time in the Mexican Ministry of Energy national development plan earlier this year as a potential future replacement for fossil fuels, although there are no concrete plans yet for research, technology transfer, financing, or development of projects.

Market prospects for hydrogen

In Mexico, activity among hydrogen projects is limited due to the absence of current projects or even research/awareness on the potential demand and uses of hydrogen. However, this could be a significant area of growth for Mexico due to the growing global interest in hydrogen, the possibility to replace other fuels with hydrogen, especially for purposes of industry, and the potential of renewable resources in Mexico.

In the power industry, hydrogen could be used to reduce intermittency or renewables power production, either alone or combined with other storage systems. Even long-distance transporting of renewable energy becomes a possibility, a possibility which should be interesting to México, due to its renewable potential or even a way to use carbon exceeds not used for carbon power plants.

There are no specific (private or public) financing options for hydrogen projects in Mexico. Clean energy certificates (**"CELs"**) are a public mechanism that could provide financial benefits to hydrogen projects, if the hydrogen produced is used for energy generation and meets the guidelines set by the Electricity Industry Law (or Ley de la Industria Eléctrica **"LIE"**) so that it can be catalogued as "clean" energy. CELs are discussed in further detail below; but in the meantime, that there is no clear indication towards the market at this time since the regulation was recently amended on this subject, favouring the State Productive Enterprise, Comisión Federal de Electricidad. Aside from this, there is little incentive to encourage the financing of hydrogen projects.

Challenges facing hydrogen projects

Legal Framework gaps

No specific legislation or regulation is tackling the hydrogen industry in the Mexican legal framework. The above does not entail that hydrogen projects may not be developed, as they may live under the power, natural gas, water, and other regulations, but legal uncertainties would arise and deter investment.

Hydrogen is mainly addressed as part of the power sector as the LIE and the Energy Transition Law, catalogues its power output as – potential – "clean" energy for purposes of crediting clean energy certificates. Under this legislation, "clean" energy is classified as that generated by the use of hydrogen through its combustion or its use in fuel cells, provided that certain efficiency parameters are complied with and subject to calculation rules. Even as for those cases, regulation seems to be incomplete and perfectible.

For instance, according to the General Administrative Provisions (as explained hereunder) containing the efficiency criteria and establishing the calculation methodology to determine the percentage of fuel-free energy in energy sources and electric power generation processes, as long as there is an efficiency factor of 70%, grey hydrogen may be considered 100% clean. Meanwhile, electrolysis is only considered to be made with grid electricity and is entitled to be considered clean in a percentage equivalent to that of the grid itself. Electrolysers directly connected to a power plant are omitted either for benefits or to specify the lack thereof.

No incentives for non-electrified hydrogen have been provided for in Mexican legislation, although Mexico does have a carbon tax.

Other than this, there is a lack of regulatory provisions in this sector. This constitutes a challenge for the development of hydrogen projects in Mexico as there is no consistent and complete framework covering the hydrogen value chain.

Financial Insecurity

On 15 June 2021, Standard and Poor's (**"S&P"**) Global Ratings, rated Mexico's sovereign bond rating at BBB, with a negative outlook, in anticipation of the economic impact that coronavirus would have on the country. This drop in the index denotes the lack of security for investors in the sector, caused by temporary shocks, lower confidence in the private sector, and low investment dynamism. The main objective of the index is to measure how much the government, through its various policies and regulatory changes, influences the investments captured in the energy sector. This low rating is likely to have a negative impact on investors' decisions to finance hydrogen-related projects in Mexico.

Regulation of hydrogen

General Aspects

As in other jurisdictions, the legal and regulatory framework for hydrogen is not yet comprehensive. As described in more detail below, there is no consistent and complete framework covering the hydrogen value chain in Mexico.

Policy and government programmes

On 7 July 2020, the Energy Sectoral Program 2020–2024 (Ministry of Energy, 2020) derived from the National Development Plan 2019–2024, was published. This program acts as a principle to guide the "rescue and promotion" of the energy sector, which states the following:

"To make sustainable use of all the nation's energy resources, increase available reserves, and enhance the energy security of current and future generations of Mexicans. The energy policy must be directly linked to the policy on the nation's water and subsoil resources. Likewise, to explore the use of other energy sources such as hydrogen."

In Mexico, the institutional framework for the promotion and application of alternative energy is very limited, since there is a preference to develop technologies for the use of traditional (i.e., fossil fuel-based) energy sources; there is a lack of knowledge on the part of the authorities about the magnitude and possible use of hydrogen as an alternative energy source.

Primary legislation

There is no express regulation of hydrogen within the Mexican Constitution (the **"Constitution"**). Notwithstanding this, Article 27 of the Constitution establishes that the State has direct control over natural resources obtained from Mexican territories (this includes all continental platforms and underwater baseboards of the islands; all minerals or substances found in veins, mantles, masses, or deposits; all solid mineral fuels; oil; and all solid, liquid or gaseous hydrogen carbides).

Despite the State's direct control of these assets, such resources may be used or exploited by private companies through permits or concessions granted by the Energy Regulatory Commission or National Hydrocarbon Commission, on behalf of the government. Different permits must be requested to carry out various activities relating to the production and use of hydrogen, all of which are regulated by the Hydrocarbons Law (or *Ley de Hidrocarburos*); permits are required for natural gas processing, export, import, transportation, storage, distribution, compression, decompression, liquefaction, regasification, commercialisation, and sale. The necessity of having to apply for a permit may impact a company's decision if it intends to obtain hydrogen from natural gas.

Generation related regulation

Energy generation (whether using hydrogen or any other energy source) is regulated under the LIE.

The LIE states that hydrogen may be used to generate "clean" energy through combustion or fuel cells, provided that its use complies with the minimum efficiency criteria. The criteria are set out in the Energy Transition Law; this provides that, for hydrogen exploitation to be considered "clean", minimum efficiency shall not be less than 70 % of the calorific value of the fuels used in the production of such hydrogen. This provision is further developed by the Energy Regulatory Commission (**"CRE"**) in terms of the resolution, which issues the General Administrative Provisions containing the efficiency criteria and establishing the calculation methodology to determine the percentage of fuel-free energy in energy sources and electric power generation processes.

Regulation of hazardous activities

The key Official Mexican Standards (or *Norma Oficial Mexicana* **"NOM"**) that regulate hydrogen are:

— NOM-018-STPS-2015, Harmonized System for the Identification and Communication of Hazards and Risks from Hazardous Chemicals in the Workplace. This NOM establishes a new mandatory scheme that aims to harmonise the communication of chemical substances and mixtures in the workplace. It includes specifications for the labelling of hazardous chemicals and training requirements for employees.
— NOM-017-CRE-2019, Methods for Measuring Variables to Calculate the Percentage of Clean Energy and Compliance Assessment Procedure. This NOM applies specifically to power plants using hydrogen and establishes minimum measurement requirements and methodologies that must be used to obtain the values of variables for determining fuel-free energy, so that such energy may be deemed as "clean", and for the related compliance assessment. Compliance with the NOM is necessary for CELs to be awarded.

Besides the above, there are no NOMs that establish rules and specifications on hydrogen management.

Transportation sector laws

There are no express provisions within the Mexican legal framework that regulate the transportation of hydrogen. Therefore, relevant guidelines will differ depending on the method in which hydrogen is transported (e.g., via pipeline, in cryogenic liquid tanker trucks, or gaseous tube trailers). Provisions contained in the Regulations for Land Transport of Hazardous Materials and Hazardous Wastes must be considered.

Additionally, if hydrogen will be produced using natural gas, it may be necessary to obtain a permit for the transportation of natural gas (using pipelines or other resources) and, if applicable, for the storage of natural gas. These permits must be requested from the CRE, as is further detailed, below.

Permitting for hydrogen projects

There are no specific permits that must be obtained for the use or production of hydrogen. However, depending on the end-use of the hydrogen, it may be necessary to obtain some of the following permits (it should be noted that this is not an exhaustive list):

Generation permit: this permit must be requested before the CRE and will be granted if the applicants fulfil the requirements set forth by the applicable law. This permit allows the applicant to generate electricity and favours participation in the wholesale electricity market. Together with a market participant agreement executed by the National Centre for Energy Control (or *Centro Nacional de Control de Energía* **"CENACE"**), the generation permit will allow a generator to obtain CELs and, as a result, the financial benefits that arise from such instruments, as further detailed below.

Natural gas-related permits: if hydrogen is obtained from natural gas, there are gas-related permits that must be obtained. The necessary permit will depend on the activity that will be performed (natural gas processing, export, import, transportation, storage, distribution, compression, decompression, liquefaction, regasification, commercialisation, or sale). These permits are also granted by the CRE and requirements are set by the Hydrocarbons Law. The guidelines for the activities are referred to in the third section of the Hydrocarbon Law (*Reglamento a que se refiere el Título Tercero de la Ley de Hidrocarburos*). Accordingly, permits will be granted as long as these specific technical and financial requirements are fulfilled (such requirements will depend on the specific permit being obtained).

Financing of hydrogen projects

If the energy produced by a hydrogen source meets the legal and technical standards to be considered "clean", in accordance with the LIE, it will be awarded CELs. CELs have monetary value and can be sold in the wholesale electricity market or through bilateral agreements. All energy consumers, whether domestic or industrial and suppliers, both renewable and "conventional", are obliged to pay for a set amount of CELs each year (the amount will be based on a percentage of their energy consumption – for 2020, this is 7.4 % and will increase to 13.39% in 2022). CELs can be understood as financial instruments through which the use of clean energies is promoted. Such instruments are regulated by the LIE and the Wholesale Electricity Market Rules, and the authority in charge of its regulation is the CRE. Renewable energy power plants which generate 100% "clean" energy, will be awarded 1CEL/MWh; and combined cycle generators or plants that use co-generation will be awarded 1CEL for each 5MWh generated.

There are no financial incentives or schemes promoted by the Government at this moment aside from CELs.

Regulatory bodies

There is no specific regulatory body which is responsible for the regulation of hydrogen projects in Mexico. As far as hydrogen falls under the existing regulation of the gas and electricity markets, the competent authorities are:

— The Ministry of Energy;
— The Energy Regulatory Commission;
— The National Hydrocarbons Commission;
— National Commission for the Efficient Energy Use;
— The Ministry of Communications and Transport;
— The Ministry of the Environment and Natural Resources; and
— The Ministry of Finance and Public Credit.

Upcoming developments

There have been attempts to increase hydrogen regulation in Mexico in recent years, however, such attempts have not been successful. At the time of writing, there are no hydrogen initiatives planned to be discussed by the Mexican legislative branch, nor any relevant initiatives to be considered.

Even though there are no current legal or project developments, private parties are focusing their efforts on the research into hydrogen and hydrogen-focused education. For example, entities such as the SMH and National Hydrogen Net *(Red Nacional de Hidrógeno),* have joined efforts with CONACYT, as well as several universities from across the country. The aims of these alliances include being able to:

— plan and direct the development, promotion and diffusion of scientific publications on hydrogen and/or fuel cell technologies;
— implement schemes to incorporate students, teaching staff and researchers within their institutions to help develop hydrogen-derived energies and/or fuel cells;
— direct programs and projects aimed at hydrogen technologies for the formation, training, transfer and licensing of technology and technological services for the country.

The Netherlands

Authors:
Martika Jonk
Marcellina Rietvelt
Mark Schapink

Current status for hydrogen in the Netherlands

Introduction

The Netherlands is on the forefront of the development of international hydrogen infrastructure, with the city of Rotterdam being Europe's largest container seaport, the proximity of the Netherlands to the North Sea offshore wind farms, an international natural gas pipeline network, and depleted natural gas fields and national salt caverns that can be used for hydrogen storage.

The Dutch government has set out its national strategy on hydrogen and corresponding policy agenda in its letter dated March 2020.[1] The importance of hydrogen for achieving a decarbonised energy system is clearly set out. The National Climate Agreement, entered into between the government, industry and other stakeholders in 2019,[2] also sets out ambitious targets for hydrogen, with key concepts being upscaling, cost reduction and innovation.

The Dutch energy system is changing, and the role of natural gas is decreasing as a result of the energy transition. Electricity currently provides for 20% of energy consumption, but is estimated that it will cover approximately 50% by 2050, with gaseous energy carriers providing at least 30% of final energy consumption. In order to achieve this, scaling-up the production of both green gas and hydrogen is essential. The Dutch government also sees hydrogen as an opportunity for the Dutch economy; firstly, because it may influence companies in deciding to invest in the Netherlands, and secondly, because hydrogen may lead to exciting opportunities for Dutch companies and Dutch knowledge institutions.

[1] Kabinetsvisie Waterstof 30.03.2020 MEZ DGKE/ 20087869
[2] Klimaatakkoord 28 June 2019

The Netherlands has some unique selling points with regards to hydrogen: it has empty gas fields in the North Sea that can be used for CO_2 storage, substantial offshore wind installations that can – in the long term – produce green hydrogen, and also an extensive natural gas infrastructure, which can, with little adjustment, be used for the transportation of hydrogen. Additionally, on the retail side, large industrial players are located in the Netherlands, such as Shell's refinery, Yara and Tata Steel.

A large number of projects, pilot-projects and initiatives are in the process of being constructed and developed. A few examples are listed below:

— the Yara-Dow H2 pipeline, which became operational in 2018 and is the first hydrogen pipeline in the Netherlands. This is a retrofit of a former natural gas pipeline, linking the hydrogen industry;
— the Hystock plant, a 1MW plant which converts solar energy into hydrogen via electrolysis. This became operational in 2019 in Zuidwending and serves as a showcase of the entire chain;
— in the north of the country, Groningen has been recognised by Brussels as the "Hydrogen Valley", i.e. a geographical area hosting an entire hydrogen value chain, from production to distribution and from storage to local end-use. This has applications in industry, mobility and the built environment. This is the first region to receive a European subsidy as recognition as a Hydrogen Valley;
— the mobility market is being developed in the northern part of the country with hydrogen refuelling stations and several hydrogen buses already in operation;
— Gasunie is developing a terminal for the import of green ammonia, including storage and loading facilities and a connection to the so-called (Dutch) Hydrogen Backbone (see Figure 1 on p.131) (the **"Backbone"**);
— Gasunie is also investigating with Vopak the construction of a terminal for the import of hydrogen.

It is recognised that the development of the electricity and hydrogen grids should be coordinated. With this in mind, the Dutch gas infrastructure company, Gasunie, has teamed up with TenneT, the Dutch transmission system operator, to produce a joint study on an integrated infrastructure in the Netherlands and Germany. This will be an important project as it will help determine where the most appropriate locations for electrolysers across the country will be.[3] Also, until 2030, Gasunie will invest seven billion euros (EUR 7bn) towards the energy transition goal. This largely entails the repurposing of existing natural gas pipelines for hydrogen. With this, the Netherlands is the first European country to be developing nation-wide hydrogen infrastructure. The development of this hydrogen chain is planned in a 10 year-long roadmap with four phases:

— 2021–2022 – preparing the market: stimulating electrolysis and hydrogen applications in industrial clusters;
— 2023–2025 – developing regional infrastructure: starting phased roll-out of the Backbone;
— 2026–2028 – facilitating growth and market creation: connecting industrial clusters with each other, storage facilities and abroad;
— 2029–2030 – global market readiness: continued growth of offshore wind for hydrogen, realisation of import and transit.

[3] Gasunie & TenneT: Infrastructure Outlook 2050, a joint study on integrated energy infrastructure in The Netherlands and Germany (2019); Gasunie & TenneT, Phase II Pathways to 2050. A joint follow-up study (2020)

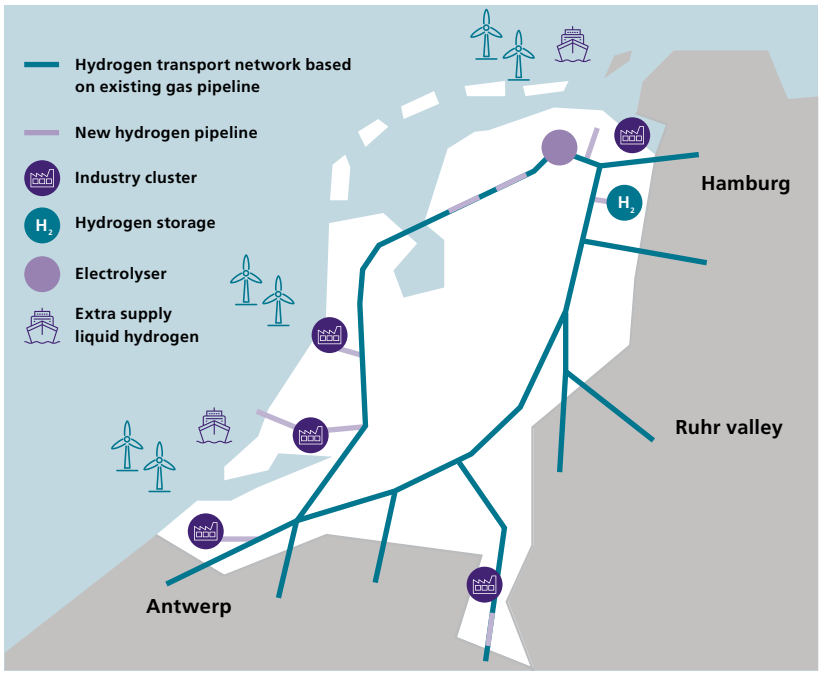


Figure 1: Planned Hydrogen Backbone in the Netherlands

Hydrogen Backbone

The Dutch Government has tasked Gasunie with creating a ring-shaped national hydrogen pipeline to supply industrial clusters. This is the Backbone and the aim is that it will make hydrogen cheaper to transport and will act as a platform to connect hydrogen producers with off takers. The 2021 Budget Day has underpinned an amount of six billion eight hundred million euros (EUR 6,8bn) as a support package for climate change. An amount of seven hundred and fifty million euros (EUR 750m) thereof is labelled for the Dutch hydrogen ambition. For 85% of the Backbone, the existing methane gas grid will be retrofitted to allow for the transport of hydrogen, whilst 15% will be new pipelines. Gasunie has been tasked with retrofitting and build the network that will connect the five large industrial clusters in the Netherlands with hydrogen production sites, ports and storage facilities. Ultimately the Backbone is expected to also include cross-border connections. Total costs are estimated at one billion five hundred million euros (EUR 1,5bn) and the project is scheduled for completion in 2027.

Additionally, the Backbone will be part of a future European Hydrogen Backbone. In July 2020, 11 gas infrastructure companies (including Dutch Gasunie) proposed creating a hydrogen "backbone" from Sweden to southern Spain and Italy. In the first phase of the project, hydrogen clusters across Europe are to be connected.[4] The assumption is that 75% of existing natural gas pipelines will be utilised and new pipelines will only be required for the remaining 25% of the project. Based on this assumption, the investments are estimated to be twenty seven-sixty four billion euros (EUR 27bn – 64bn) by 2040.

HyStock Hydrogen storage

As demand and supply will not be balanced whilst building a hydrogen market, large scale underground storage facilities are needed too. In early 2021, Gasunie successfully completed injection tests of hydrogen into a depleted salt cavern at Zuidwending. The first cavern is expected to be operational in 2026, with the aim being to have four hydrogen storage caverns at Zuidwending by 2030.

[4] European Hydrogen Backbone Report July 2020

Hydrogen is most prominent in the Netherlands in the following areas:

Transport sector use

The National Climate Agreement sets out a target of 50 refuelling stations, 15,000 fuel cell vehicles and 3,000 heavy duty vehicles by 2025, and a further 300,000 fuel cell vehicles by 2030. Subsidy schemes are currently being developed.

Hydrogen has also been a popular choice in the context of decarbonising public road transport, particularly buses.

Ports and Industry Clusters

The Porthos project,[5] (please see greater detail below), is led by a consortium of state-owned companies with the aim of reducing emissions by 2030 by focusing on the capture and transport of CO_2 from industry in the Port of Rotterdam, to ultimately produce blue hydrogen on a large-scale. Porthos is the first CO_2 storage project in the Netherlands.

There is also the opportunity for hydrogen to play a role in industry in the Netherlands, specifically in the development of hydrogen infrastructure and clusters to support industry.

Use in Buildings and Heating

Since the discovery of the Groningen gas field – the largest gas field in Europe – the Netherlands has been nearly completely dependent on natural gas for the heating of homes and commercial buildings. In March 2018, the Dutch government decided to strive for a complete end to the use of natural gas in the built environment by 2050. Furthermore, the government has decided to close-down the Groningen field by 2030 at the latest, as a result of earthquakes caused by gas exploration. Moving away from natural gas is therefore key for the Netherlands overall net zero goals. Blue hydrogen is viewed as a temporary necessity in order to scale up grey and green hydrogen.

A number of pilot heating projects using green hydrogen have been undertaken, for instance in Rozenburg, where a pilot is being conducted by grid operator Stedin to heat homes using 100% hydrogen. Since there is not yet an infrastructure for the transportation of hydrogen in the Netherlands, the hydrogen is produced locally through electrolysis. The hydrogen is then transported to residential homes through an existing gas pipeline. For this purpose, the gas pipeline has been tested in stages, whereby for the initial test nitrogen was used. After the first tests were successfully carried out, the next stage of testing was carried out with 100% hydrogen, which also turned out to be successful. At present, 40 residential homes are being heated by hydrogen.

Another project is a cooperation between i.a. Stedin, Eneco, Gasunie, Deltawind and the Province of South Holland whereby the possibilities for developing a hydrogen city are being assessed. The aim of the project is to have the entire village of Stad aan 't Haringvliet (in which there are 600 residential homes) switch to hydrogen by 2025. The hydrogen will be produced by electrolysis using electricity generated by wind turbines. At present, the project is in the investigation stage, whereby every party to the project has its own task. For example, Stedin is investigating whether the existing gas grid is suitable for the transportation of hydrogen and Deltawind is exploring the possibility of using existing wind turbines to produce hydrogen.

[5] See: www.porthosco2.nl

Another project is being developed in Hoogeveen, in the Province of Drenthe, where the first residential area that will be fully connected to hydrogen is being built. The project consists of two phases: during the first phase 16 residential homes are being built with a shared hydrogen facility. The hydrogen is produced by means of electrolysis using electricity generated by solar panels that are installed on the roofs of all 16 homes. In the second phase, 80 residential homes will be built, which will also have solar panels, however, these 80 homes will be supplied with hydrogen from the nearby Hystock hydrogen plant. The hydrogen will be transported from the plant to the homes by means of a newly installed gas pipeline. The aim is to demonstrate that gas pipelines are suitable for the transportation of hydrogen. Further detail on the Hystock Project is provided below.

Electricity sector use

The use of low carbon hydrogen in gas plants will help in achieving CO_2 reduction in the electricity sector in the long run. More detail of this, specifically the Magnum Project, is provided later in this chapter.

Agriculture use

There are opportunities in the agricultural sector for the use and production of hydrogen, particularly with regards to zero-carbon hydrogen offering possibilities to decarbonise heavy machinery.

Market prospects for hydrogen

The development of the hydrogen market in the Netherlands is in its early stages, with significant prospects for growth over the coming years. There has been no significant M&A or financing activity in the sector yet.

Challenges facing hydrogen projects

Reducing cost and securing demand

The biggest challenge facing hydrogen projects in the Netherlands is to create and implement a low-carbon hydrogen supply chain. Demand, storage, supply and infrastructure all need to be developed. The upscaling of hydrogen and the creation of demand are key requirements for reducing overall costs. The Netherlands aims to become a hydrogen hub due to its favourable location, large ports, extensive gas and electricity grids, its storage capacity, and sufficient demand in its industrial clusters.

Regulation of hydrogen

Legislative framework overall

Use of the existing gas grid

The Dutch government has recognised that a solid regulatory framework is key to the development of the hydrogen economy. In its State Vision for the Development of Markets for the Energy Transition, dated 22 June 2020,[6] the Minister of Economic Affairs and Climate Policy stated that one of the main policy issues will be the transition of the natural gas infrastructure from natural to green gas and low carbon hydrogen. The policy agenda will include studies looking into the role of the national gas infrastructure company Gasunie in the hydrogen chain.

Temporary tasks for network operators
The government considered some temporary roles for Gasunie regarding transport, storage and conversion in order to kick-start the hydrogen market. Both private and public hydrogen networks are foreseen.

The production of green hydrogen from electricity and water will be promoted through an innovation subsidy instrument (**"SDE++ regulation"**) and temporary support for upscaling. Furthermore, the government recognises the importance of large-scale infrastructure projects in order to encourage consumption, though no specific laws have yet been enacted in this regard.

Legislation overall

No specific legislation has been adopted for hydrogen which means that the existing laws on regulation of gas, and those applying to the energy, transport and heating sectors, apply in the context of hydrogen projects.

The Dutch gas market is regulated by the Dutch Authority for Consumers and Markets (*Authoriteit Consument & Markt* (**"ACM"**)). Anyone engaging in gas supply, gas shipping or gas transportation, or participating in the operation of gas interconnectors or providing smart metering in respect of gas, must have a licence to do so under the Gas Act. The licences include measures relating to the safe operation of the gas network and provisions relating to price controls.

The ACM published a guideline on 14 September 2021 aiming to provide clarity regarding the role of network companies in the market for alternative energy carriers.

This guideline clarifies what options the current legal framework offers network companies active in this market. It refers, in particular, to Articles 10d of the Gas Act and 17c of the Electricity Act. According to the ACM explanation, network companies can use the possibilities offered by the law to help shape the energy transition, and market parties know where they can and cannot expect competition from network companies or where they can seek cooperation with network companies. In this way, the market for alternative energy carriers can develop as well as possible, which also benefits the energy transition.

It should be emphasized that the Dutch legislator is currently working on a new bill, the Energy Act. This law is intended to replace the current Electricity Act and Gas Act. This may mean that the rules regarding alternative energy carriers, including hydrogen, that network companies must adhere to and that the ACM explains in their guideline, will change in the (near) future.

Within the current legal framework, network companies can perform the following actions or activities with regards to alternative energy carriers:

— network companies may install and manage transmission pipelines and associated resources for alternative energy carriers and provide the transport of energy carriers over that infrastructure;
— network companies may build and maintain production installations for alternative energy carriers for third parties, but they may not manage or own them;
— production, trade and supply of alternative energy carriers by network companies is not permitted, with the exception of:

[6] Brief MEZ 22 juni 2020 Rijksvisie marktontwikkeling voor de energietransitie.

- situations in which these activities are inextricably linked to the infrastructure; or
- the activities are carried out through minority participations and joint ventures where there is no decisive control of the network company. Network companies can thus help develop or shape markets for alternative energy carriers in a more far-reaching way via minority participations and joint ventures, in collaboration with other parties (a form of public-private partnership).

Injection into gas grid regulation

Although with minor adjustments to the pipeline it is technically possible to blend hydrogen with natural gas in an existing gas network, Gasunie has decided to modify the pipeline so it can deliver 100% hydrogen rather than a blend. Gasunie is focusing on the development of a pure hydrogen backbone for several reasons, the main being that it is not very efficient to blend pure hydrogen with natural gas and separate it at the end to enable the use of hydrogen as a resource. The secondary reason is that the Netherlands has the opportunity to develop a separate hydrogen backbone relatively easily by using existing natural gas pipelines. In addition, residential and commercial heating boilers have already been developed for use with 100% hydrogen.

Health and Safety laws

The Netherlands has initiated a four year Hydrogen Safety Innovation Programme that will be implemented as a public-private partnership. This aims to identify safety issues and will propose policies to address those issues.

Regulatory bodies

There is no specific regulatory body that is responsible for the regulation of hydrogen projects. Instead, a number of regulators would have responsibilities depending on the activity in question.

Regulatory Body	Role
Local Authorities, Municipalities and Provinces	— Regulate the use of land — Undertake Environmental Impact Assessment
State Supervision of the Mines ("SodM")	— Related to the storage of hydrogen
Rijksdienst Wegverkeer ("RDW")	— Approves hydrogen transport vehicles
Minister of Economic Affairs	— Regulates new pipelines and decommissionings
Autoriteit Consument & Markt ("ACM")	— Regulates the gas network

Upcoming developments

Recent developments

There have been several hydrogen projects initiated and developed or recently announced, of which the following are notable:

Porthos: This project is led by a consortium of state-owned companies: Gasunie, EBN and the Port of Rotterdam. Porthos aims to reduce emissions by 2030, in line with Dutch climate targets, by focusing on the capture of CO_2 within the port of Rotterdam from existing hydrogen production to produce large-scale blue hydrogen. The CO_2 captured is being stored in an empty gas field in the North Sea. In November 2020, Porthos and four companies (Air Liquide, Air Products, ExxonMobil and Shell) signed a new agreement to keep working together towards the realisation of definite transport and storage contracts and for the preparations for the capture, transport and storage of CO_2. In the next stage, both Porthos and its private sector partners will be completing various technical studies and permit procedures.

The final investment decision for Porthos has been planned for 2022, after which the realisation can proceed. The project is expected to be operational by 2024.

Hystock Project: This project, initiated by Gasunie, researches the production of hydrogen generated with solar energy through electrolysis. Through Hystock, Gasunie is trying to stimulate the market for pure green hydrogen. Where a lot of other European initiatives focus on blending hydrogen, Hystock focuses on hydrogen fully produced by means of renewable energy. The green hydrogen plant, which has been operational since July 2019, converts 1MW of solar energy generated by 5,000 solar panels into green hydrogen. This equates to 400kg of hydrogen per day.

Magnum Project: The Magnum power plant is a 1.32GW gas-fired combined-cycle power plant located in Eemshaven. Operational since 2014, the three-unit plant is owned and operated by Vattenfall. The powerplant will generate electricity by using hydrogen. The facility is capable of generating enough power to serve the needs of approximately two million Dutch households. An innovative hydrogen conversion project is currently underway at the power station to convert one of its units to run on pure hydrogen by 2023. Upon completion, the Magnum power plant will be the world's first such facility to generate 100% carbon-free electricity using hydrogen as fuel.

Hydrogen Storage: In 2011, Gasunie discovered the possibility of storing hydrogen in salt caverns. At present, its subsidiary Energystock has been storing hydrogen in six salt caverns in Zuidwending, in the province of Groningen. Nouryon (formerly AkzoNobel) and Cory Energy are now also researching possibilities to make use of the salt caverns in Zuidwending. Storage in the salt caverns is intended to address the problem whereby production of solar and wind power is unable to meet demand due to the fluctuating weather conditions. By converting the power into hydrogen and storing it in the salt caverns, supply and demand can be balanced. In addition, it will help in balancing the Dutch electricity grid and prevent blackouts caused by an overload.

North Sea Wind Power Hub: In 2016, Dutch TSO TenneT proposed to make CO_2 reduction targets feasible and affordable by building a large European electricity system in the North Sea, based on a "hub-and-spoke" principle. Offshore wind parks will be connected to a hub in the North Sea, from which the electricity generated is partially converted into hydrogen and connected to shore via pipelines. In July 2019, this concept was further developed by the North Sea Wind Power Hub-consortium (consisting of TenneT, Gasunie, Havenbedrijf Rotterdam and Energinet). After in-depth investigation, the consortium concluded that instead of having one large island, eight to ten smaller energy hubs (of 10–15GW each) would be more optimal for realising the "hub-and-spoke" principle. The consortium envisages having the first energy hub operational by 2030.

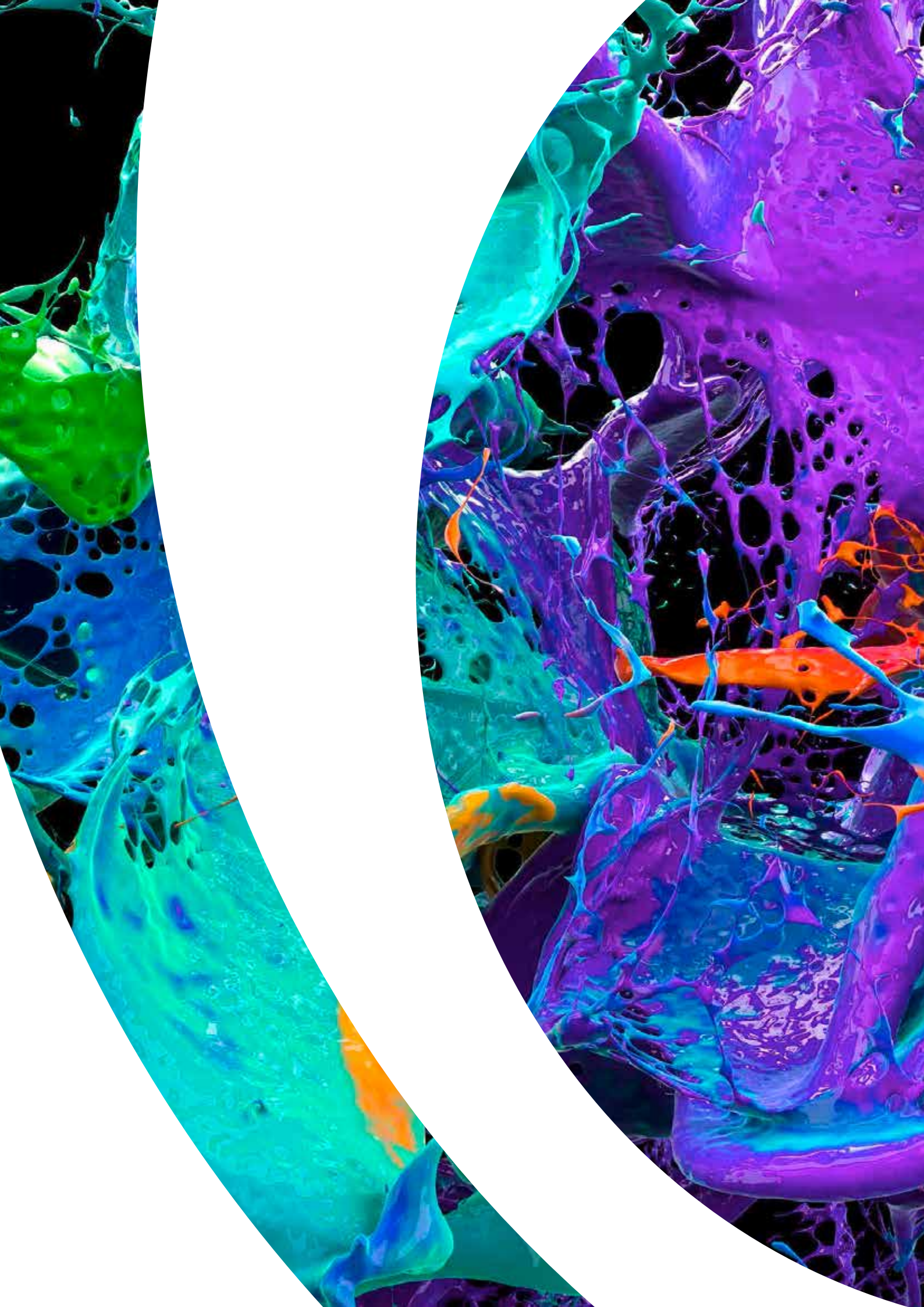
Element 1: In 2018, Gasunie Deutschland announced its cooperation with Dutch TSO TenneT and gas transmission company Thyssengas on the build of a 100MW power-to-gas pilot using offshore wind energy. The project is called "Element 1" since hydrogen is the first element in the Periodic Table. The installation is built near the North of Germany where the power generated by offshore wind turbines converges before being allocated. Whenever supply exceeds demand, the excess power can be converted into hydrogen and may be temporarily stored. The installation is expected to become operational by 2022.

Djewels: A consortium of Gasunie, Nouryon (formerly AkzoNobel) and BioMCN are planning on building the biggest European green hydrogen plant (20–60MW) in Groningen. The construction of the plant is part of the Hystock-project (discussed above) and has received financial support from the European Union (eleven million euros (EUR 11m)) as well as the Netherlands Enterprise Agency (six million euros (EUR 6m)).

PosHYdon: This is a joint project between Gasunie, TNO and Nextstep (a Dutch association focused on decommissioning and reuse). The project will use Neptune's Q13 oil platform, based in the Dutch North Sea for an offshore green hydrogen plant. The pilot aims to integrate three energy systems in the North Sea: offshore wind, offshore gas and offshore hydrogen, by producing hydrogen from seawater on the Q13 platform. The aim of the pilot project is to gain experience of integrating working energy systems at sea and in the production of hydrogen in an offshore environment.

Hydrogen refuelling stations and buses: In 2016 the Dutch government agreed with the public transportation sector that, as of 2030, all buses should be emission free. Several provinces, such as Groningen, Drenthe and South Holland now have hydrogen fuelled buses in commercial operation within their public transport system. By 2021, at least 50 buses will be operational. As a consequence, the Netherlands is also expanding its amount of hydrogen refuelling stations. At present, there are nine operational hydrogen refuelling stations in the Netherlands, and twelve more are currently in development.

Hydrogen Delta Network NL: In September 2021, Gasunie and North Sea Port signed an agreement for the development of a regional hydrogen transport network in Zeeland. This "Hydrogen Delta Network NL" builds on the current position of the region for hydrogen and is expected to take shape in the coming years. This is to be followed by the connection of this regional infrastructure to the national Dutch and Belgian hydrogen infrastructures.



Norway

Authors:
Olav Hasaas
Siv V. Madland
Samuel Skrunes
Camilla Grytten

Current status for hydrogen in Norway

Introduction

In Norway, 225,000 tonnes of hydrogen are currently produced from natural gas for use in industrial processes. The production of hydrogen from natural gas ("grey" hydrogen) has a high emission of CO_2, but the cost of hydrogen produced this way is only a third of the emission-free alternative.

The Norwegian government's goal is that, by 2050, the greenhouse gas emissions will be reduced with 90 and 95% compared with levels in 1990. Norway has, as part of the follow-up to the Paris Agreement, announced a strengthened climate target to reduce emissions with 50% and up to 55% by 2030, compared with 1990.

To reach this goal, the government will implement a strengthened focus on hydrogen-related research and technology development. In many sectors, work is now being done to develop solutions for hydrogen as an energy carrier. Several projects are in the process of testing hydrogen for various energy purposes.

Transport sector

Hydrogen can play an important part in the transport sector. For passenger vehicles and local transportation, battery powered vehicles seem to be the preferred technology, but in heavier vehicles and the maritime sector, hydrogen fuelled transport is seen as a possible alternative to achieve emission-free transportation.

For maritime transport, there are several planned and ongoing projects. For instance, Norled AS is investing in hydrogen and will start the world's first hydrogen ferry, the "MF Hydra". The ferry became operational in July 2021, initially with a battery, and will later switch to hydrogen during the spring of 2022 when the hydrogen plant is completed.

BKK, Equinor, and Air Liquide want to build an industrial plant to produce liquid hydrogen, which can be used as fuel in shipping.

Industry sector

The use of hydrogen in the industry falls into three categories: used as an input factor in production, as an energy carrier, or used in the process itself. In addition, there are some industrial processes where hydrogen is currently produced as a by-product.

Almost all hydrogen used in Norway today is used as an input factor in the chemical industry and in refining petroleum products. The hydrogen used today is almost exclusively produced by reforming natural gas without capture and storage of CO_2 (i.e., "grey" hydrogen). If carbon is captured and stored, or the production is done by electrolysis, the emissions will be significantly reduced.

Tizir in Tyssedal are working on developing and testing technology required to use hydrogen as a reducing agent in titanium oxide production.

Challenges facing hydrogen projects

Cost challenges

The production and processing of low carbon hydrogen is more expensive than the current process for producing hydrogen from natural gas without carbon capture and storage.

There are few large-scale CCS projects ("blue" hydrogen), therefore it is difficult to estimate a cost of capture and storage of CO_2. Prerequisites such as a significant market for hydrogen, access to natural gas infrastructure, and infrastructure for CO_2 capture and storage entails a significant need for space and therefore geographical restrictions with this production method.

The production of green hydrogen via electrolysis is significantly more expensive than to reforming methane gas. Electrolysers today are produced in small quantities and have small capacities. It is expected that prices will fall if the demand increases, and green hydrogen can be produced at a larger scale.

Uncertainties regarding price and demand can therefore pose a problem for the successful development of hydrogen projects.

Legislative Framework gap

In common with many jurisdictions, Norway does not have a well-defined legal and regulatory framework for hydrogen projects in the various sectors. There is no complete framework that covers the hydrogen value chain, and navigating can be challenging.

Challenges facing hydrogen projects

Legislation gaps

The Norwegian energy market is regulated by the Act relating to the generation, conversion, transmission, trading, distribution, and use of energy etc. (the **"Energy Act"**).

The legislative history for the Energy Act shows that the production, storage, and transport of hydrogen does not fall under the Energy Act. However, facilities for production of hydrogen must comply with the Energy Act and its regulations as outlet customers in the grid – just as other industrial plants.

Pollution regulation

The production of hydrogen is in accordance with the Pollution Control Regulations appendix 1 4.2 an activity that is covered by the requirements for permits in section 36-1 (2).

The production of hydrogen by electrolysis does not, in principle, cause any pollution, but a permit is still required.

Requirements for the application for a permit are listed in said Regulation sections 36-2 and 36-3.

Injection into the Gas Grid – blending hydrogen into the existing gas networks

Possibilities for mixing hydrogen into natural gas, to use pipeline networks intended for natural gas transportation, are being looked at. This can contribute to an early introduction of hydrogen in export to Europe and the hydrogen can be produced from renewable or fossil production. This will make it possible to use the huge European natural gas network to store and transport hydrogen.

Real Estate and Consenting laws

The Planning and Building Act applies to all types of activities related to real estate. Implementation of any measure can only take place if they are not in conflict with the Act and associated regulations and the municipal area and zoning plan. Measures can only be implemented if no prohibition in law, regulations, plans or the like prevents it.

Plants for production of electricity with hydrogen as an input factor – for example, fuel cells or any gas turbines – require a plant license in accordance with the Energy Act Section 3-1, if the plant is over the threshold for a licensing obligation. Facilities that receive such license, do not require a separate permit pursuant to the Planning and Building Act, see section 1-3 (2).

Further, a licence from the regulatory authority must be acquired to trade in electrical energy, as stated in the Energy Act section 4-1.

Natural gas is "petroleum" according to the Petroleum Act. To develop a petroleum deposit, the licensee will have to submit to the Department for approval a plan for the development and operation of the petroleum deposit (**"PUD"**). A separate plan must be approved for plants and operations of facilities for transport and for the utilisation of petroleum (**"PAD"**), if this is not covered by an approved PUD.

Capture, Transport, and Storage of CO_2 in the Petroleum Sector for blue hydrogen

Regulation for the Petroleum Act [Forskrift til petroleumsloven] chapter 4a applies to the capture, transport, and storage of CO_2 in the petroleum sector, which is implemented in accordance with the plan for development and operation approved pursuant to section 4-2 (1) of the Act.

Before injection and storage of CO_2 underwater, the licensee will need a permit. The licensee will also need to ensure that appropriate dispositions may be made in the form of financial security or equivalent to ensure that all obligations arising from the Regulation can be fulfilled. The financial security must be valid and effective before the injection starts.

Health & Safety laws

Hydrogen gas is categorised as a flammable gas category 1, and therefore falls within the scope of the Act relating to the prevention of fire, explosion, accidents involving hazardous substances, and the fire service. The Act applies to general obligations to prevent fire and explosion, as well as central and local organisation and implementation of fire and explosion protection work.

The Act sets out several obligations such as:

— the duty to prevent and limit the harmful effects of fire, explosion, and other accidents.
— obligations to provide the necessary safety measures to prevent and limit fire, explosion, or other accidents.
— carry out systematic health, safety, and environmental work (internal control) to ensure that requirements laid down in or pursuant to this Act are complied with.

Handling of hydrogen is regulated in the Regulations on the Handling of Dangerous Substances (Forskrift om håndtering av farlig stoff). The Regulations stipulate, among other things, that a risk assessment for hydrogen plants must be prepared, and that the plants must be built and inspected according to a recognised norm. To achieve sufficient safety for third parties, it is important that the handling of hydrogen takes place at a sufficient distance from surrounding objects. The regulation requires companies to document whether there is a need for spatial measures restrictions on hydrogen handling facilities. This is important to consider when hydrogen plants are to be established.

Equipment used for handling hydrogen must be in accordance with the requirements of the Regulation on the Pressure Equipment (forskrift om trykkpåkjent utstyr).

Companies that store five tons of hydrogen or more will additionally be covered by the Regulation on major accident (Storulykkeforskriften). The last two regulations are directive-based, which means that the requirements are equivalent to the regulations in other EU/EEA countries.

Furthermore, compliance with the Regulation on Health and Safety in Explosive Atmosphere is necessary. The Regulation concerns the protection of workers and other persons, as well as material values against the dangers arising from explosive atmospheres, setting out requirements for protective equipment and protective systems.

Transport of Hydrogen regulation

Hydrogen must be transported in accordance with the requirements of the Regulation on Carriage of Dangerous Goods by Road (forskrift om landtransport av farlig gods). This regulation is directive-based and is equivalent to the regulation in other EU/EEA countries.

The Regulation sets general requirements for transport personnel, clear safety marking and packaging, and for the equipment and materials used for the transport of dangerous goods.

Vehicles used for transport must meet the relevant requirements in "Accord relatif au transport international des marchandises dangereuses par route" (**"ADR"**) chapter 9.

Regulatory bodies

There is no specific regulatory body that is responsible for the regulation of hydrogen projects. Instead, a number of regulators would have responsibilities depending on the activity in question.

Regulatory Body	Role
The Directorate for Civil Protection (DSB)	— The authority for regulation of dealings with flammable, reactive, pressurised, and explosive substances, including hydrogen. — The authority for regulation of transport of dangerous goods. — The administrative authority with regards to regulation of electrical safety, i.e., requirements for safe execution and use of supply networks and electrical installations, including installations for production of hydrogen.
Local Authority / Town and County Authority	— Regulates the use of land. — The authority enforcing pollution regulations in their respective town / county.
Ministry of Climate and Environment and the Norwegian Environment Directorate	— Superior authority on pollution regulations.
Minister of Economic Affairs	— Regulates new pipelines and decommissionings
Ministry of Petroleum and Energy	— Regulates generation, conversion, transmission, trading, distribution, and use of energy.

Regulatory Outlook and Market Prospects

Recent developments

The hydrogen market in Norway is at an early stage with significant prospects for growth over the coming years. The Ministry of Petroleum and Energy (**"MPE"**) published a Roadmap for Hydrogen in its White Paper to the Norwegian Parliament in June 2021.

The long-term vision of the MPE is to have a well-established market for the production and use of hydrogen in Norway by 2050, with hydrogen being, where this is a good solution, used as an input factor in industrial activities, as fuel in ships and vessels both in coastal waters and for long-distance transport and as fuel for heavy vehicles by road. Furthermore, the MPEs vision is that the Norwegian energy and supplier industry and related industries are international leaders in the export of hydrogen and certain hydrogen technologies and solutions, creating economic growth to the benefit of the Norwegian society.

In the short term, by 2025 the vision of the MPE is to support the development of technology through pilot and demonstration projects for the production and use of pure hydrogen in maritime transport, in heavy transport by road, and in the industry. The projects shall contribute to early market introduction and market development, as well as facilitating the development of geographical hydrogen hubs. The government will facilitate for collaboration with private actors to establish:

— five hydrogen hubs for maritime transport, with opportunities for the development of associated land transport solutions based on hydrogen;
— one or two industrial projects with associated production facilities for hydrogen, in order to demonstrate value chains with potential for global dispersal; and
— five to ten pilot projects established for the development demonstration of new and cost-effective hydrogen solutions and technologies.

The MPE also intends to strengthen R&D and the demonstration of new hydrogen solutions and technologies by establishing a research centre for hydrogen and ammonia.

In the medium term, by 2030 the MPE's vision is that hydrogen as an energy carrier has been established as a real alternative in the maritime sector and is maturing as a good alternative in the Norwegian industry. The first projects in the maritime sector without need for government funding are being planned. The MPE's vision is to contribute to a development that enables:

— a network of geographically dispersed, demand-based hydrogen hubs in line with the supply vessels and vehicles;
— hydrogen vessels that are a competitive and safe alternative for shipping in Norwegian waters and short sea shipping areas;
— realisation of full-scare industrial hydrogen projects with significant dispersal potential for Europe and the rest of the world;
— the use of hydrogen as a competitive alternative to fossil energy; and
— Norwegian hydrogen activities to be linked to the development of a market for hydrogen in Europe in the form of export of goods and services.

The Roadmap also states that the government intends to carry out an assessment of new instruments, such as "Contracts for difference" ("**CfD**"), aimed at realising large industrial projects such as large-scale production and use of hydrogen. In this context, CfD means a subsidy model in which both positive and negative deviations from a pre-set reference price are compensated for.

It is assumed that, by 2030, the technology for the use of hydrogen at sea and in heavy transport by road will mature. Eventually, hydrogen and/or ammonia could also become a low-carbon fuel for larger ships/vessels. The need for hydrogen hubs and infrastructure will depend on the demand for hydrogen. In a start-up phase, the demand for hydrogen for maritime purposes is expected to be limited. Modular production plants for green hydrogen will therefore be well suited for this phase.

The demand for hydrogen for industrial purposes will depend on the establishment of larger hydrogen production plants. It can therefore provide a basis for establishing hydrogen production based on natural gas with CO_2 management. However, such production facilities are dependent on the availability of CO_2 storage. It is therefore unlikely that blue hydrogen can be produced earlier than 2025 in Norway.

In September 2021, there was a Parliamentary election in Norway, resulting in the Labour Party taking over from the Conservative Party. It is relatively safe to assume that the work with the Energy Report and the guidelines for hydrogen will proceed also after a new government has been formed; the Labour Party has expressed that the Energy Report is a good foundation for the work to be done in shaping the Norwegian energy sector for years to come.

Upcoming Developments

There has been a lot of news about hydrogen projects in Norway, including several IPOs of technology companies, specific projects for the use of hydrogen as fuel for larger vehicles and ships, and plans to use hydrogen to cut emissions in industrial processes.

A selection of Norwegian hydrogen projects:

Sintef and Varanger Kraft have received NOK 50m from the EU to test hydrogen production from surplus power from the Raggovidda wind farm in Finnmark.

Meløy Energi, Nel, and Greenstat are the companies behind Glomfjord Hydrogen, which has a project for production of hydrogen using electrolysis. It should be able to deliver around one tonne a day when local demand increases.

Reinertsen New Energy has tested a plant for hydrogen production from gas combined with CO_2 capture at Equinor's gas plant at Tjeldbergodden.

Hellesylt Hydrogen Hub is a collection of actors in hydrogen. They have received NOK 37.6m from Enova's Pilot-E program for a facility that will supply hydrogen to ferries and cruise ships in the Geirangerfjord.

The Tizir smelter in Tyssedal wants to replace coal with hydrogen in their production.

The shipping company Wilhelmsen and partners such as Equinor and Norsea Group will launch the hydrogen-powered cargo ship "Topeka" in 2024. The ship will transport goods between oil bases along the Norwegian coast. It will also carry liquid hydrogen – in addition to using hydrogen as fuel.

Nasta AS is cooperating with Sintef and Skanska, among others, in developing a 30-tonne crawler excavator driven by hydrogen and batteries.

Norled and a series of partners have been given economic support from the EU through the Flagship project to, amongst other things, review if one of the local ferries can start using hydrogen instead of biodiesel, as was the original plan.

Sunnhordaland Kraftlag, Kvinnherad kommune and Gasnor have signed a cooperation agreement in order to determine the possibilities of starting a large-scale production of floating hydrogen in Kvinnherad.

BKK, Equinor and Air Liquide are planning to develop a complete supply chain for production, storage, transport and use of hydrogen in the maritime industry.

Peru

Authors:
Alejandro Diez Canseco
Carlos Hamann
Augusto Astorga

Current status for hydrogen in Peru

Introduction

The hydrogen industry is emerging in Peru but is at an early stage. Hydrogen is likely to develop over the coming decade as it will become key to the country achieving a reduction of 30% of its carbon emissions by 2030,[1] as agreed under the Paris Agreement.

In early 2021 the Peruvian Hydrogen Association called H2 Peru, was created. Its main goal is to promote the development of the green hydrogen industry in Peru, which is expected to generate employment and new competences. Among the strategic partners of this Association are Total Energies, Engie, Siemens Energy, Anglo American, Goldfields, and Fenix Power.

Currently in the Peruvian oil and gas sector, hydrogen is used in the process of desulfurisation of diesel fuels in oil refineries, in order to produce "cleaner" fuels which, when consumed, will contribute to reducing greenhouse emissions in comparison to traditional fuels, and as such, will safeguard air quality and public health. The hydrogen used is all "grey" hydrogen made using fossil fuels.

In this regard, oil refineries in Peru have started adapting and implementing carbon reduction strategies in their hydrogen facilities. The *Pampilla Refinery*, one of the country's most important oil refineries, owned by Repsol, started the operation of a hydrogen plant in 2016. The *Talara Refinery*, operated by NOC Petroperu, is also currently in the process of adapting its own hydrogen plant as part of a major upgrade that will increase its refining capacity and make the refinery more energy efficient. Longer term, low-carbon hydrogen options may be pursued also.

[1] http://www.minam.gob.pe/cambioclimatico/wp-content/uploads/sites/127/2019/01/10.-Mitigaci%C3%B3n.pdf

According to Peru's National Energy Plan 2014 – 2025,[2] there is a deep political commitment for the promotion of clean energy strategies. Likewise, the National Energy Policy 2010–2040,[3] approved by Supreme Decree N° 064-2010-EM, has set having a "diversified energy mix, with an emphasis on renewable sources and energy efficiency" as one of the country's main goals for 2040. According to the aims of the Supervisory Agency for Investment in Energy and Mining (**"OSINERGMIN"**), by 2040, renewables will represent 20% of Peru's energy production. Since green hydrogen is produced from renewables, the opportunities for producing such hydrogen will increase, given the decreasing costs of renewable energy generation.

Market prospects for hydrogen

Peru's market for production and use of hydrogen is currently very limited. However, as the country's energy policy has shifted towards a clean energy approach, with more focus on efficient energy sources and the reduction of carbon emissions, the government may therefore implement a legal framework that could potentially include the promotion of a low-carbon hydrogen market.

In the mining sector, companies are said to be considering the use of hydrogen in their operations. This requires huge amounts of diesel in the various phases of their operational processes. In this way, the use of hydrogen might contribute towards making mining a more sustainable activity. Though studies and breakthroughs on this topic still need to be developed, these will most likely be pushed by the increasing pressure placed upon the mining sector to decarbonise their activities and thus, reduce emissions.

Challenges facing hydrogen projects in Peru

Absence of legal framework

Peru has yet to implement any legislation regarding hydrogen-based projects. The introduction of such legislation would contribute to clarifying and promoting the use of hydrogen in different industries.

Given the nascent status of low-carbon hydrogen discussions as a clean energy alternative, there is still little public awareness of it.

When this industry attracts enough attention from the Peruvian Government, given its evident benefits for achieving low-carbon emissions, the Government will most likely approve a Hydrogen National Strategy by which regulations, incentive schemes, infrastructure, transport, and storage of hydrogen would be specifically regulated.

[2] https://minem.gob.pe/minem/archivos/file/institucional/publicaciones/PEN_INGLES_2014_2025.pdf
[3] http://www.minem.gob.pe/minem/archivos/DS_%20N%C3%82%C2%BA%20064-2010-EM.pdf

Regulation of hydrogen

Legislation overall

As mentioned above, Peru has no legislation that regulates hydrogen-based projects specifically. As a result, the general regulations on industrial gasses apply to hydrogen. Such regulations, which include technical standards, are the following:

- Law N° 28256, Law that regulates the Land Transportation of Hazardous Materials and Waste;
- Supreme Decree N° 021-2008-MTC, which approved the National Regulations for Land Transportation of Hazardous Materials and Waste;
- the Peruvian Technical Standard NTP 512.001:1989 (Revised in 2012) "Requirements for storage, transportation, handling and transfer of compressed gases"; and
- the Peruvian Technical Standard NTP 399.013:1974 (Revised in 2012) "Identification Colours of Industrial Gases Contained in Pressure Containers, such as Cylinders, Bottles and Tanks".

However, considering that hydrogen is used in oil & gas processes, industry specific regulations can apply. For example, Law N° 28694 established that the regulation of the sulphur levels contained in diesel fuel were of public necessity and of national interest, and also established tax measures to promote clean fuels. In compliance with this law, oil refineries decided to implement hydrogen plants, in order to "clean" their diesel fuels.

In 2018, a project was presented to Congress, to promote the use of vehicular natural gas, liquefied petroleum gas, hydrogen, and other non-polluting energy sources in government vehicles as well as in public and privately owned urban public transport vehicles, which include buses, micro-buses and taxis.[4] This bill has not yet been approved but once it passes would create a market for low emission vehicles, including those powered by hydrogen and would in turn create demand for hydrogen fuelling stations. It is worth mentioning that approx. 70% of metropolitan journeys in Lima, capital city of Peru, are made by public transport, such as buses and taxis.

Furthermore, in early 2021, a project was presented to Congress,[5] to -among others- promote projects for the production of green hydrogen by using the power generated through renewable energy resources technologies as a mechanism to reduce carbon emissions from transport, industry and agriculture. For such purpose, a National Plan for green hydrogen development is to be drafted and approved by the Ministry of Energy and Mines. Though this is a very recent project, and the process for its eventual approval is long and includes its passing through the Energy Commission and further other reviews that may somehow vary it, it is a very important step towards the implementation of hydrogen-based projects.

Transport of hydrogen by road regulation

The transport of hydrogen is regulated by the National Regulations for Land Transportation of Hazardous Materials and Waste, approved by Supreme Decree N° 021-2008-MTC, under the provisions for flammable gasses transport, in accordance with the UN Orange Book. These regulations require that a permit is obtained from the Ministry of Transport and Communications for transporting hydrogen.[6]

[4] Bill Project N° 3753/2018.
[5] As per article 37 of Supreme Decree N° 021-2008-MTC.
[6] As per article 37 of Supreme Decree N° 021-2008-MTC.

Regulatory bodies

Peru does not have a regulatory body that exclusively regulates projects related to hydrogen and as such, the competent authority for the regulation of the development, construction and operation of projects that incorporate the use of hydrogen will depend on the applicable industry. The responsible agencies who may be involved are the following:

Activity	Regulatory Bodies
Transport	— Ministry of Transport and Communications: sets the legal framework. — Superintendence of Land Transport of People Cargo and Goods (**"SUTRAN"**): supervises and inspects compliance with legal framework.
Energy	— Ministry of Energy and Mines: sets the legal framework. — Supervisory Body for Investment in Energy and Mining (**"OSINERGMIN"**): supervises and inspects compliance with legal framework. — Environmental Audit Agency (**"OEFA"**): supervises compliance with environmental regulations.
Environmental Instruments	Depending on the Environmental Instrument required and the industry in which the project falls, any of the following authorities may be relevant: — the Ministry of Energy and Mines; — the National Service of Environmental Certification for Sustainable Investments (**"SENACE"**); or — the Ministry of Production.

Upcoming developments

As the hydrogen industry expands worldwide, and considering Peru's commitment to producing cleaner and less carbon producing energies, the government may start regulating and promoting, in a more active way, investment in hydrogen-related projects in the near future.

At present there are no low carbon hydrogen projects being developed in Peru but, as mentioned above, **Talara's Refinery,** located in the north coast of Peru, is going through a major upgrade process. The upgrade is valued at USD 5bn and expected to be finished in the fourth quarter of 2021, due to some unexpected delays.

Poland

Authors:
Piotr Ciołkowski
Michał Andruszkiewicz

Current status for hydrogen in Poland

Introduction

Hydrogen has been recognised as having a key role in the Polish energy transformation. There is significant opportunity for the development of hydrogen projects in all relevant sectors, such as industry, electricity and heat generation, as well as for energy system management and in transport. The relevant stakeholders' plans are ambitious and apply to a range of sectors, however, as discussed below. As well as facing technical barriers, they are also confronted with an underdeveloped legal framework and lack of clear financial support mechanisms.

Poland currently has a substantial hydrogen market and Poland is the fifth largest producer of hydrogen worldwide (with the annual production of hydrogen equal to approximately 1m tonnes). Poland produces 14% of all hydrogen produced in Europe, which is used predominantly in industrial processes. Currently, hydrogen is primarily used in the petrochemical processes or as a side product generated in the processing industry. Grupa Azoty S.A. (**"Grupa Azoty"**) – the largest chemical consortium in Poland – is currently the biggest producer of hydrogen in Poland, producing approximately 420,000 tonnes of hydrogen annually and it will be increased when the new Polimery Police Project is into operation. The new installation will produce hydrogen in the process of propane dehydrogenation. Hydrogen will be a by-product of this reaction and hydrogen will be of very high quality, reaching the level of 99.99% purity.

Grey hydrogen is also generated by PKN ORLEN S.A. (**"PKN ORLEN"**) – the biggest player in the Polish fuel market – for production processes and as a side product in the process of chlorine generation for the production of polyvinyl chloride. PKN Orlen is producing approximately 145,000 tonnes of hydrogen annually.

As in mid-2021, the development of dedicated hydrogen projects in Poland is limited, though there are hydrogen generation, transportation and storage projects in planning stages, as detailed below. For future projects, most of the planned decarbonised hydrogen projects expect to use hydrogen for transport and in electricity grid management (by storing surplus energy generated by renewable projects in the form of hydrogen).

At the same time, hydrogen still represents an insignificant part of the worldwide and EU energy offer, although there are dynamic perspectives related to the development of that area throughout Europe. At the turn of 2020 and 2021 many European countries announced that they were adopting national strategies/plans for the development of hydrogen technologies.

Polish hydrogen strategy 2030

As specified above, as one of the main hydrogen producers in the world, Poland has set ambitious goals related to the planned development of hydrogen technologies. These goals and the manner of achieving them were defined in detail in the draft Polish Hydrogen Strategy 2030 with the prospects to 2040 (the **"Strategy"**), published by the Ministry of Climate and Environment on 14 January 2021. The Strategy has been officially adopted by the resolution of the Polish government passed on 2nd November 2021. However, at the date of publication this Guide, the final version of the Strategy has not been published yet in the Official Journal of the Republic of Poland. For the purposes of preparing this Guide it was assumed that the final version of the Strategy is compliant with its project.

The Strategy is meant to respond to the changes taking place in the European and global energy environment, resulting in a shift from conventional fuels to low-carbon solutions. Hydrogen can play a significant role in the decarbonisation process.

Therefore, future actions envisaged by the Strategy are focused on the development of green and low-emission hydrogen economy, and the Strategy itself refers to three sectors enabling the use of hydrogen – **energy, transportation, and industry.** The Strategy also addresses the methods of producing hydrogen, its distribution, and necessary legal changes for the creation of a stable regulatory environment and rules for financing hydrogen technologies.

The priority areas adopted within the Strategy refer to the **concept of combining sectors,** which provides for: an increase in the use of electric energy from Renewable Energy Source (**"RES"**) and its consumption by specified sectors of the economy (such as the transportation sector, various industry sectors and the heating sector – heating of buildings) in order to minimise the dependence on fossil fuels contributing to greenhouse gas emissions to the environment. If renewable hydrogen and the concept of sector combination are implemented, the emission reduction potential in 2050, as compared to 2020, will be approximately 68%.

The Strategy also complies with the actions presented in the draft Polish Energy Policy 2040 (**"PEP 2040"**), outlining the directions for the energy sector development, taking into account the tasks to be performed in a short-term perspective, which also cover activities related to hydrogen.

The authors of the Strategy also refer to the European regulations and assumptions, which are aimed at achieving climate neutrality by 2050, in line with the EU vision presented in the European Green Deal and the Paris Agreement.

The Strategy emphasises that the hydrogen economy may be developed by establishing the entire value chain and constructing infrastructure which will facilitate its use. Achieving this requires the development of electrolyser installations, a hydrogen distribution network, including creating the relevant transmission and transportation infrastructure, hydrogen storage facilities, refuelling infrastructure, production of fuel cells used in energy, heating, transportation, and other sectors of the economy. The overarching objective of the Strategy is also to create a Polish branch of hydrogen economy, amongst other ways by developing and making use of national patents and hydrogen technologies. The Strategy emphasises the need to use Polish research and development potential in the area of hydrogen technologies and to become a supplier of electrolysers, pyrolysis installation, fuel cells and hydrogen storage tanks, reactors and catalysts for methanation (Power to Gas or **"P2G"**), or for Power to Liquid (**"P2L"**) technologies and other components.

The authors of the Strategy are of the opinion that implementing the above assumptions requires planning legal solutions supporting the development of hydrogen use. It is crucial to support demand, and specifically to create appropriate technical conditions and incentives for companies, as well as to secure the financing of hydrogen technologies from the EU leverage package, which will contribute to their further development.

As was mentioned above, the goals formulated in the Strategy relate to three priority areas of using hydrogen: energy, transportation, and industry, as well as its production and distribution, and the need to establish a stable regulatory environment.

The Strategy also assumes the development of a broad range of competence for the hydrogen economy. The main task within that scope is to prepare qualified personnel to create, construct, and operate hydrogen installations. The projected dynamic growth of hydrogen mobility should take place in parallel with educating personnel skilled for maintaining such vehicles and refuelling stations. The Strategy also emphasised that the hydrogen economy growth creates a possibility for employees from coal-based sectors to effectively change their qualifications. To this end, it will be necessary to commence educational activities, which will make it possible to increase social awareness of the fact that structural changes of the labour market do not entail only the liquidation of positions but also the creation of new jobs. Therefore, the Strategy anticipates that the Government should undertake actions and be involved in social campaigns sharing knowledge on the current hydrogen use and the security rules that should accompany such hydrogen use.

Energy & Industry sector uses

As specified in the Strategy, the application of hydrogen technologies in the energy sector needs to be commenced in the context of an increasing share of non-controlled electric energy from RES in the Polish energy mix. Under the draft Energy Policy of Poland until 2040, the share of RES in the net electric energy production will reach at least 32% in 2030. A significant portion of generation capacity from renewable energy installed in Poland is based on sources whose operation profile depends on weather conditions (wind, sun, partially water) and which operate for an insignificant number of hours a year.

The actions planned in the Strategy for the forthcoming five years, which are meant to support the performance of that objective, include the need to support the stable operation of distribution grids, including commissioning class 1MW P2G installations based on Polish technologies, determining the legal framework for hydrogen technology operation, support for research and development in relation to the creation of co- and poly-generation systems for the construction of demonstration installations. Studies also are envisaged in relation to the development of the hydrogen storage methods, including the possibilities of making use of large-scale salt caverns. Subsequently, the plans to be implemented by 2030 envisage the commissioning of medium-sized co- and poly-generation installations with hydrogen being the main fuel, commencing the use of hydrogen as energy storage capacity, and the installation of fuel cell systems.

The year 2030 is also a year for which the use of hydrogen as energy capacity storage is scheduled to commence with a view to supporting the operation of the RES-based energy grid. By 2030, favourable conditions should be created for establishing installations throughout the country that use fuel cells for blocks of flats, small housing estates and public buildings, which installations may also serve as a source of emergency energy supplies.

The Strategy proposed supporting actions aimed at obtaining and using low-carbon hydrogen for industrial production processes. Using low-carbon hydrogen will make it possible to significantly reduce the greenhouse gas emission within that branch of the economy in which achieving the climate neutrality is the most difficult.

The Strategy assumes that heavy industry could observe the highest increase in the consumption of low-carbon hydrogen. According to the forecasts, electrolysis using RES, with natural gas prices as high as in Europe, will achieve a cost parity for certain products and processes after 2030.

Therefore, actions designed in the Strategy to achieve this objective include: providing support until 2025 in respect of initiatives related to obtaining and using low-carbon hydrogen in petrochemical production processes, implementing a coal contract of differences as an instrument supporting climate transformation in industry, the development of technologies consisting in the production of steel in the process of its original melting process, financial and organisational support for feasibility studies of industrial hydrogen valleys as part of creating circular industrial processes.

In turn, it is envisaged that by 2030 at least five hydrogen valleys with a significant element of hydrogen transmission infrastructure in the form of pipelines will have been constructed.

Transportation sector use of hydrogen

Hydrogen for transport is a cornerstone of Poland's hydrogen economy. There is wide ranging interest within the Polish industry around the development of hydrogen transportation infrastructure, such as refuelling stations for hydrogen fuelled vehicles. One example is PKN ORLEN's focus on developing hydrogen generation and distribution installations of hydrogen fuel for this purpose. Furthermore, state funding is available to encourage individuals to purchase hydrogen fuelled vehicles. The Strategy of Sustainable Development of Transport for 2030 predicts that low emission transport, including technologies such as hydrogen, will be key in addressing the negative impact on the environment.

A number of local companies have begun developing hydrogen refuelling stations. These include the state-owned energy companies PKN ORLEN, PGNiG and LOTOS, who are planning to develop a network of hydrogen vehicle refuelling stations by 2021. PKN ORLEN's first refuelling station for hydrogen-fuelled vehicles shall be open in 2021.

PKN ORLEN is also planning to develop a hydrogen hub, with hydrogen generation installations located in Włocławek, in 2021, and in Płock at a future date. PKN ORLEN has signed a Letter of Intent (**"LOI"**) with Pojazdy Szynowe PESA Bydgoszcz S.A. – the largest manufacturer of railway vehicles in Poland – for the construction of a hydrogen fuelled train. Furthermore, PKP Cargo S.A. – the largest rail freight operator in Poland and the second in the EU – has also signed a LOI with JSW concerning joint initiatives for the commercial use of the hydrogen as a fuel.

In relation to buses, Solaris Bus & Coach S.A. – one of the leading European bus manufacturers – is currently producing a fleet of hydrogen fuelled buses.

Therefore, the Strategy envisages that the potential of hydrogen includes replacing conventional fuels, specifically in municipal/public transport, road, railroad or sea/maritime transport, and subsequently also in aviation (also unmanned aircraft aviation).

To totally decarbonise that branch, it will be necessary to implement fuel cell electric vehicles (**"FCEVs"**). FCEVs will be of special importance in the scope of public transport, as well as heavy goods and long-distance road transportation.

The Strategy assumes increasing use of hydrogen as an alternative fuel in transportation, precisely thanks to the significant advantages of FCEVs, including the fact that they can cover long distances without the need to refuel (more than 500km). In line with the Strategy's assumptions, FCEVs will play a special role in the process of decarbonising public transportation in the future, as well as heavy goods and long-distance road transportation, where there is a limited possibility of using electric vehicles.

Therefore, in the perspective of the next five years, the Strategy assumes the creation of conditions in which 500 hydrogen-driven buses manufactured in Poland will be admitted to operation, as well as 32 hydrogen refuelling stations and hydrogen cleaning installations will be constructed. The plans also include the construction of the first hydrogen-driven passenger trains/freight locomotives which will replace their combustion equivalents at railway lines which cannot be easily electrified. The projections also include the examination of the possibility and profitability of the application of hydrogen in transporting synthetic gas produced through hydrogen methanation and launching pilot programmes related to using hydrogen in heavy goods road, railroad, sea and inland/river transport.

In a 10-year perspective, the Strategy assumes that the number of hydrogen-driven buses in operation will increase to 2000, and that the refuelling infrastructure and hydrogen cleaning installations will be further developed. The forecasts state that diesel trains will be replaced with hydrogen trains and that the use of hydrogen in heavy goods transport, railroad, sea, and inland/river transport will grow. Within the same perspective, work is envisaged to produce synthetic fuels in the reaction of hydrogen with CO, CO_2, N_2. It is also planned to further increase the use of hydrogen in heavy goods road, railroad, sea, and inland/river transport.

Energy System Management using hydrogen

According to the Strategy, it will be necessary to create, by 2030, conditions for commissioning installations for producing hydrogen from low- or zero-carbon emission sources, as the majority of hydrogen in Poland is currently produced from fossil fuels. The above choice is not meant to discriminate the existing production methods but is aimed at encouraging Polish industry towards a low-carbon economy transformation.

To this end in line with the Strategy – within the next five years, activities will be undertaken with a view to commissioning the installation for hydrogen production from low-carbon sources, amongst others by electrolysis, from biomethane, waste gas, natural gas with CCS/CCU, by pyrolysis, and other alternative technologies of hydrogen production, as well as commissioning synthetic gas production in the process of hydrogen methanation.

By 2030, it is projected that the capacity installed in RES will be used for the production of hydrogen and synthetic fuels by electrolysis. The installed capacity of electrolysers will then reach 2GW, which will enable the generation of approximately 6,415GWh, i.e. 193,643 tonnes of hydrogen annually, which represents approximately 20% of the existing total hydrogen production in Poland.

The plan to be realised by 2030 also encompasses securing conditions for constructing installations in Poland for hydrogen production at nuclear power plants.

The Strategy emphasises that in order for the economy based on hydrogen to develop, it is necessary to efficiently supply it from the production place to its end recipient and its secure storage. Therefore, a gradual development of the hydrogen transmission and distribution grid is proposed. The existing solutions relating to hydrogen transportation provide for pipelines, road and railroad transportation, and it is expected in the future that network will be expanded to include oceanic transportation.

It has not yet been confirmed, under Polish conditions, whether electric energy transmission proves to be more efficient so that hydrogen is produced from it near the demand centres, or whether transmission of hydrogen generated at RES installations or of synthetic natural gas (**"SNG"**) produced from it by the existing gas grid is regarded as more efficient. The possibility of transmitting hydrogen by dedicated pipelines also needs to be considered. In the perspective of the first five years, it is also necessary to examine the existing gas infrastructure in relation to possible hydrogen feeding and transmitting mixes of hydrogen and gas.

Therefore, in the perspective outlined up to the year 2025, it is assumed that actions will be taken based on the analyses carried out, through:

— the development of the hydrogen transmission and distribution grids, whether by transmitting electric energy, transmitting hydrogen/SNG by the existing gas grid or by transmitting hydrogen by dedicated pipelines;
— the preparation of a feasibility study in respect of the north-south pipeline and the establishment of the so-called "Hydrogen Highway", and examining the existing gas infrastructure from the perspective of the possible hydrogen feeding and transmitting mixes of hydrogen and gas.

The plan of actions to be completed by 2030 stipulates adjusting selected sections of gas grid for transmission and distribution of gas doped hydrogen, constructing dedicated pipelines for hydrogen transmission and distribution or expanding the electric energy grid to transmit electric energy and feeding SNG produced in P2G systems into gas grids.

Challenges facing hydrogen projects in Poland

Legal framework gaps

Regulatory shortcomings – for example, in the transport and generation sectors – are a barrier to hydrogen development in Poland. There are still no specific provisions concerning technical conditions or localisation outside industrial areas. Therefore the Strategy assumes the implementation of comprehensive legal regulations related to hydrogen, the development of hydrogen technology and financing of projects based on that technology (more details provided in section *Regulation of hydrogen* of the Guide).

Financial support and incentives

Currently, the National Fund for Environmental Protection and Water Management supports matters connected with the generation and use of alternative fuels in general, which would include hydrogen. Nevertheless, a designated hydrogen support scheme is still needed.

There remains a need for more engagement of public and private funds in the development of the hydrogen sector generally, not just with regards to transportation. To date, companies developing hydrogen projects have utilised their own funds or have benefitted from EU financial support.

Research and education efforts

The National Centre for Research and Development supports the research and development into hydrogen storage projects. The National Fund for Environmental Protection and Water Management also provides financial support for research and education in respect of alternative fuels. However, awareness of hydrogen and an understanding of its applications amongst the general public is low.

The Hydrogen Development Technology Programme is a government level policy designed to consider new areas for use of hydrogen in energy, transportation, and the natural gas network.

GAZ-SYSTEM S.A. (**"Gaz-System"**) – the Polish Gas Transmission System Operator and a member of Hydrogen Europe since 2019 is conducting a programme, "HYready", which is aimed at analysing the possibility of the injection of hydrogen into the network. The company is seeking to transport hydrogen, together with natural gas or via a dedicated network, and is also considering hydrogen injection into underground storage.

PGNiG is conducting a project "ELIZA", which is aimed at providing technology for generation of hydrogen from renewable energy sources.

Regulation of hydrogen

Specific legislation/regulation

Currently, there is no dedicated hydrogen law in Poland. Existing provisions of the Polish legal framework primarily captures hydrogen in transportation, although this area is also not well covered. According to the assumptions underlying the Strategy, the draft comprehensive legal regulation concerning that subject is to be published at the end of 2021 and during 2022.

The Strategy provides for the drawing up of comprehensive legal regulations enabling the creation of a competitive and efficiently operating hydrogen market in Poland, removing current barriers to the development of that market.

The most important activities in that field include the creation of a legal framework for hydrogen being used as an alternative fuel in transportation, the creation of the legal grounds for the hydrogen market operation and, in the longer term, the development of the hydrogen legislative package, i.e. provisions detailing the market operation, implementing EU law in that respect, and implementing incentives to low-carbon hydrogen production.

According to the timetable adopted in the Strategy: in Q3-4 2021 the planned actions include the creation of a legal framework for hydrogen being used as an alternative fuel in transportation, and it is planned to elaborate the grounds for the hydrogen market operation and, at the turn of 2021/2022, the development of the hydrogen legislative package is scheduled. The work related to preparing legislative changes, as envisaged in the Strategy, is already delayed.

At present, the adoption of a comprehensive regulation by implementing a separate comprehensive "Hydrogen Law" has been seriously considered.

As at the date of this study, no draft acts which could regulate the above areas have been drawn up.

Policy and government programmes

As previously mentioned, there are a number of government initiatives, such as the National Centre for Research and Development, the National Fund for Environmental Protection and Water Management, as well as the Hydrogen Technology Development Programme that has formulated the National Energy and Climate Plan 2021–2030.

Primary legislation

Hydrogen legislation in Poland is fragmented. There is no dedicated act for hydrogen in the Polish legal framework. Thus, the stakeholders are forced to follow general rules arising from the Polish system of energy law, which are currently not always suitable for the development of the hydrogen technology.

However, to the extent that it is technically possible to transport hydrogen via the gas network, hydrogen could be treated as a gaseous fuel under the definition provided by the Energy Law Act. Thus, general provisions for gaseous fuels are applicable in this respect. Nevertheless, there are currently no direct provisions concerning hydrogen's injection into a gas system or a storage system.

In June 2021, the Ministry of the Climate has proposed an amendment to the Act on the Fuel Quality Monitoring and Scrutinising System. The draft legislation classifies hydrogen within the definition of fuels under this Act and outlined its use for transportation. Furthermore, the Act deals with the quality of such hydrogen. Under this Act, the minister responsible for energy matters was authorised to issue the regulation, which provides in detail the quality conditions for hydrogen and for collecting samples of it for control purposes. The Act was passed by the Polish Parliament and signed by the President of Poland on 27 August 2021.

Generation related laws

A licence for the generation of gaseous fuels is not required by the Energy Law Act. It is worth mentioning that there is a general requirement to obtain a licence in order to generate electricity from hydrogen.

Connection and distribution system related regulation

Pursuant to the Energy Law Act, there is a requirement to arrange a connection agreement to the gas network and the Distribution System Operator (**"DSO"**) is responsible for providing conditions concerning connection to the grid. Activity of DSOs is also regulated, in particular a relevant licence is required alongside a number of other regulatory requirements.

Transportation of hydrogen

The Act on Electromobility and Alternative Fuels deals with the use of hydrogen and liquid biofuels in transportation. It sets out rules for the development and operation of infrastructure and relevant disclosure requirements concerning alternative fuels and applies in particular to hydrogen. This act also provides a framework for refuelling stations for hydrogen fuelled zero-emission buses.

Financing and incentives for hydrogen projects

The Act on Protecting the Environment sets out the operating principles, which provides financial support for hydrogen transportation projects, amongst other alternative fuel projects. The financial support is provided by National Fund for Environmental Protection and Water Management in the form of a grant from the Fund, once the criteria indicated in the programme have been met by the entity.

As regards supporting the financing of new hydrogen investment projects, the Government plans to allocate its own budget funds to carry out such projects, as well as to mobilise investors to fully use the resources made available with the EU programmes.

The Strategy points out that, at present, the following programmes and funds are available in Poland in relation to supporting the development of hydrogen projects: IPCEI (Important Projects of Common European Interest) EU programme, the Infrastructure and Environment Operational Programme, or programmes established within the Polish Development Fund: PFR Green Hub, which is to support the financing of venture capital projects.

The National Fund for Environmental Protection and Water Management established two programmes "Nowa Energia" (New Energy) and "Zielony Transport Publiczny" (Green Public Transport), also covering hydrogen investments planned in the future. Since 2021 the Hydrogen Technology Support Programme *(Program Wsparcia Technologii Wodorowych)* has been in place within the National Centre for Research and Development *(Narodowe Centrum Badań i Rozwoju).*

To secure financing of the development of the said objectives, the Strategy envisages that the Government will establish a multi-year programme supporting the development of hydrogen technology under Article 136 of the Act on Public Finance dated 27 August 2009, with a value at the level of PLN 100m annually in the years 2022–2026.

As stated in the Strategy, by 2025, the achievement of the objectives related to the implementation of hydrogen technology in the energy sector and transportation, along with securing the planned production (50MW of electrolysers), will require an investment of approximately PLN 2bn. However, the above estimate does not take into account the costs of electric energy necessary to produce hydrogen, the costs of maintaining hydrogen-driven buses (fuel, maintenance services) or the development of transmission and distribution.

Regulation of hazardous activities

The main acts regulating this area are:

- the Act on Protecting the Environment (together with its secondary legislation) is key in Poland as it concerns environmental protections, particularly for the scope of the integrated permit, which is a required and crucial permit for hydrogen generation installations. This Act is also important as it regulates other permits, such as emission permits;
- the Act on Providing Information on the Environment and its Protection, Public Participation in Environmental Protection, and on Environmental Impact Assessments concerns the carrying out of environmental impact assessments and includes an obligation to conduct such assessments with respect to planned hydrogen generation projects. For this reason, it is vital for the development phase of hydrogen projects. Moreover, this Act is a guarantee of the participation in the proceedings concerning the issuance of the integrated permit for hydrogen generation installation. Installations that generate gases, such as hydrogen, are treated as potentially materially polluting installations under the regulation published by the Minister of the Environment;
- the Act on Preventing Environmental Damage and the Remediation of Environmental Damage deals with liability and subsequent remediation for damage caused by, *inter alia,* installations for which an integrated permit is required. According to the Regulation of the Council of Minister the installations required for hydrogen storage would qualify as such installations under this Act on projects that may significantly affect the environment.

Transport, import and export of hydrogen

Since there are no dedicated regulatory solutions for hydrogen under the existing legal framework in Poland, the provisions applicable for gaseous fuels should be taken into account in this respect. There is a general obligation to obtain a licence for the business activity of the distribution of gaseous fuels, however, the distribution of gaseous fuels in the network with a capacity below one MJ/s is not subject to the licensing requirement. Specific rules related to transport of dangerous goods apply to road and railway transportation. The Regulation of the Ministry of Health on the method of marking places, pipelines, containers, and tanks for storing or containing hazardous substances or hazardous mixtures would also apply to the transportation and storage of hydrogen.

Regulatory bodies

Since there are no hydrogen-specific provisions, the general provisions concerning the investment process and exploitation of industrial installations and devices apply to hydrogen.

The most important regulatory bodies are:

— the President of the Energy Regulatory Authority which governs the licensing of gaseous fuel storage and its distribution, and tariffs related to the gaseous fuel market; and
— local authorities that govern spatial planning and the building process, which are vital areas for the installation of electricity generators and refuelling stations, among other things.

Regulatory outlook and market prospects

The potential of hydrogen to enhance the economy is recognised in Poland. There is a huge interest in this technology; Polish authorities are convinced that Poland could be one of the leading countries in this area and could be a transit country for the mixture of natural gas and hydrogen in the future. This enthusiasm is reflected in various strategic documents for the sector where hydrogen is considered, especially in the Strategy, which main assumptions were described in this study. The use of hydrogen in transportation as a fuel and as a technology for energy storage are currently the main areas of growth in Poland.

Hydrogen technology is still at the early stages of development in Poland. There remains a lot of scope for M&A activity and investment opportunities that are also open for private investors and funds. To date, however, no significant activity of this type has taken place and companies involved in this market are predominantly state-owned. Nevertheless, the private sector is becoming increasingly involved in this area. One example is a recent acquisition of an electrolyser by Zespół Elektrowni Pątnów-Adamów-Konin S.A. – a private owned complex of four thermal power plants - for the purpose of generating hydrogen from renewable sources. Furthermore, in June 2020, Polenergia S.A. – the largest Polish private energy group – signed an LOI with Siemens Energy sp. z o.o. and Siemens Gas and Power GmbH & Co. KG concerning the introduction of solutions which shall make it possible to produce and use hydrogen in the Polish market.

Since a number of commercial banks are starting to opt out of financing carbon intensive, fossil fuel energy projects, their attention is likely to turn to providing debt financing to stakeholders investing in new, low carbon technologies, such as hydrogen projects. This will be important given that the infrastructure needed for the development of low carbon hydrogen projects is likely to involve significant capital expenditure (e.g. new pipelines, electrolysers etc.).

Low carbon hydrogen production is currently expensive compared to the production of hydrogen from coal or methane gas, having not yet benefitted from the price reductions seen across certain, more mature low carbon technologies. Developers, therefore, will often need financial assistance beyond their own equity investment to support hydrogen projects. However, smaller developers are not always able to satisfy the conditions attached to bank financing. State support may, therefore, have a crucial role in funding hydrogen projects at least initially and particularly for smaller developers.

While there is some government support in research and development (discussed in more detail above), more government engagement is required in order to develop this technology, especially in more capital-intensive areas, such as infrastructure. This is because a significant part of the Polish gas infrastructure is old, and consequently not suitable for the purpose of transporting hydrogen. Despite the fact that Poland is one of the most active issuers of these bonds, there are still no plans concerning this method of financing for hydrogen technology.

It is worth noting that, in Poland, all kinds of hydrogen are at present produced mainly for its producers' own needs, which, however, does not result from the lack of possibilities of producing larger amounts of hydrogen. The producers jointly indicate that production can be increased as the production capacities of the hydrogen installations are not 100% utilised. However, the current lack of a developed hydrogen trade market means that most producers simply do not find it profitable to produce hydrogen in amounts larger than their own needs related to the core business of these business entities.

Upcoming developments

On 7 July 2020, an LOI was signed by the Ministry of the Climate and 17 other entities, concerning the establishment of cooperation for the purpose of building a hydrogen economy and conclusion of a hydrogen sector deal. Signatories include leading Polish companies, energy and transportation organisations, such as: Grupa Azoty S.A., Grupa Lotos S.A., Instytut Ekologii Terenów Uprzemysłowionych, Instytut Energetyki, Instytut Nafty i Gazu – Państwowy Instytut Badawczy, Jastrzębska Spółka Węglowa S.A., Operator Gazociągów Przesyłowych Gaz-System S.A., PKP Energetyka S.A., Politechnika Rzeszowska, Polski Koncern Naftowy ORLEN S.A., Polskie Górnictwo Naftowe i Gazownictwo S.A., Polskie Stowarzyszenie Paliw Alternatywnych, Tauron Polska Energia S.A., Toyota Motor Poland Company Limited sp. z o.o., TÜV SÜD Polska Sp. z o.o., Wałbrzyskie Zakłady Koksownicze "Victoria" S.A., Stowarzyszenie Polski Wodór, and Poczta Polska S.A. The signatories of this LOI declared to cooperate in the research and development of hydrogen. The purpose of the agreement will be to prepare a roadmap aimed at developing the hydrogen economy. The roadmap will be related to the development of strong national and local competence in the field of production of key components in the hydrogen technology value chain, hydrogen mobility and hydrogen in the sectors of the economy in which climate neutrality is not easily achievable.

Furthermore, there are also plans to use the Baltic Pipe Project (a gas pipeline that is under construction connecting the Norwegian, Danish and Polish markets) in order to transport hydrogen and other gases.

An Inter-Departmental Team for Hydrogen Economy has recently been established by the Polish government.

With the first zero-emission buses already in the testing phase, local governments are placing orders for the buses and they are expected to start driving on Polish roads soon.

Currently Polskie Górnictwo Naftowe i Gazownictwo S.A. (**"PGNiG"**) – the leader in the Polish natural gas market - plans to introduce hydrogen as a blend into the gas network for commercial sale to customers, particularly in the heat sector but also, in the future, alongside other associated services. Moreover, the company is planning to develop hydrogen energy storage. The company is also seeking to develop Power 2-Gas technology, however, PGNiG needs the introduction of regulatory solutions which would allow it to operate this kind of project. Currently, the company is at a stage of conducting research on the proportion of hydrogen that may be blended in the existing gas network. PGNiG's testing gas network is scheduled to start operation in 2022.

Grupa LOTOS S.A. (**"LOTOS"**) – a member of Hydrogen Europe and a leading oil company in Poland, which, together with Grupa Azoty, is responsible for half of hydrogen production in Poland – is developing a hydrogen purification project. The 'Pure H2' project is aimed at developing a hydrogen cleaning and distribution installation which would produce low greenhouse gas emissions. In addition, LOTOS' 'Project Hestor' is developing onshore hydrogen storage for use in industrial processes. LOTOS has also established an electrolysis research and development project in conjunction with Polskie Sieci Elektroenergetyczne S.A. (**"PSE"**), the Polish Energy Transmission System Operator, to produce green hydrogen for use in its refining processes. Whereas Gaz-System – considers the future use of hydrogen via its injection into the gas network and its storage.

There are also plans for changes in relation to decarbonisation. One example is the activity of Tauron Polska Energia S.A. (**"Tauron"**), which supplies electricity to over 5.6m customers per year and is the largest distributor of electricity in Poland. Tauron set up a pilot project in the Łaziska hard coal-fired power plant concerning production of green hydrogen from renewable energy.

One of the areas of development of Jastrzębska Spółka Węglowa S.A. (**"JSW"**) – the largest producer of high-quality coking coal in Poland and the largest commercial group of coking plants in the EU – has been the separation and purification of hydrogen from coal gas using pressure swing adsorption (**"PSA"**) technology.

The activities of Polish companies described above are fully consistent with the objectives set out in the Strategy, concerning the implementation of hydrogen technologies in energy, industry and transportation sectors of the Polish economy.

Portugal

Authors:
Mónica Carneiro Pacheco
Manuel Branco

Current status for hydrogen in Portugal

Introduction

Hydrogen is a key element in Portugal's near term energy transition. There are a number of ongoing projects concerning hydrogen production and transportation. Portugal also has a number of projects for decarbonising of industry as well as the decarbonisation of electricity and heat generation.

Whilst, at present, low-carbon hydrogen is not widely used, Portugal is endeavouring to grow the domestic use of clean hydrogen. Green hydrogen, in particular, is expected to be a major contributor in helping Portugal comply with its ambitious 2030 targets as set out in the National Plan regarding Climate Energy (**"PNEC"**). Additionally, the European Union in its Hydrogen Strategy[1] has set out its intentions of investing EUR 40m in the ongoing Portuguese projects.

The most important document in relation to hydrogen is the National Strategy for Hydrogen (the **"Strategy"**) which was launched for consultation in May 2020. The Strategy set out a number of proposed projects and funding options in relation to using green hydrogen in the sectors mentioned below. The public consultation closed on 6 July 2020 and publication of the final document was approved and published on 14 August by Resolution of the Council of Ministers.

We have set out below some key hydrogen related projects currently in development in Portugal.

Hydrogen Production

The company Fusion Fuel is aiming to develop hydrogen production using Solar PV energy, i.e. electrolysis using solar power. The company claims that the method they use to create green hydrogen is as cost-efficient as traditional methods that produce brown and blue hydrogen. The advantage of DC PEHG[2] technology is in obtaining energy converting rates of 27% (from solar to hydrogen) with low production costs. This is because hydrogen is produced directly at the place of solar energy production with no need for transportation, transformation or other infrastructure. Hydrogen production is expected to start in 2022.

[1] "A hydrogen strategy for a climate-neutral Europe" https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[2] Corresponds to the usage of photovoltaic concentration simultaneously with the heat that in that technology is dissipated, to proceed with the electrolysis of the water in a decentralised way, avoiding all the transmission losses due to the fact that the electrolysis is physically coupled to the production of energy and heat.

Separately, EDP, Portugal's largest utility, has also set a target in respect of hydrogen production from offshore energy with the development of a modular and standardised system. Its aim is to be able to open new markets with hydrogen production and to increase competition in the offshore energy sector.

Transport sector

In the transport sector, there are a few projects in development, such as *Power-to-Mobility*. This also includes the development of hydrogen refuelling stations for small and large road vehicles. In the case of the *Power-to-Mobility* project, it anticipates offering hydrogen fuel which is produced from solar energy and the project expects to have an average capacity of 300kg/H2/day.

For marine transportation, *Shore-to-ship* is another project in respect of the refuelling of cruise ships. Again, this will take the form of a green hydrogen refuelling station, and the installation is expected to have an average capacity of 1000kg/H_2/day.

Lastly, the development and manufacture of hydrogen buses is being undertaken by a partnership consisting of CaetanoBus, SA and Toyota. On 13 August 2021 in Cascais, the first ever hydrogen-powered bus was put into circulation in Portugal (which was 100% manufactured in the country). The bus uses the same fuel cell as the Toyota Mirai and has a driving range of 400–600km, with refuelling only taking 10 minutes. This bus is particularly innovative as the tank is located on the roof, providing a larger capacity for passengers. The Municipality of Cascais has already stated that by the end of 2021, the first hydrogen refuelling station will be ready and open to the public.

Industry sector

The Ultimate Technology to Industrial Savings (**"UTIS"**) is developing a project to decarbonise certain industrial processes using hydrogen. The base principle of the company's technology is the injection of a low amount of hydrogen and oxygen into the combustion system. The hydrogen will be produced locally (1 to 10m^3/h) in dedicated units adapted for the use of various types of energy sources.

Heating sector use of hydrogen

Portugal relies on methane gas for electricity production and heating. Accordingly blending and pure hydrogen based heating is the long term goal. As such, EDP is investing around EUR 12.6m (over the next four years) to develop new power-to-hydrogen-to-power (**"P2H2P"**) solutions integrated in combined cycle thermal power plants (**"CCGT"**). The name of the project is "FLEXnCONFU" and the project will be developed for hydrogen production in the Ribatejo Combined Cycle Power Plant. It has been planned that an electrolyser with an installed capacity of 1MW and 12MWh of storage capacity will be connected.

The project's main objective is to develop new power-to-X-to-power (**"P2X2P"**) solutions integrated in CCGTs with dedicated hydrogen and ammonia firing turbines; the ultimate aim being to reduce the burning of natural gas to produce electricity. EDP has stated that the first step is to gain experience in hydrogen production and in its conversion in electricity. After this, the project intends to demonstrate the possible injection of hydrogen into natural gas pipelines. This is seen as a solution that will allow economies of scale in the generation, transport and distribution of hydrogen in the future.

Market prospects for hydrogen

Although the hydrogen market in Portugal is nascent, it is expected to grow rapidly in the near future. In terms of funding, Portuguese Secretary of State of Energy stated that the European Union is willing to invest heavily in Portugal.

Policy and government programmes

The abovementioned Strategy has said that it is possible to blend around 22% of hydrogen into the natural gas network without impacting the calorific power of the gas in the grid. As such, the calorific power remains within the limits of the legislation. There is also a longer term goal to export pure hydrogen through a gas pipeline in the future.

Other programs include the PNEC and the RNC50 (Carbon Neutrality Roadmap)[3] which have a main role to identify and release guidelines for the decarbonisation of Portugal by the year 2050, and hydrogen is now seen as a vital component in helping to reach that target.

Primary Legislation

Since 28 August 2020, Portugal has introduced specific legislation regarding hydrogen regulation, albeit this is not very detailed. In fact, with the publication of Decree-Law no. 62/2020, of 28 August, which also transposed Directive (EU) 2019/692, green hydrogen has been included in the remit of the Portuguese National gas system (former National Natural Gas System), and defined as a gas of renewable origin.

This Decree-Law guarantees that the production of this type of gas is a liberalised activity with low administrative requirements of eligibility. Accordingly, a hydrogen producer can allocate the product for any purpose, particularly self-consumption, injection in public gas networks, bulk supply to any consumer, either for industrial or private purposes, export or for use in other sectors, such as transport.

On the other hand, following the approval of the Strategy and in line with the clear commitment that the Government intends to make on hydrogen and biomethane as fundamental for Portugal to achieve carbon neutrality by 2050, such decree-law creates the conditions for the material incorporation of gases of renewable origin or low-carbon content within the national gas system. In light of the relevant modifications and reorganisation that it introduces in the sector, its publication led to the revocation of Decree-Law no. 30/2006, of 15 February and of Decree-Law no. 140/2006, of 26 July, as amended, (whose principles related to the organisation and functioning of the National Natural System are now gathered in a single legal instrument).

It should also be noted that, with the entry into force of this decree-law, the consumers will be obliged to consume a certain share of gases of renewable origin or low-carbon gases and the supplier of last resort will be entrusted with the role of facilitator between production and commercialisation. This is intended to ensure the acquisition of this type of gas as it will be needed by other market agents to meet the minimum incorporation share of hydrogen on the network.

[3] Portugal has committed itself internationally to reducing its greenhouse gas emissions so that the balance between emissions and removals from the atmosphere is zero by 2050. This objective has been given the name of "carbon neutrality".

Regulation of hazardous activities

To pursue environmental protection, Portugal guarantees the right to a balanced ecological environment. Among others, the Decree-Law 62/2020 requires a statement by the Environmental Impact Assessment Authority that the relevant hydrogen project is not subject to an environmental impact assessment (**"EIA"**) or, if there is the need for such an assessment, that the project has obtained a favourable EIA and has complied with any conditions imposed on it.

Regulatory bodies

The hydrogen sector is regulated within the remit of gas regulation.

DGEG (from the State's direct administration) and ERSE (the energy regulator) are the regulatory bodies responsible for the regulation of the Portuguese energy sector. DGEG's mission includes seeking to contribute towards the promotion and evaluation of energy policies. It is also responsible for issuing permits necessary for injection into the power grid and regulates the development of systems, processes and equipment linked to the production, transmission, distribution, and use of energy. The ERSE regulates the electricity and natural gas markets in relation to trade relations and quality-service. The legislation that establishes the general principles of the organisation and functioning of the National Natural Gas System, the National Electric System and electric mobility attributes regulatory competence to ERSE.

Following the release of the Strategy, it is possible that new regulatory bodies may be established in the future.

Upcoming developments

Goals for 2030

Portugal aims to have hydrogen represent a viable and suitable energy source by 2030. Therefore, the national goals are to have the following targets achieved over the coming decade:

— 5% of hydrogen in road transportation consumption, in the energy sector consumption and in the final consumption of overall energy.
— 15% of hydrogen injected into the natural gas network.
— 50 to 100 hydrogen refuelling stations developed across Portugal.
— A reduction of natural gas important to a value of EUR 300 to EUR 600m.
— Investment of EUR 7bn on hydrogen production projects.

Upcoming projects

In addition to the projects identified in the Strategy, three further domestic projects are worth noting:

"H2 Sines"
This project which is due to begin construction in 2021 is to create a EUR 7bn hydrogen solar power plant in the Sines Industrial and Logistics Zone (ZILS). Sines was chosen as the location for hydrogen production infrastructure owing to the deep waters that surround the port as well as the existing electricity grid connections. It also has the most optimal weather suited to producing solar energy. The project involves 13 companies with partners from Germany, Denmark, and the Netherlands. The objective is to produce hydrogen powered by solar PV generation and then export it to the Netherlands and other northern European countries. When fully operational, it will have the capacity to produce around 465 tonnes of hydrogen a year.

In a first phase, the installation of a 10MW electrolysis pilot project is foreseen, which, throughout this decade, shall evolve to a 1GW capacity, aiming in time to install around 1.5GW of renewable electric energy generation capacity to feed the electrolysers.

Synthetic Fuel for Aviation
This is a project being developed by Solabelt and Akuo Energy. The goal is to use green hydrogen produced by electrolysis using electricity generated from solar PV sources to produce an alternative aviation fuel. The production of such fuel should be around 10 tonnes a year. The forecasted investment for this project is around EUR 90m. The project is being developed but there is no estimated date to become operational as of yet.

Hydrogen Auctions
In the first semester of 2021, the Government gave a presentation offering details of the first green hydrogen auction. The Portuguese Secretary of State for Energy mentioned that such hydrogen auction is scheduled to be held during the course of 2021.

It was also stated that such auction will not be aimed for producers, but for hydrogen users and thus all companies shall be eligible to go to auction, including energy traders. Finally, the Portuguese Secretary of State for Energy stated that a certain amount of hydrogen shall be auctioned, but it has not yet been defined what such amount will be.

Romania

Authors:
Varinia Radu
Ramona Dulamea
Raluca Diaconeasa
Daniela Coman

Current status for hydrogen in Romania

Introduction

In 2018 Romania signed the Hydrogen Initiative. By signing this proposal, Romania committed to continuing research and innovation into how it will use hydrogen as an energy source for the future. Hydrogen and its associated technologies are being explored for use in the electricity storage sector, the transport sector and in industry.

According to the Integrated National Plan in the field of Energy and Climate Change 2021–2030 (**"PNIESC"**), submitted to the European Commission in April 2020, Romanian authorities are considering the implementation of a number of pilot and demonstration projects to promote the use of hydrogen in the production of electricity and in the industrial sectors.

In order to promote decarbonisation and the adoption of these new technologies, there will need to be a consolidation of the legal framework, intensifying dedication to research and innovation (in both state-owned and private companies), increasing and diversifying funding sources and developing educational resources, as well as supporting projects that promote the increased use of hydrogen.

Romania is also developing a hydrogen strategy, which is envisaged by the recently approved National Recovery and Resilience Plan. The strategy focuses on the development of new distribution networks capable of supporting a gas blend comprising of initially 10% gas and hydrogen. The National Recovery and Resilience Plan includes provisions regarding:

— the development of renewable gas distribution infrastructure (using natural gas in combination with green hydrogen as a transitional measure);
— green hydrogen production capacity; and/or
— an electricity storage, hydrogen-ready distribution network. This is to be completed and function in the Oltenia region.

In February 2021, the Romanian Official Gazette published Decision 11/2021 of the Chamber of Deputies on the adoption of the opinion on the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A strategy for hydrogen: for a climate neutral Europe COM (2020) 301.

The Decision includes 18 points and sets guidelines for a future national strategy on hydrogen, including the development of a legal framework to support the expansion of the hydrogen market, as well as the revision of existing renewable energy legislation to integrate new developments into the hydrogen market.

Energy & Industry sector use

At present, hydrogen is used mainly in the chemical industry, specifically in refineries and for ammonia production. In Romania there are currently 13 industrial producers of hydrogen (all from fossil fuels), and the hydrogen market comprises of two main types of players: captive producers, which produce hydrogen for their direct customers or their own use; and by-product hydrogen resulting from chemical processes, the chlor-alkali industry.

The Societatea Națională de Gaze Naturale Romgaz SA Mediaș (**"Romgaz"**), the largest natural gas producer in Romania, plans to build an electricity plant that will integrate hydrogen into the production of electricity through a 200MW natural gas power plant in Turnu Severin – Halanga.

In June 2020, Romgaz and Liberty Galați, the largest integrated steel plant in the country, signed a memorandum for the construction of a gas plant alongisde wind and solar PV capacities. The aim of the EUR 1.2bn project is to develop greenfield investment projects, specifically the development of natural gas-fired electricity generation and hydrogen, to be used by the steel plant. The investment should make the Galati steel plant carbon-neutral by 2030.

Several municipalities are testing hydrogen fuelled buses to be used for public transportation and have announced their intention to purchase these vehicles. These municipalities include: Oradea, Bucharest and Cluj.

The Romanian authorities have also initiated discussions with Alstom Europa for the introduction of hydrogen fuelled trains to the Romanian rail network. The Minister of Transport stated in March 2021 that Romania wants to test the trains with hydrogen, being a new and promising technology.

In March 2021, Hidroelectrica approved the memorandum of understanding with Verbund AG for the joint development of the project 'Green Hydrogen @ Blue Danube' aimed at the production, transport, and sale of green hydrogen.

Hidroelectrica wants to develop in partnership with Verbund green hydrogen by electrolysis of water on a large scale in Romania, using a mix of green energy (off grid wind and on-grid hydro). The resulting hydrogen would be incorporated into a mineral oil and transported on the Danube to countries in the Transregational Danube Interreg program, such as Austria, Bulgaria, the Czech Republic, Germany, Hungary, Slovakia, Montenegro and Serbia.

Research and education efforts

Several public universities and research institutes in Romania are involved in hydrogen and fuel cell research and development. In particular, a number of projects are conducting intensive investigations on various issues related to hydrogen energy, particularly in relation to hydrogen storage. Public funding for the research and development of hydrogen is available through the Executive Unit for the Financing of Higher Education, Research, Development and Innovation (**"UEFISCDI"**) subordinated to the Ministry of Education and Research. From public estimations, Romanian research authorities have spent more than EUR 20m for hydrogen and fuel cell related research since 2000.

The National Hydrogen and Fuel Cell Centre (**"ICSI"**) develops and implements projects on new technologies (including hydrogen projects). The ICSI was a partner to the HyUnder project and has collaborated with the Joint Technology Initiative on Hydrogen and Fuel Cells Research Group and N.ERGY Group.

In 2012, the Romanian Association for Hydrogen Energy (**"AEHR"**) was founded. The AEHR aims to support actions related to the hydrogen economy and fuel cells, as well as the infrastructure and renewable energy associated with them. This will be achieved through: technology transfer, promoting Romanian contributions, close cooperation with international and national associations, supporting the implementation of educational policies and research and the promotion of education.

The **"Choose Renewable Hydrogen"** initiative currently includes companies and associations which are also active in Romania, such as EDP, Enel, Iberdrola, MHI Vestas. The initiative is expected to develop renewable hydrogen projects under the scope of the European Green Deal.

Market prospects for hydrogen

Financial support and incentives

The use of pricing tools to provide incentives for low-carbon transport will be useful in helping deploy hydrogen in the transport sector in Romania. This deployment can be achieved by encouraging the purchase of "green" cars, the use of low-carbon fuels and reducing the use of cars, generally. Specific tools already implemented to achieve these objectives are represented in the application of tax reductions for green vehicles (e.g. hydrogen, methane and electric vehicles).

Hydrogen based projects may also be eligible for the Contract for Difference mechanism. This is currently being developed by the Ministry of Economy, Energy and Business Environment (**"ME"**) as a viable option for implementing a support scheme for the development of the new low-carbon generation sector in Romania.

The InvestEU programme also provides support in developing infrastructure for alternative fuels: electricity, hydrogen and liquefied or compressed natural gas mixed with bio-methane (> 50%) and other low and zero emissions technologies.

Several companies that are active in wind energy production have proposed a number of storage projects to be financed by European funds, through the 10d mechanism – Modernisation Fund. One of the projects, with a value of EUR 50m, *"uses PEM electrolysers (alkaline electrolysers with proton exchange membranes - ed.) in order to balance the production of wind energy and to produce hydrogen from excess (or cheap) electricity, which will be introduced into the natural gas network or used in industrial applications for the decarbonisation of industrial processes (steel industry, ammonia, petrochemical industry"*.[1]

Challenges facing hydrogen projects in Romania

Legal framework gaps

Romania has yet not developed hydrogen specific legislation. This will be instrumental for the further deployment of hydrogen.

It is also important that the country removes any barriers that may affect hydrogen production at fuel supply level; this is because hydrogen production is classified as an industrial production activity, regardless of its origin of production.

[1] https://www.economica.net/proiecte-de-stocare-a-energiei-de-peste-100-mw-in-romania-unele-care-implica-si-hidrogenul-pe-lista-cererilor-de-finantare-din-bani-europeni_178590.html

Regulation of hydrogen

Policy and government programmes

According to PNIESC, in order to achieve energy security, Romania needs to "diversify its resources, including the development of new capacities of renewable energy and integration with other markets in the region as well promoting the use of hydrogen".

The Romanian Government has recently adopted a Memorandum initiated by the Ministry of European Funds and supported by the Ministry of Education and Research. The Memorandum proposes funding, in the next programming period (2021 – 2027), for Romania's first hub dedicated to hydrogen, for research and development in respect to the use of hydrogen in transportation, district heating and nuclear energy generation, as the "fuel of the future".

Primary legislation

An amendment was made the Energy Law on 24 July 2020 in order to include hydrogen production provisions (**"Law 155"**).

In accordance with Law 155, the general regulatory framework on hydrogen will be established by the energy regulator, ANRE. ANRE will elaborate on the technical and commercial regulations regarding the operation of a hydrogen terminal and the methodology of related tariffs, within six months from receiving an application to authorise the construction of the terminal. Tariffs for services provided by the hydrogen terminal operator, regarding the operation of the terminal (e.g. hydrogen storage facilities), are established by the economic operator concerned. These will be approved by ANRE and published on the operator's own web page.

Law 214/2020 provides a comprehensive programme for the development of smart grids at national level. However, no specific reference to hydrogen infrastructure is included.

Generation related regulation

Law 155 introduced the requirement for a license to be held for the commercial generation of hydrogen. Secondary legislation is soon expected which will provide further regulatory provisions in respect of licensing and the operation of hydrogen production.

Connection and distribution system related laws

According to Law 155, ANRE will need to establish the conditions and standards for the injection of hydrogen into existing natural gas networks. This will facilitate hydrogen blending into the gas grid and will need to be in line with the proposals awaited in the national hydrogen strategy.

Transport, import and export of hydrogen regulation

In March 2017, the National Policy Framework for Market Development Regarding Fuel Alternatives in the Transport Sector and for the Installation of Relevant Infrastructure in Romania was established. The national legislation and policy framework do not include any specific number of hydrogen filling stations that are to be developed.

In Romania, no specific legal framework has been developed regarding the design, authorisation, construction, and operation of hydrogen filling stations.

The policy on the installation of the infrastructure for the alternative fuels sets out the minimum requirements for the creation of alternative fuel infrastructure, including recharging points for electric vehicles and refuelling points for compressed or liquefied natural gas and hydrogen. It also outlines common techniques for recharging and refuelling points, as well as requirements for user information.

Separately, the law 37/2018 on the promotion of the ecological transportation provides that local public authorities, autonomous utilities, and private companies which supply transport services (e.g. taxi companies) are obliged to ensure that at least 30% of their total future fleet are "green" transport solutions. These may include electric, hybrid, hybrid plug-in, or hydrogen (**"FCV"**) vehicles, motors powered by compressed natural gas, liquefied natural gas propulsion engines, and biogas propulsion engines.

Law 34/2017 on the installation of infrastructure for alternative fuels lays down minimum requirements for the creation of an alternative fuel infrastructure, including recharging points for electric vehicles and refuelling points for compressed natural gas, liquefied natural gas and hydrogen, to be implemented through national policy frameworks. It also proposes common technical specifications for such recharging and refuelling points, as well as user information requirements.

Secondary legislation and other legal documents

The draft of Romania's National Energy and Climate Plan includes various references to hydrogen. There have also been a number of initiatives set out by various stakeholders advocating for a transition to a hydrogen economy from a carbon-dependent one.

At the end of 2020, ANRE published in the Official Gazette several orders outlining a legal framework for hydrogen projects: Order 200/2020 on the approval of the Framework Conditions for validity associated with the establishment authorisation for new hydrogen production installations; Order 201/2020 on the approval of the Framework Conditions for validity associated with the license for commercial operation of new hydrogen production facilities; and the 2020 Validity condition associated with the establishment authorisation for new hydrogen production facilities.

Regulation of hazardous activities

Hydrogen is classified as a dangerous substance for transport and is included in the list of dangerous goods as per the European Agreement concerning the International Carriage of Dangerous Goods by Road (**"ADR"**), which has been implemented at a national level. From a legal and administrative perspective, the same regulations apply for the storage of hydrogen as the storage of other flammable and dangerous gases.

Regulatory bodies

The Romanian Energy Regulatory Authority is responsible for the drafting of the regulatory framework regarding technologies such as hydrogen.

A number of regulators also have responsibilities depending on the activity in question:

Regulatory Body	Role
Local Authority / Town and Country Planning Authority	— Regulates the use of land — Undertakes Environmental Impact Assessment — Usually has the role of the hazardous substance authority in relation to storage
National Agency for Mineral Resources	— Manages the national pipeline system of oil and natural gas transportation
Transgaz	— Technical operator of the national gas transmission system and is responsible for its operation. It monitors quality, safety, efficiency and environmental conditions.

Upcoming developments

Over the next few years, it is anticipated that the government will promote and foster the decarbonisation of economy, industry, and business by supporting the introduction of new technologies, such as hydrogen and fuel cells, in order to reduce emissions and protect the environment.

There is discussion amongst decision-makers to reshape the existing energy legislation, and as such it is expected that the legislation and rules supporting decarbonisation will be updated and simplified soon. At a national and local level, decision-makers should find appropriate ways to promote new technologies, such as hydrogen, to attract international as well as domestic investment. Increased awareness about the role of hydrogen has been promoted by government officials who also state that it is of paramount importance that Romania adopts a hydrogen national strategy.

Russia

Authors:
Thomas Heidemann
Dmitry Bogdanov

Current status for hydrogen in Russia

Introduction

Russia is witnessing a growing interest at governmental and industry sector levels in the development of the hydrogen industry. There have been efforts in this regard since the early 2000s, when a number of research and development projects were started in the hydrogen space. The Russian company Norilsk Nickel invested USD 40m specifically for this purpose. This was generally in line with worldwide trends at that time of looking for alternative sources of energy with reduced emissions. However, by the 2008 financial crisis when oil prices plummeted, research in hydrogen energy in Russia was suspended and Norilsk Nickel stopped financing the project.

A fresh focus on energy transition and decarbonisation has inspired a renewed interest in hydrogen energy. In August 2019, a meeting on this topic was held in the Russian Ministry of Energy. Both officials and representatives of state-owned companies Gazprom, Rostech and Rosatom met to discuss worldwide trends and perspectives of hydrogen projects in Russia. It was decided that a state programme of hydrogen energy would be developed in Russia along with a road map for the future.

In October 2020, the Russian Government adopted the road map (the **"Road Map"**)[1] for developing hydrogen energy in Russia in the period up to 2024. This has become the first official document in this area in the country.

In July 2021, the government created an interdepartmental working group to oversee the development of hydrogen energy in Russia. The group, chaired by a deputy prime minister, includes the representatives of several federal ministries, state universities, state-owned investment bank VEB.RF and major corporations, such as Gazprom, Rostech, Rosatom, Novatek and several others.

In pursuance of the Road Map, in August 2021 the government adopted another important document – The Concept of Hydrogen Energy Development in Russia (the **"Concept"**).[2] It defines the goals, tasks, initiatives and key measures for developing hydrogen energy in Russia for medium term (until 2024) and long term (until 2035) and also sets out the main benchmarks up to 2050.

Following the global trends, it is anticipated that a third document – strategy – will be also prepared in the future.

[1] Decree of the Russian Government No. 2634-r dated 12 October 2020.
[2] Decree of the Russian Government No. 2162-r dated 5 August 2021.

Industry sector use

At present, hydrogen is produced in Russia primarily for use in the oil refinery, steel and chemical industries. There are several producers of hydrogen, most of which are subsidiaries of world's leading brands such as Praxair, Air Liquide and Linde. In Russia, hydrogen is often produced directly at the plant, where it is used. The total average annual volume of hydrogen currently produced and consumed in the country is about 5m tonnes. Currently, all of the locally produced hydrogen is classified as "grey".

Transport sector use

Whilst it is generally acknowledged that in the future hydrogen will have a role to play in decarbonising passenger vehicles and public road transport, there are no projects in this area being developed in Russia to date.

In September 2019, the Administration of the Sakhalin Region, Russian Railways, Rosatom and Transmashholding signed a cooperation agreement on the organisation or development of hydrogen-powered railway transportation in Sakhalin. To date, the parties are still preparing the project's technical and economic assessment. According to the Road Map, the first test field for trains with hydrogen fuel cells will be built by Rosatom by 2024.

In November 2019, the first hydrogen-powered tram was tested in St. Petersburg. At the end of 2020, the Russian president ordered the government to create hydrogen-powered city buses by 2023. The Moscow Government has also announced plans to operate hydrogen-powered buses in 30 years' time. However, all these plans are still far from the implementation of a nationwide use of hydrogen-powered transportation system in the country.

All in all, the hydrogen industry in Russia is currently in its early stages and further development will largely depend on governmental decisions on state strategy and support in this area.

Market prospects for hydrogen

According to a report prepared in 2019 by the infrastructure centre EnergyNet (the **"Report"**),[3] in order to create a hydrogen energy sector in Russia by 2025–2035, investments of up to USD 3.9bn per year will be necessary. Such investments, however, have the potential to produce an annual profit of up to USD 3.1bn. The Report emphasised that the export of hydrogen to the global market should be a top priority for the Russian economy, with an ambitious goal to make up to 15% of the global hydrogen export market by 2030. Development of hydrogen projects in other sectors like transport and energy are also being considered.

Russia has all of the internal resources (such as power, water and natural gas) and sufficient capacities to produce hydrogen for a global market. Its location close to potential importers such as the EU, China and Japan, is also an important advantage. The Report also considers the available capacities of several hydro power and nuclear plants which may have the potential to produce low-carbon hydrogen.

The Report was considered at a meeting held by the Russian Ministry of Energy in August 2019, and as such it is anticipated that the majority of upcoming projects will be concentrated on the creation of a hydrogen export market.

[3] https://energynet.ru/upload/Перспективы_России_на_глобальном_.pdf

The Road Map and Concept also envisage the export of hydrogen playing a key role in the coming years. According to the Road Map, Gazprom and Rosatom will be the country's main producers of hydrogen. Both plan to launch their pilot hydrogen production plants by 2024.

It is likely that in relation to hydrogen projects, investors will apply the same financing approaches as used in other energy sectors, such as oil and gas. Consequently, there could be a combination of both equity and debt financing typically using standard project financing such as bank credit facilities, with equity financing currently being the more preferable option. It may be also possible to implement the projects through structures or joint ventures co-established with state-owned companies like Gazprom, Rostech and Rosatom or with state funds like Russian Direct Investment Funds acting as equity investors. In the latter case, investors may also attract debt financing from the dedicated state-owned investment bank VEB.RF.

The Concept does not provide any specific state incentives for investors. Thus, at present, investors may apply for government's general support mechanisms, including investment tax credits, tax reliefs, special investment contracts, investment protection and promotion agreements, other benefits and subsidies that depend on the projects' specificity. Dedicated tax and export customs exemption could also be considered among possible means of boosting development in the hydrogen production sector.

Lack of dedicated state incentives in this area makes hydrogen projects in Russia riskier and less predictable in terms of profitability as compared to, for example, other renewable energy projects in wind, solar and medium (up to 50MW) hydro power industries, where the applied beneficial tariffs fixed for 15 years allow investors to receive a guaranteed 12% profit margin.

Challenges facing hydrogen projects in Russia

State support and incentives

As mentioned above, there are currently no dedicated state support measures or incentives for the hydrogen industry in Russia. It is expected that the government will pay more attention to this issue at the first stage of the development of hydrogen energy in the country, as stipulated by the Concept, from 2021 to 2024. The lack of state support prevents the implementation of major projects in this emerging industry, particularly because such projects require significant investments at the early stages and such capital outlays would not be secured by guaranteed profit.

Production costs and demand

The production and processing of low-carbon ("green") hydrogen, which will likely be the most attractive type of hydrogen for export purposes as countries endeavour to achieve their net-zero targets, is more expensive than producing "grey" hydrogen. The production of hydrogen at scale may be a solution for reducing costs, but such production is subject to securing demand for the hydrogen produced.

Despite the efforts currently taken by the government to secure export opportunities for hydrogen producers (for example, an agreement was signed with Japan in 2019 on the preparation of the technical and economic assessment of hydrogen export), it is still not completely clear how and where Russia's hydrogen will be sold. Ideally, such sales should be secured by long-term contracts. However, it is also possible that when exporting hydrogen, Russia could face some obstacles (mainly of a political nature), which will be similar to those it currently encounters when selling gas to the European Union and China.

Infrastructure re-development needs

Russia has existing natural gas pipelines and infrastructure which could be re-developed to be used with hydrogen. This infrastructure, namely the United Gas Supply System, is currently owned by Gazprom which has a monopoly to export natural gas via pipelines.

Alternatively, industrial ports and transport fleets could be renovated and updated to facilitate the export of hydrogen. At present these are used to export liquefied natural gas but with alterations could be used to export hydrogen.

Research and development needed

Most of the technologies and equipment currently used for hydrogen production in Russia are of foreign origin. The Russian Government has noted that any national research and development of hydrogen should be supported by the state, but significant progress has not been made yet. As a result of the sanctions imposed on Russia by the EU and USA, it is now more important than ever to increase the research and development into hydrogen. Otherwise, there is a risk that the above sanctions will be in future expanded to this area, similar to research and development in oil and gas industry.

The Concept provides for such incentive measures as subsidies for local producers and the implementation of localisation and import substitution regulations. However, the relevant legislation is yet to be developed.

Legal framework gaps

In Russia there is currently no specific legislation specifically dedicated to the hydrogen industry.

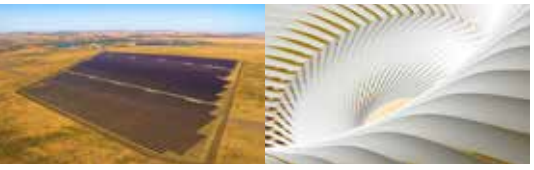
This area is therefore regulated by various legislative acts and by-laws, some of which are contradictory or out-of-date. As a gas, hydrogen would be regulated in a manner similar to natural gas in accordance with the Federal Law on Gas Supply in the Russian Federation No. 69-FZ of 31 March 1999 and Federal Law on Gas Exports No. 117-FZ of 18 July 2006. However, this would require significant revision of these two laws. This is an additional barrier preventing investment into the large-scale deployment of hydrogen.

The applicable laws and regulations, particularly those relating to safety and licensing issues, need to be reviewed and harmonised in order to encourage effective development of hydrogen. The Concept sees such harmonisation as one of the key measures for developing hydrogen energy in Russia.

Controversies between stakeholders

Despite the adoption of the Road Map and Concept, there are still certain controversies between the interests of the industry's main stakeholders.

Major gas producers (such as Gazprom, Novatek) are apparently interested in maintaining the status-quo, which would enable them to keep their current gas supplies and use gas to produce "blue" hydrogen (with CCS/CCUS technologies).



On the other hand, Rosatom, which operates nuclear plants, is primarily interested in the production of "pink" hydrogen (by using nuclear energy).

The above controversies have probably affected the process of drafting and adopting the Concept, which currently provides that most classes of hydrogen ("blue", "pink", "green" and even hydrogen whose carbon footprint has been compensated for by the relevant climate projects) should be treated as low-carbon hydrogen. Such a broad interpretation may lead in the future to certain obstacles for hydrogen export from Russia to countries that have declared their commitments to decarbonisation goals (first of all, the EU countries).

Regulation of hydrogen

Specific legislation / regulation

As stated above, there is no dedicated hydrogen law in Russia. Existing provisions of Russian legislation primarily capture hydrogen as a flammable gas within the framework of regulations on industrial safety (see, e.g., the Federal Law on Industrial Safety of Hazardous Industrial Facilities No. 116-FZ of 21 July 1997).

The abovementioned Federal Law on Gas Supply in the Russian Federation No. 69-FZ of 31 March 1999 applies only to natural and oil-well gas.

The Concept envisages the creation or adoption of the relevant legal framework for hydrogen production at the first stage of development of the hydrogen energy in Russia, i.e., from 2021 to 2024.

Since no dedicated act for hydrogen is adopted in Russia so far, stakeholders are forced to follow general rules arising from the Russian laws, which are not always suitable for the development of the hydrogen projects.

Policy and government programmes

The Road Map provides for the implementation of the following activities:

— strategic planning;
— incentives and state-support measures;
— formation of production capabilities;
— implementation of priority pilot projects;
— scientific and technical development;
— improvement of the regulatory framework; and
— development of human resources and international cooperation.

The Road Map further specifies some pilot projects, namely:

— setting up capacities for the generation of "green," "blue," and "yellow" hydrogen;
— developing and manufacturing gas turbines running on methane-hydrogen fuel; and
— creating a prototype model of hydrogen-powered railway transport.

Interestingly, the Road Map has devoted a separate section to the development of international cooperation. Above all, the section provides for long-term bilateral cooperation with hydrogen producing and consuming countries. It also encourages the promotion of Russian hydrogen and hydrogen-powered technologies on the international markets.

It is clear from the Road Map's orientation that Russia sees itself as a hydrogen producer. Although the Road Map covers the Russian domestic market, its main focus is the country's role as a hydrogen exporter.

The Concept further develops the main principles and ideas outlined in the Road Map. The Concept's ultimate goal is to create export-oriented hydrogen production, with the serial use of hydrogen technologies in various sectors of the Russian economy by 2050. The Concept envisages the implementation of these measures in three stages.

— The first stage (2021 to 2024) envisages the creation of three hydrogen clusters and the implementation of pilot projects on production and exportation of hydrogen, as well as boosting the use of hydrogen energy on the domestic market.

— The second stage (2025 to 2035) will see the launch of the first commercial projects on hydrogen production with a gradual increase of export volumes.
— At the third stage (2036 to 2050), Russia will become one of the world's largest exporters of hydrogen, related products and technologies.

One of the Concept's most important measures is the creation of three hydrogen clusters in Russia, namely:

— The North-Western Cluster (which will be located in St. Petersburg and the Leningrad Region), will export hydrogen to the EU and reduce the carbon footprint of Russia's export-oriented industries;
— The Eastern Cluster (which will be based in the Sakhalin Region in Russia's Far East), will export hydrogen to the Asia-Pacific region and develop hydrogen infrastructure for the transportation and energy industries; and
— The Arctic Cluster (which will be located in the Yamalo-Nenets District in North-Western Siberia), will develop autonomous low-carbon power supply systems and export hydrogen.

The Concept also envisages the possibility of creating a South Cluster in the future.

The Eastern Cluster is currently playing the leading role in the Russian hydrogen energy production sector, as it is generally seen as a pilot region for the development of a low-carbon economy in the country, including both hydrogen and greenhouse gas emission reduction projects.

Targets for 2035

At present the Energy Strategy of Russia for the period until 2035 adopted by the Russian Government on 9 June 2020 provides for the following targets for hydrogen export from Russia:

— 0.2m tonnes – by 2024; and
— 2m tonnes – by 2035.

Licensing of hydrogen projects

Since hydrogen is classes as a flammable gas, i.e. a hazardous substance, its generation, treatment, use, storage and transportation are subject to licensing subject to the volume in question – from 20 tonnes and above.

Moreover, an entity/person operating the relevant facility where hydrogen is generated, used, transported or otherwise processed, must observe numerous safety regulations applicable to operation of hazardous industrial facilities, such regulations being often contradictory and excessive.

Design and construction regulation

The design and construction of hydrogen processing facilities is subject to a permitting regime, which requires an expert examination of design documentation and obtaining of construction and commissioning permits following the general requirements set out in the Russian Town-Planning Code. Parties involved in the construction process, i.e. designers and general contractors, are required to be members of the respective Russian self-regulatory organisations.

Import and export of hydrogen regulation

The existing legislation on natural gas exportation (first of all, the Federal Law on Gas Exports No. 117-FZ of 18 July 2006 mentioned above) is not applicable to hydrogen, therefore, its import and export is subject to general customs regulations. This legislative area is likely to be developed in more detail soon.

Regulatory bodies

There is presently no specific regulatory body in Russia responsible for regulation of hydrogen projects. Since major hydrogen projects are expected in the energy sector, the Russian Ministry of Energy is driving the process within the interdepartmental working group (see above).

Other regulators would have responsibilities depending on the activity in question. For example, the Federal Service for Environmental, Technological and Nuclear Supervision is authorised to supervise compliance with applicable regulations on industrial safety of entities/persons operating the relevant facilities where hydrogen is generated, used, transported or otherwise processed. The Federal Anti-monopoly Service regulates compliance of natural monopoly entities (including Gazprom's monopoly on exporting natural gas via pipelines) with anti-monopoly requirements.

In general, regulatory powers, including licensing, are mainly concentrated at a federal level. Regional and local authorities are primarily involved in permitting formalities related to design and construction.

Upcoming developments

It is expected that the third document – strategy – will be prepared and adopted to supplement the Road Map and the Concept. This should boost the development of hydrogen projects, introduce state support measures and hydrogen-specific legislation. This, in turn, should attract investments to this industry.

It is likely that the first major hydrogen projects in Russia will focus hydrogen exports. However, there is also the potential to use hydrogen in both domestic energy and transportation sectors, particularly in heavy duty trucks and railways. It can be also assumed that these projects will be mainly developed on a regional (cluster) principle.

It is important to note that such developments are fully in line with the ultimate goals of energy transition and shift to a decarbonised economy as recently declared in Russia. In particular, following the base case scenario, it is envisaged to reduce greenhouse gas emissions by 67% by 2030 of the year 1990 volume, and to decrease carbon intensity of the national GDP by 9% (by 2030) and by 48% (by 2050) compared to the year 2017 volume.

It will be, however, a great challenge to increase the domestic demand for hydrogen in the current circumstances when decarbonisation is still underestimated in the national economy. Therefore, it is expected that hydrogen production in Russia will mostly be export-oriented in the coming years.

Singapore

Authors:
Marc Rathbone
Adrian Wong
Jacob Quek

Current status for hydrogen in Singapore

Introduction

Singapore has traditionally been one of the key global players in the downstream oil and gas industry and energy sectors. Despite its relatively small size, it was ranked as the world's fourth-biggest exporter of refined petroleum in 2019.[1]

As the world undergoes an energy transition towards net zero, Singapore is implementing its whole-of-nation Green Plan 2030 and aims to become a leading regional hub and enabler of energy transition and development (including carbon trading, green financing, consulting and risk management and other services).[2] In 2016, Singapore ratified the Paris Agreement, committing to tackle climate change through reducing its emissions intensity by 36% below 2005 levels by 2030.[3]

While the hydrogen market is nascent in Singapore, there is a growing expectation that the use of green hydrogen will play a substantial role in enabling Singapore to reduce its carbon footprint and achieve its long-term environmental goals. To achieve this, the Singapore government is actively pursuing hydrogen as one of the emerging low-carbon alternative energy solutions which it is looking into.[4]

Hydrogen as an Alternative Energy Solution

In 2021, the Singapore government, through a multi-ministry effort comprising the National Climate Change Secretariat (**"NCCS"**), Singapore Economic Development Board (**"EDB"**) and the Energy Market Authority (**"EMA"**), commissioned consultancy firm Kellogg Brown & Root Asia Pacific Pte Ltd (**"KBR"**) to conduct a *"Study of Hydrogen Imports and Downstream Applications for Singapore"*.[5]

1 https://www.bloomberg.com/news/articles/2021-07-18/singapore-prepares-to-swap-its-oil-hub-status-for-greener-future
2 Ibid.
3 https://www.todayonline.com/commentary/hydrogen-more-sustainable-bet-spores-energy-future;
https://www.nccs.gov.sg/media/press-release/singapore-s-submission-to-the-united-nations-framework-convention-on-climate-change-(unfccc)
4 https://www.ema.gov.sg/ourenergystory;
https://govinsider.asia/inclusive-gov/singapore-hydrogen-energy-market-authority-ema-ntu/
5 https://www.nccs.gov.sg/media/press-release/singapore-looks-to-develop-and-deploy-lc-technological-solution

On 23 June 2021, the ministries released a joint press release on the preliminary findings of the study, which can be summarised as follows:

— 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.
— Given Singapore's limited renewable energy resources, it is challenging for Singapore to produce green hydrogen at scale using only domestic green electricity.
— As such, Singapore would also need to explore various supply pathways for price-competitive low-carbon hydrogen (including importing hydrogen via shipping, piping from neighbouring countries etc.).

The above press release sheds much light on Singapore's views and approach towards the hydrogen as a potential alternative energy solution in the coming years. To further develop and assess the viability of hydrogen, the Singapore government (including government linked organisations) have partnered up with several multinationals and research institutions on a host of hydrogen projects, some of which are listed in *Upcoming developments* below.

Transportation sector use

In April 2021, in a first of its kind initiative, the Royal Dutch Shell company announced that it will be collaborating with the Singapore government on a feasibility study to use hydrogen fuel cells for ships, which involves *inter alia* the development and installation of a fuel cell power unit on an existing vessel used for the transportation of goods.[7]

In terms of land transportation, unlike some of its counterparts in Asia (such as China, Japan and South Korea), Singapore is not yet considering hydrogen fuel cell vehicles as a mainstream option. In 2013, Singapore had previously conducted trials on a small fleet of fuel cell and diesel hybrid buses for use in public transportation, but this was not eventually implemented.[8] Instead in its 2018 Budget, Singapore placed its emphasis on electric vehicles (including electric buses for public transportation) as an alternative to internal combustion engine (**"ICE"**) vehicles.[9] However, this decision was queried in the February 2020 session in parliament partly because several other countries appear to be favouring hydrogen fuel cell vehicles as one of the preferred alternatives to ICE vehicles.[10]

It remains to be seen whether the Singapore government will continue to "put its eggs in one basket" or consider a shift in policy to explore hydrogen fuel cell vehicles as a complement to its push for alternative greener means of transportation.

Market prospects for hydrogen

The hydrogen market in Singapore is still in its infancy and has significant prospects for growth. It is anticipated that the opportunities in the near future will come mainly in the form of pilot projects by the Singapore government/ Singapore companies in collaboration with some of the global frontrunners in hydrogen technology or research institutions, as Singapore continues to assess the viability and scalability of hydrogen as a low-carbon alternative energy solution which is capable of fulfilling a significant portion of Singapore's energy needs.

7 https://www.shell.com.sg/media/2021-media-releases/shell-to-trial-first-Hydrogen-fuel-cell-for-ships-in-singapore.html
8 https://www.google.com/search?q=singapore+fuel+call+buses&oq=singapore+fuel+call+buses&aqs=edge..69i57.3126j0j1&sourceid=chrome&ie=UTF-8
9 https://www.todayonline.com/singapore/mps-concerned-govts-plan-put-all-eggs-electric-vehicle-basket.
10 Ibid.

Singapore does not currently possess the large-scale facilities for mass hydrogen production, nor the tough, high-pressure, insulated fuel tanks that are required for large scale hydrogen storage.[11] Indeed, the Singapore government has indicated that it will be challenging for Singapore to rely solely on the development of such infrastructure and facilities locally, and therefore Singapore will also actively pursue options for the import of green hydrogen as an alternative. The key driver in this space will continue to be Singapore's environmental goals under the Green Plan 2030, and the import of hydrogen and the development of associated infrastructure and facilities will lead to growth of the hydrogen economy in the coming years

As the hydrogen market is relatively new and still developing, there has been little M&A or project financing activity to-date in this area in Singapore. Market players continue to observe this area with anticipation as the hydrogen market continues to mature and develop in Singapore.

Challenges facing hydrogen projects in Singapore

Costs and Commercial Viability

One of the key challenges faced in the hydrogen market today (not just in Singapore, but also in Asia and the rest of the world) is the issue of high costs and the creation of a sufficiently large marketplace to achieve economies of scale. While electrolysis using electricity from renewable energy sources is the most environmentally sustainable method of producing hydrogen, it is two to three times as expensive compared to hydrogen produced with natural gas or fossil fuels.[12] Analysts are of the view that Asia needs to quickly find ways to cut hydrogen production costs, draw in investors, and diversify its usage beyond oil refining, fertilisers, and petrochemicals.[13]

As research and development in hydrogen infrastructure, production, and storage advance (both in Singapore and globally) it is hoped that hydrogen will become more viable in the near future and form part of Singapore's energy sustainability. For instance, there are several companies globally that are developing the capability to produce 'Turquoise Hydrogen' (a mixture of green and blue hydrogen) which produces solid carbon rather than carbon dioxide.

Some market participants in Singapore have indicated that a key part of their strategy to sustain increased hydrogen production is through the use of hydrogen sale contracts. With an increase in long-term stable demand for hydrogen locally, producers anticipate that they will be able to enjoy certain economies of scale in hydrogen production which could eventually lead to reductions in costs.

Health and Safety concerns

The issue of health and safety has always been a key consideration in the use of hydrogen. Hydrogen is a light gas that is colourless and odourless (even when it burns), and is highly flammable, and its large-scale use has commonly been perceived as risky because of how easy it may leak and ignite in relatively low temperatures.[14] This difficulty is accentuated in Singapore due to its relatively small size, which imposes geographical limitations on where large-scale hydrogen plants and infrastructure can be located.

[11] https://www.todayonline.com/commentary/hydrogen-more-sustainable-bet-spores-energy-future
[12] Ibid.
[13] https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/042020-asia-may-draw-lessons-from-singapores-swift-move-on-hydrogen
[14] https://www.todayonline.com/commentary/hydrogen-more-sustainable-bet-spores-energy-future

Notwithstanding, various technological advancements in recent years, which have rendered handling hydrogen safer, its safety and handling risks make it more difficult to transport and handle than methane gas. That said, it is assuring that Singapore has a strong safety track record as regards energy production and storage and often applies an incremental approach to assessment of long-term risk. For instance, the Singapore government will use a series of pilot projects (such as the self-contained power grid on Semakau Island), to assess the safety and sustainability of hydrogen as an energy solution before it is implemented in Singapore on a larger scale.

Legislative framework gaps

As with many jurisdictions exploring the use of hydrogen as a new and emerging technology, Singapore does not have a well-defined legislative framework which specifically applies to hydrogen (please see more detail below). This gap in legislation may create some degree of legal uncertainty as the hydrogen market develops and matures, which will need to be addressed in due course.

That said, the Singapore government is typically capable of enacting new and appropriate laws within a relatively short time frame when needed, and it is expected that legislative reforms will eventually take place as hydrogen's role as a low-carbon alternative energy solution becomes increasingly significant in Singapore.

Regulation of hydrogen

As highlighted above, Singapore does not have a specific or well-defined legislative framework for hydrogen. As such, there is a need to consider the applicability of existing laws relating to such hazardous gaseous materials in Singapore more generally, as different legislation will apply at the various stages of importation, transport, production, and storage of hydrogen.

Hydrogen is regulated as a flammable material under the Fire Safety Act (Cap. 109A) (**"FS Act"**) and its subsidiary Fire Safety (Petroleum and Flammable Materials) Regulations (**"FS Regulations"**) in Singapore. In particular, the FS Act is the key legislation which stipulates that the following activities are licensable in Singapore in respect of hydrogen:

— Storage;
— Import;
— Transportation;
— Dispensation; and
— Conveyance over Pipelines.

An importer of hydrogen also needs to be cognisant of the provisions in the Maritime and Port Authority of Singapore Act (Cap 170A) (**"MPA Act"**) and its subsidiary Maritime and Port Authority of Singapore (Dangerous Goods, Petroleum and Explosives) Regulations 2005 (**"MPA Regulations"**). Compressed hydrogen is defined as a "First Schedule dangerous good" under the MPA Regulations, and therefore vessels carrying compressed hydrogen are subject to certain restrictions on *inter alia*, movement, proceeding into certain prescribed areas of a port in Singapore, anchoring, and mooring, as well as discharging and loading of compressed hydrogen.

Lastly, persons in the business of processing, manufacturing or bulk storage of hydrogen should be aware of the provisions in the Workplace Safety and Health Act (Cap 354A) (**"WSH Act"**) and its subsidiary Workplace Safety and Health (Major Hazard Installations) Regulations 2017 (**"WSH Regulations"**). Under the WSH Regulations, hydrogen is named as a "dangerous substance", and any premises where processing, manufacturing or bulk storage by way of trade or for the purpose of gain is carried on in respect of hydrogen is deemed to be a "major hazard installation".

Occupiers of a major hazard installation are required under the WSH Regulations to, amongst others:

— take all measures necessary to reduce the risk of major accidents to as low as is reasonably practicable and to limit the consequences of major accidents;
— keep and maintain a safety case in respect of the major hazard installation, and review, and if necessary, revise the safety case at least once every five years;
— comply with registration requirements of the major hazard installation; and
— notify and report any process-related incident to the Commissioner for Workplace Safety and Health.

Regulatory bodies

There is no one specific regulatory body which is specifically responsible for the regulation of hydrogen in Singapore. Instead, the various pieces of legislation mentioned above which apply to hydrogen are each administered by a specific regulatory body as prescribed under such legislation:

Legislation	Regulatory Body
FS Act and FS Regulations	— Commissioner of Civil Defence
MPA Act and MPA Regulations	— The Maritime and Port Authority of Singapore
WSH Act and WSH Regulations	— Commissioner for Workplace Safety and Health

Upcoming developments

In 2017, Engie SA began building a small, self-contained power grid on Semakau Island (off the southern coast of Singapore) to demonstrate the usefulness of hydrogen gas in converting power from solar panels and wind turbines (which are intermittent by nature) into fuel which can be stored for extended periods of time and can generate electricity as required.[15] The "Site Acceptance Test" of the hydrogen-based energy storage system in Semakau Island was completed in November 2020.[16]

[15] https://www.businesstimes.com.sg/energy-commodities/a-tiny-island-off-singapore-may-hold-keys-to-energys-future
[16] https://www.todayonline.com/commentary/hydrogen-more-sustainable-bet-spores-energy-future

In March 2020, five Singapore companies (most of which are government-linked) and two Japanese companies entered into a Memorandum of Understanding (**"MoU"**) to develop ways to utilise hydrogen as a green energy source. The participants are PSA Corporation Limited, Jurong Port Pte Ltd, City Gas Pte Ltd, Sembcorp Industries Ltd, Singapore LNG Corporation Pte Ltd (**"SLNG"**), Chiyoda Corporation and Mitsubishi Corporation, and involves the research and development of technologies related to the importation, transportation, and storage of hydrogen.[17]

Keppel Data Centres Holding (**"Keppel Data"**) has been actively looking into hydrogen for use in data centres:

— In 2019, Keppel Data entered into a consortium with SLNG and the National University of Singapore to develop new energy-efficient cooling technology for data centres.
— In June 2020, Keppel Data and Mitsubishi Heavy Industries Asia Pacific signed an MoU to explore the implementation of a hydrogen-powered, tri-generation plant concept for data centres in Singapore. Keppel Data also signed an MoU with Royal Vopak to study the commercial viability of establishing LNG (liquefied natural gas) and hydrogen infrastructure for power and cooling plants, which may form part of the development of a near-shore floating data centre park project.
— On 12 May 2021, it was announced that Keppel Data, Linde Gas Singapore Pte Ltd, Kawasaki Keavy Industries Ltd, Mitsui O.S.K Lines Ltd, and Vopak LNG Holding B.V signed an MOU to study the technical and commercial viability of a liquefied hydrogen supply chain, which includes "the feasibility of having a production and liquefaction plant and export terminal at the exporting country, transportation via ocean-going tankers, as well as an import terminal, storage units and regasification facilities in Singapore".[18]

On 17 June 2021, a new alliance was announced between DNV and Keppel Offshore and Marines (**"Keppel Offshore"**) with an aim to accelerate the adoption of hydrogen as an energy source in Singapore.[19] The parties intend to work together (with Keppel Offshore providing an R&D Facility where safety studies and pilot activities will be conducted) on the following areas:

— safety requirements for hydrogen as a fuel source;
— infrastructure requirements for hydrogen storage and local transportation; and
— offshore applications for hydrogen technology.

On 15 July 2021, the Ministry of Trade and Industry of Singapore (**"MTI"**) announced that Singapore and New Zealand signed an agreement regarding cooperation on low-carbon hydrogen. The arrangement between the two countries aims to foster closer cooperation by facilitating opportunities to:[20]

— chart standards and certifications and scale up each countries' respective hydrogen economies;
— establish supply chains for low-carbon hydrogen and its derivatives;
— conduct joint research, development, and deployment studies; and
— strengthen networks and partnerships.

17 https://www.citygas.com.sg/press-release/companies-collaborate-to-explore-hydrogen-as-a-low-carbon-alternative-for-singapore/.
18 https://www.reuters.com/article/singapore-hydrogen-linde-pu-idUSL1N2MZ0F9
19 https://www.dnv.com/news/dnv-and-keppel-offshore-marine-sign-collaboration-agreement-to-develop-hydrogen-projects-in-singapore-202250
20 https://www.mti.gov.sg/Newsroom/Press-Releases/2021/07/Singapore-and-New-Zealand-Sign-Arrangement-Regarding-Cooperation-on-Low-Carbon-Hydrogen

Slovakia

Author:
Oliver Werner

Current status for hydrogen in Slovakia

Introduction

Whilst hydrogen projects, hydrogen transport and the development of related infrastructure in Slovakia are in early stages of development, there is an interest from both the public and private sectors to explore the possibilities in this area, which has been supported by the Slovak Ministry of Economy. The Ministry is responsible for the development of an implementation strategy for renewable energy and the overall decarbonisation of the Slovak industry and transport. The Ministry prepared the National Hydrogen Strategy *"Prepared for the future"* (the **"National Hydrogen Strategy"**) which has been adopted as a non-legislative document by the Slovak Government in June 2021. The purpose of this documents is to increase the competitiveness of the Slovak economy and at the same time make a significant contribution to a carbon-neutral society in accordance with the Paris Agreement. Further, it defines the conditions for the deployment of hydrogen technologies in accordance with the long-term strategic plan for the development of the Slovak Republic.

Transport sector

The automotive industry in Slovakia is the most important sector and driving force of the economy with a 13% share of the Slovak GDP. In 2019, the automotive industry made up 49.5% of Slovakia's total industrial production, while the export share was 46.6%. Since 2007, Slovakia has been the world's largest producer of cars per capita, producing 202 vehicles per 1,000 inhabitants in 2019. One of the biggest challenges the Slovak automotive industry faces is to reduce its carbon footprint and shift towards low-carbon energy sources, such as hydrogen. To decarbonise, car manufacturers – for example, Kia Motors Slovakia – are considering producing hydrogen powered vehicles in the future. The National Hydrogen Strategy states that hydrogen is a viable alternative to internal combustion engines and electromobility especially in public transport, commercial long-distance transport, trains, planes, ships, construction equipment but also in agriculture, forestry, and the defence industry.

Currently, there is only one hydrogen powered vehicle on the Slovak market: Toyota Mirai (Hyundai NEXO is expected to be introduced to the local market in the near future). Slovakia is still waiting for hydrogen fuelling infrastructure for fuel cell electric vehicles (**"FCEV"**), however, the first hydrogen fuelling station in Bratislava is expected to be operational as soon as Autumn 2021 with other major cities following in the foreseeable future as one of the main priorities of the National Hydrogen Strategy.

According to the Slovak Ministry of Economy, the future development and use of hydrogen technologies for transport in Slovakia will be determined by several factors. At present, customer behaviour in Slovakia in relation to the purchase of FCEVs is influenced by the relatively high price of such vehicles compared to vehicles with an internal combustion engine (**"ICE"**). On the other hand, FCEV prices in the M1 category (the vehicle classification system according to the United Nations Economic Commission for Europe) are approximately the same level as battery electric vehicles (**"BEV"**) in the corresponding size and features. Another economic factor is the fuel price; hydrogen currently has a similar price to petrol and diesel. The price of hydrogen has been stable and recently decreasing due to the reduction of its production costs, so this may influence customer behaviour in due course.

Industry sector

Currently, there are two big producers of hydrogen in Slovakia. These are the chemical plants: Fortischem and Duslo located in Nováky and Šala. Hydrogen produced is used mainly in their own manufacturing processes and is not exported.

Heating sector

The Slovak government is considering potential for hydrogen injection into the natural gas grid to displace methane gas consumption and reduce emissions.

According to the National Hydrogen Strategy, the use of hydrogen produced from renewable energy sources can have a positive impact on the reduction of primary energy consumption in the Slovak Republic, compared to conventional heat production in heating plants and cogeneration, under certain conditions. One of these conditions is the use of seasonal storage, i.e., the accumulation of hydrogen during periods of surplus electricity exports onto the grid and its deferred use in the heat sector during electricity shortages or increased heat consumption in the winter period.

Quantifying the effective rate of substitution of natural gas by hydrogen for use in the heating sector will require further analysis. This will including examining the ability of the electricity grid to manage the additional electricity consumption, as well as the ability of the gas grid to accumulate and store the necessary volumes of hydrogen in the long term.

The domestic methane gas grid is well-developed (94% of the population has access to natural gas grid in Slovakia) and interconnected with several neighbouring countries. The gas distribution network provides methane gas to more than 80% of households, as well as to commercial buildings. Most of the gas supplied is used for heating.

Hydrogen blending is not yet utilised or regulated in Slovakia. However, we would expect that heating with methane gas will remain dominant, therefore blending hydrogen with methane may be attractive for decarbonising heating.

Market prospects for hydrogen

The hydrogen market in Slovakia is in early stages with significant prospects for future growth. The new Minister of Economy stated in July 2020: *"Slovakia is an automotive power, so its ambition in the future is to be among the world's leaders in alternative propulsion systems [in road vehicles]. The Ministry of Economy will play a key role in this effort".* Much effort has also been put into research and development of hydrogen storage technologies, including by Technical University of Košice, one of the leading institutions in this field.

Due to the limited use of hydrogen in Slovakia, there has been little by way of private financing to date. However, there is public funding available (national and EU) for the development of renewable energy resources, funded by both the State and European resources.

Slovakia is also considering producing low carbon hydrogen using nuclear energy. With four operational pressurised water reactors in use (a fifth unit is in the construction phase and a sixth in planning), Slovakia expects to produce more nuclear energy than necessary for domestic electricity consumption so could use the excess energy for powering electrolysers to produce hydrogen.

Since most hydrogen used in the chemical industry is currently produced from fossil fuels, decarbonising the industrial sector with green or blue hydrogen is necessary. The Minister of Economy has suggested that blue hydrogen produced by Slovak nuclear powerplants could be sold for use in the German chemical industry.

Finally, Slovakia is considering the introduction of hydrogen powered buses into the Slovak public transport system. Hydrogen powered buses have already been successfully deployed in other European countries, including the Czech Republic, so would serve as models for Slovakia. The Bratislava Transport Company (**"DPB"**) has already announced the purchase of the first hydrogen buses in Slovakia. These will be 12-metre fuel cell-powered buses with a range of more than 350km. They are expected to be on Bratislava's roads in late 2022/early 2023.

Challenges facing hydrogen projects in Slovakia

Lacking infrastructure

The most significant barrier to the rollout of FCEVs in Slovakia is the absence of a network of hydrogen fuelling stations. The Slovak Ministry of Economy has stated that a basic network of fuelling stations in the main transport hubs and clusters will be built by 2023.

Regarding hydrogen blending into the natural gas grid, technical barriers need further consideration. Even though the Slovak natural gas grid is well developed, one of the concerns around hydrogen injection is the possible corrosion of the pipelines in the gas grid in the case of a higher concentration of hydrogen. This matter is now subject to ongoing engineering and scientific inquiries.

Legislative framework gaps

As in many other jurisdictions, there is no specific legislative regulatory framework in Slovakia for hydrogen technology and projects.

The main legal provision governing hydrogen is § 2 (4) Act No. 309/2009 Coll. on the Promotion of Renewable Energy Sources and Highly Efficient Cogeneration and on Amendments to Certain Acts, which recognises hydrogen as a source of renewable energy: *"for the purposes of this Act, a fuel produced from renewable energy sources (hereinafter referred to as "biofuel") means (i) biohydrogen, which is hydrogen produced from biomass".* The regulation of hydrogen in Slovakia is discussed in more detail below.

Despite its non-legislative nature "National Hydrogen Strategy Prepared for the future" can provide valuable insight into the developments in the field. According to the National Hydrogen Strategy, the Slovak Government will aim to accelerate the creation of the legislative framework and financial conditions for the implementation of hydrogen technologies. This shall be mainly achieved by the introduction of legislation and safety regulations to support the readiness of the gas infrastructure for the transport, distribution, and storage of hydrogen and removing legislative barriers to the deployment of solutions using hydrogen.

Regulation of hydrogen

Legislation overall

There is very little legislation that specifically relates to hydrogen projects. Instead, hydrogen projects must navigate the existing legislative landscape which applies to renewable energy projects and gases generally. The most significant relevant laws are:

— Energy Act No. 251/2012 Coll. and on Amendments to Certain Acts;
— Act no. 309/2009 Coll. on the Promotion of Renewable Energy Sources and Highly Efficient Cogeneration and on Amendments to Certain Acts; and
— Act no. 250/2012 Coll. on Regulation in Network Industries.

The Slovak gas market is regulated by the Regulatory Office for Network Industries, a government administration body for the national regulation of network industries.

The Slovak Ministry of Economy and its Slovak Innovation and Energy Agency are crucial for further development of hydrogen projects in Slovakia. They lead and coordinate efforts in the field of renewable energy and oversee allocation of appropriate government and European funds. Since March 2020, the development of hydrogen projects and technologies has been promoted by the Minister of the Economy.

Injection into the gas grid – blending hydrogen into the existing gas networks

The injection of hydrogen into the gas grid is not explicitly regulated at present. Existing laws on injection, transport, and use of gas would apply to hydrogen as they do for methane gas. Slovakia has not introduced its own legislation regarding hydrogen blending. Instead, Slovakia is monitoring the efforts of other EU countries which have introduced limits on the injection of hydrogen into the gas grid and are undertaking research to raise the limit to between 20 and 30%. According to the National Hydrogen Strategy, the Government will examine the potential of the natural gas transmission network to be used also for hydrogen transport if its capacity will not be fully utilised for the transport of natural gas. At the same time, solutions will be sought for the technological adaptation of the gas distribution network to the possibilities of distribution of hydrogen, depending on the development of the hydrogen market.

The natural gas distribution network is very well developed in the Slovak Republic. According to the National Hydrogen Strategy, it will be possible to use the Slovak gas distribution network for the transport and distribution of hydrogen after technical modifications, which will be preceded by a detailed expert analysis of the technical condition of the pipelines. The use of hydrogen and various forms of gaseous mixtures containing hydrogen will play an important role in the decarbonisation of the heating and industry in the Slovak republic.

Real Estate and Consenting regulation

Major hydrogen projects are likely to be considered as significant national investments which may be subject to faster planning proceedings. Significant investments are defined and regulated by Act No. 175/1999 Coll. on Certain Measures Concerning the Preparation of Significant Investments and on Amendments to Certain Acts.

In case of building a new site as part of a hydrogen project or rebuilding an existing site for such purpose, all relevant provisions of Act No. 50/1976 Coll. Act on Spatial Planning and Building Regulations (Building Act) must be complied with.

In relation to storage and production of hydrogen on site, an Environmental Impact Assessment (**"EIA"**) may be required according to Act No. 24/2006 Coll. on Environmental Impact Assessment and on Amendments to Certain Acts.

Health and Safety laws

Health and Safety relating to hydrogen is not explicitly regulated. However, the following health and safety regulations, that deal with the treatment of dangerous gases, would have to be complied with:

- Act No. 124/2006 Coll. on Safety and Health at Work and on Amendments to Certain Acts;
- Act No. 67/2010 Coll. on Conditions for Placing Chemical Substances and Chemical Mixtures on the Market and on Amendments to Certain Acts (Chemical Act); and
- Act No. 128/2015 Coll. on the Prevention of Serious Industrial Accidents and on Amendments to Certain Acts, which lists hydrogen as a dangerous substance.

Everyone involved in the control of handling hazardous chemical substances in the workplace must be familiar with the EU legislative framework for dangerous substances, including health and safety legislation concerning protection of employees from health and safety risks in general and from hazardous substances in the workplace. Also, employers are required to carry out a workplace risk assessment for all safety and health risks, including those arising from hazardous substances, and to lay down appropriate protective and preventive measures.

Transport of hydrogen by road regulation

Slovakia is a member party of the European Agreement concerning the International Carriage of Dangerous Goods by Road (**"ADR"**).

The ADR regulates the transport of hydrogen, which is classified as a dangerous good under Annex *Regulatory bodies and relevant govermental and non-profit bodies*.

Drivers transporting hydrogen in Slovakia must receive appropriate training and vehicles must meet specifications required for hazardous cargoes.

Regulatory bodies and relevant govermental and non-profit bodies

There is no specific regulatory body which is responsible for regulation of hydrogen projects in Slovakia, but several Slovak ministries, government agencies and local authorities have the development of hydrogen projects on their agendas.

Regulatory Body	Role
Local Authorities / Town Planning Authority and the District Office	— Regulates the use of land — Undertakes Environmental Impact Assessment
The Office for the Regulation of Network Industries	— Exercises control over compliance with regulations of the internal electricity market and regulation for internal natural gas market
Ministry of Economy	— Responsible for support of innovations and new technologies and for the energy sector — Oversees subsidy schemes for the support of renewable sources of energy and renewables-based means of transport
Slovak Innovation and Energy Agency	— Responsible for raising awareness about energy efficiency, renewable energy sources and innovations in all fields of economy and provides expert consulting in those areas — Represents the Slovak Republic before relevant international institutions — Oversees the deployment of national and EU funds to decrease demand on energy, introduce low carbon technologies and grow competitiveness, innovative solutions and smart specialisation of the economy

The Slovak Renewable Energy Agency (**"SK REA"**), a non-profit organisation established in 2006 to promote the development of renewable energy sources in Slovakia, is a useful point of reference in relation to future hydrogen projects. The activities of SK REA range from helping to raise public awareness on energy-efficient solutions to providing support in the dialogue between the private sector and politicians, particularly on economic and legislative issues.

The National Hydrogen Association (**"NVAS"**) is a joint initiative of natural and legal persons that supports implementation of hydrogen technologies in the transition to a low carbon economy. NVAS has defined two main goals. As a professional association, it aims to play a key role in implementing best practice within the Slovak Republic and shaping effective public policy. The second key role of the association is to be an asset to its members in terms of the rapid delivery of news on regulatory decisions, new policies, and technologies in the hydrogen and fuel cell sector.

Upcoming developments

Although use of hydrogen is in its early development, there are interesting upcoming developments underway or in planning stages.

In the village of Močenok, the EU has approved funds for the development of a new wind powerplant park with an electrolyser to produce hydrogen. This development will be built next to the chemical factory, Duslo. Once operational, it is planned that the factory will no longer have to produce hydrogen for its own needs using natural gases but, instead, will get it from wind electricity. As of yet, there has been no confirmed date for construction to begin.

The Slovnaft refinery in Bratislava plans to build a large new hydrogen production plant from natural gas in the coming years. Hydrogen from this production plant will be predominantly used for internal technological processes, including the desulphurisation of oil. However, later production may be used for transport.

The production of hydrogen vehicles by Kia Motors Slovakia. The owner of Kia Motors, Hyundai Motor Group, has hydrogen cars in its portfolio already. The CEO of Kia Motors Slovakia stated that, in the future, a certain proportion of the production of hydrogen cars could take place in the Slovak factory in Žilina.

The Slovak Innovation and Energy Agency was ordered by the Minister of the Economy to build four to eight hydrogen filling stations before the end of 2020. The project is underway, however it is behind the initial timeline. There have also been talks about utilising 11 CNG filling stations operated by the major energy supplier in Slovakia, Slovenský plynárenský priemysel a.s. (**"SPP"**) to become hydrogen filling stations.

The first hydrogen fuelling station in Slovakia located in Bratislava is expected to be operational as soon as Autumn 2021. Other major cities will follow in the foreseeable future as one of the main priorities of the National Hydrogen Strategy.

A hydrogen research centre has been proposed by the Technical University of Košice to focus on the use of hydrogen to power passenger vehicles. This project has been supported by the Minister of Economy following discussions with the University and, although a timeframe has not yet been established, the project has a good prospect of being established. This proposal is also reflected in the National Hydrogen Strategy. According to this non-legislative document, the establishment of the Hydrogen Technology Research Centre of the Slovak Republic (**"CVVT"**), based in Košice, will aim to ensure and concentrate the available capacities in the field of basic and applied research and innovation. CVVT will operate as an open organisational structure, which will allow membership to all academic and research institutions from the industrial and public sector in the Slovak Republic, and possibly also from abroad. CVVT is also expected to maintain an active dialogue with the private sector.

Low-pressure hydrogen-electric bus developed by Slovak manufacturer Rošero will be presented at the Dubai Expo2021. The bus is unique in its use of low-pressure hydrogen storage in metal hydride alloy tanks. The specifications are tailored to use in urban traffic.

The trial operation of hydrogen trains could start on the Nové Zámky – Prievidza line in 2025. This timetable will be dependent on the further successful utilisation of the European Structural and Investment Funds in the new programming period.[1] The deployment of the hydrogen trains is expected to reduce the noise of the trainsets by at least 30% and save up to 6,000 tons of CO_2 per year.

Slovakian energy company BCF Energy is planning to invest one hundred and ten million euros (EUR 110m) to develop a network of 40 hydrogen refuelling stations across Slovakia, the first to be between Handlová and Prievidza. BCF Energy intends to produce green hydrogen for the network in purpose-built factories powered by solar generation. It is intended that the refuelling stations begin selling hydrogen in 2023/2024.

[1] "Over half of EU funding is channelled through the five European structural and investment funds (ESIF). They are jointly managed by the European Commission and the EU countries. The purpose of all these funds is to invest in job creation and a sustainable and healthy European economy and environment. The ESIF mainly focus on five areas: research and innovation, digital technologies, supporting the low-carbon economy, sustainable management of natural resources, small businesses."

For more information please see:
https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en

South Korea

Authors:
Dalia Majumder-Russell
Charlotte Rihoy

Current status for hydrogen in South Korea

Introduction

South Korea is seen as a global leader in the development of hydrogen projects, with many recent ambitious plans and announcements being made in the country. It has been developing hydrogen technology in major sectors of the economy such as electricity, energy, transport, commercial, retail and marine. Several key hydrogen projects and hydrogen fuel cell production units are already operating in South Korea. Further, in September 2021, the inaugural Korea H2 Business Summit, attended by fifteen member companies already involved in the hydrogen economy, was held. The companies, which include Hyundai Motors (**"Hyundai"**), POSCO Group, SK Group and Hyosung Corporation, have established the council to discuss and promote the development of the hydrogen economy in South Korea and will provide policy recommendations to the government.

Since early 2017, the Noeul Fuel Cell Facility has been operational in the Mapo District of Seoul. The 20MW fuel cell combined heat and power (**"CHP"**) facility was developed by Korea Hydro and Nuclear Power (**"KHNP"**), other government companies and POSCO Energy. The project produces power at the CHP factory with the electricity generated by the fuel cells being sold to the Korea Power Exchange and the heat being sold to Korea District Heating Company, the largest heat supplier in South Korea.

In 2017, in Hwasung City, Korea South East Power developed a 19.8MW fuel cell facility. In June 2020, the facility begun operating commercially, aiming to generate 165,000MWh of electricity per year and supply it to 43,000 households in the Gyeonggi Province. In March 2021, an agreement was signed with Korea Western Power (a subsidiary of South Korea's state electricity provider) and Samchully (a fuel gas manufacturing and piping company) for the development of an 80MW fuel cell facility. Once built, the power station, which is intended for completion by 2024, will have capacity to supply electricity to about 185,000 households.[1]

[1] https://www.ajudaily.com/view/20210326175347295#:~:text=Hwaseong%20City%20to%20build%2080%2Dmegawatt%20hydrogen%20power%20plant%20by%202024,-Lim%20Chang%2Dwon&text=SEOUL%20%2D%2D%20An%20eco%2Dfriendly,electricity%20to%20about%20185%2C000%20households

Additionally, in July 2020, Hanwha Energy Corporation (**"Hanwha Energy"**) completed construction of a 50MW fuel cell plant in the Daesan industrial complex, in Seosan City.[2] The plant was built in conjunction with other South Korean conglomerates and is the world's first plant to utilise by-product hydrogen, produced by a nearby Hanwha Total factory. It is the largest hydrogen fuel cell power plant in the world and will generate 400,000MWh of electricity to supply 160,000 households in the Chungnam Province.[3]

Energy & Industry use

With regard to production of fuel cells, South Korea's largest private energy producer, POSCO Energy is ranked among the top in terms of production volume globally. POSCO Energy's fuel cells are used for hydrogen fuel plants, biogas facilities, marine, commercial, and other infrastructure projects. At present the hydrogen produced is largely from fossil fuels but it is expected that, over time, more hydrogen will be produced from renewable sources and using CCUS technologies to create low-carbon hydrogen.

Transport sector

By country, South Korea is home to the largest proportion of hydrogen FCEVs in operation – about 14,500[4] or 33% of the global total.[5] This has increased from a 29% market share in 2020.[6] Further, the government intends to put 6.2m hydrogen vehicles on the road by 2040 – 5.9m passenger cars, 60,000 buses, 120,000 taxis and 120,000 trucks.[7] However, the significant uptake in fuel cell vehicles – which is driven in part by government subsidies[8] – has not yet been matched by an investment in refuelling infrastructure. As of 2021, South Korea has about 88 hydrogen fuelling stations[9] compared to 134 in Japan and 90 in Germany.[10] The South Korean government has announced plans to build 54 more refuelling stations by the end of 2021,[11] and aims to have developed 1,200 by 2040.[12]

At the forefront of the hydrogen transportation sector is the vehicle production at Hyundai in South Korea. Hyundai has been developing core technologies for fuel cell electric vehicles (**"FCEV"**) since it produced its first prototype in 2001.[13] Its goals are to produce 500,000 FCEV by 2030 and invest approximately KRW 7.6tn (approximately USD 6.4bn) in research and development. According to the company, it aims to produce approximately 1,100 FCEVs in 2020.[14] In September 2021, Hyundai announced plans to offer hydrogen fuel cell versions of all of its commercial vehicles by 2028.[15]

In 2016, Hyundai established a hydrogen production facility that uses by-product gas at its affiliate group's, Hyundai Steel, Dangjin Integrated Steel Mills. It began operating in February 2016 and as of 2021 produces up to 3,5000mt of steel annually.[16] The plant is capable of fully charging around 1,300 FCEVs per day and 473,000 FCEVs per a year. There are plans to increase the production capabilities of the plant to 40,000 tonnes annually by 2025.[17]

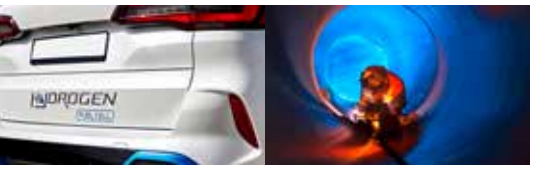
2 https://www.hanwha.com/en/news_and_media/press_release/hanwha-energy-celebrates-its-completion-of-the-worlds-first-and-largest-byproduct-hydrogen-fuel-cell-power-plant.html
3 https://www.hanwha.com/en/news_and_media/press_release/hanwha-energy-celebrates-its-completion-of-the-worlds-first-and-largest-byproduct-hydrogen-fuel-cell-power-plant.html
4 https://1fa05528-d4e5-4e84-97c1-ab5587d4aabf.filesusr.com/ugd/45185a_f7d294453f8f4342867e37e552d4c8ea.pdf
5 https://energy.economictimes.indiatimes.com/news/power/korean-hydrogen-vehicles-supply-highest-in-the-world/82307317
6 https://www.iea.org/data-and-statistics/charts/fuel-cell-vehicles-and-hydrogen-refueling-station-stock-by-region-2020
7 http://www.koreaherald.com/view.php?ud=20210825000848
8 https://www.bangkokpost.com/business/2056259/south-korea-ups-subsidies-for-eco-friendly-cars-to-speed-up-green-push
9 https://www.iphe.net/republic-of-korea
10 https://www.statista.com/statistics/1026719/number-of-hydrogen-fuel-stations-by-country/
11 https://www.bangkokpost.com/business/2056259/south-korea-ups-subsidies-for-eco-friendly-cars-to-speed-up-green-push
12 http://www.koreaherald.com/view.php?ud=20210913000863
13 https://www.autocar.co.uk/car-review/hyundai/ix35-fuel-cell-2013-2018
14 https://link.springer.com/article/10.1007/s10098-020-01936-6
15 https://www.reuters.com/business/autos-transportation/hyundai-offer-hydrogen-fuel-cell-versions-all-commercial-vehicles-by-2028-2021-09-07/
16 http://www.koreaherald.com/view.php?ud=20210520000771
17 http://www.koreaherald.com/view.php?ud=20210520000771

Another subsidiary of Hyundai, Hyundai Mobis, develops a significant portion of the technology for Hyundai's FCEVs. In particular, it produces a number of key components including the Powertrain Fuel Cell module (**"PFC"**) which consists of a fuel cell stack, hydrogen and air supply devices, a thermal management device, and battery system.

There are many other major corporations in the hydrogen fuel cell industry in South Korea, including Doosan Fuel Cell SK and Hanwha. Moreover, South Korea also has several smaller companies emerging in the market, such as BDI that, in 2020, has been contracted for the development of components and construction for a 13.28MW fuel cell plant.

Market prospects for hydrogen

While South Korea has been investing heavily in, and actively developing, hydrogen-related projects, challenges related to increasing economies of scale and commercialisation have become apparent. For example, the maintenance costs for fuel cells post-completion of a plant has been costly. In this regard, some companies have experienced difficulties upkeeping their maintenance contracts with existing plants as the costs could not be borne by the owners.



While M&A activity has been slow, it is expected that some South Korean companies may be interested in bringing new partners on board with their hydrogen projects, which in turn may give rise to opportunities for third party acquisitions. As part of this, investors will need to address the current hurdles around the relatively high maintenance costs of hydrogen fuel electric vehicles (**"HFEV"**) and improve the quality and durability of the fuel cell components. It is anticipated that, in the long run, the technology will be sufficiently refined to bring maintenance costs in line with commercial profitability. Notably, a recent announcement by Hyundai saw the company committing to reducing the cost of its hydrogen fuel cell vehicles to that of electric vehicles by 2030.[18] One example of recent M&A activity in the hydrogen arena is South Korean conglomerate SK Group's 2021 USD 1.5bn acquisition of a controlling share in US hydrogen fuel cell manufacturer Plug Power Inc.[19] As part of the wider partnership, Plug Power and SK subsidiary SK E&S Co. have also signed a joint venture agreement to provide fuel cell systems, hydrogen refuelling stations and electrolysers to the wider Asian market.[20]

An area of growth is the development of hydrogen clusters. The Ministry of Trade, Industry and Energy has announced a KRW 1.27tn (approximately USD 1.07bn) commitment to establishing a green hydrogen production cluster in North Jeolla Province, a blue hydrogen production cluster in Incheon, a hydrogen storage and transportation cluster in Gangwon Province, a hydrogen mobility cluster in Ulsan and a hydrogen fuel cell cluster in North Gyeongsang Province.[21]

On the transport side, as mentioned above, South Korea intends to continue to expand its market share in FCEVs. The FCEV market and its subsidiaries are seen as an industry with major future growth by companies like Hyundai, with significant potential for exports.

[18] https://www.reuters.com/business/autos-transportation/hyundai-offer-hydrogen-fuel-cell-versions-all-commercial-vehicles-by-2028-2021-09-07/
[19] https://www.kedglobal.com/newsView/ked202101070013
[20] https://www.electrive.com/2021/10/10/plug-power-and-sk-es-establish-hydrogen-joint-venture/
[21] http://www.koreaherald.com/view.php?ud=20210825000848

In conjunction with the national objectives to introduce electric cars and FCEVs, and phase out internal combustion engine vehicles, it is expected that South Korean FCEV-related companies will likely seek to acquire foreign companies with the necessary technology, alongside its continued research and development at home. For example, in December 2019, Hyundai acquired 100% of shares in Sichuan Hyundai, now Hyundai Truck & Bus (China) Co., Ltd, that was previously a joint venture between Hyundai and Sichuan Nanjun Automobile Group established in 2012. Hyundai has a strategy to develop Sichuan Hyundai into a specialised hydrogen vehicle research, development and production facility, with the aim of taking a lead in the Chinese market. Furthermore, Hyundai established a new joint venture, Hyundai Hydrogen Mobility (**"HHM"**), with H2E, a Swiss hydrogen energy consulting company. HHM currently has 50 FCEV trucks in circulation in the Swiss rental market, with a goal of 1,600 FCEV Switzerland by 2025. HHM was awarded "Watt d'Or 2021" – which recognises Swiss energy innovation – for their advancements in support of the Swiss hydrogen economy.[22] Switzerland is expected to be a growing market for FCEV and a forward base to infiltrate the entire European market. Closer to home, Hyundai intends to build its first overseas hydrogen fuel cell production plant in Guangzhou, China, by the end of 2021, following authorisation from the Ministry of Trade, Industry and Energy which is required for cross-border export of fuel cell technology due to concerns of possible data leaks.[23]

In relation to financing, private financing is available from most commercial banks in South Korea. For example, Kookmin Bank (one of South Korea's largest retail banks) and five other financial institutes were involved in the project financing of a USD 200m 39.6MW fuel cell facility in Incheon, South Korea, which was completed in July 2021.[24] Another example is the ESG fund announced in February 2021 by the Export-Import Bank of Korea (**"Eximbank"**), which aims to support South Korean businesses expanding overseas in areas including hydrogen.[25] Eximbank will also guarantee green bonds issued by Hanwha Solutions as part of the energy company's efforts to strengthen its hydrogen businesses.[26]

Five members of the council attending the Korea H2 Business Summit announced a combined investment of KRW 43.3tn (approximately USD 36.3bn) in the hydrogen value chain by 2030.[27]

In July 2020, the South Korean government published the Korean New Deal which included the "Green New Deal" focussing on (i) green transition of infrastructures, (ii) low-carbon and decentralised energy, and (iii) innovation in green industry. The Green New Deal will involve investment of KRW 73.4tn (approximately USD 61.3bn) to developments including expanding the supply of hydrogen vehicles, developing hydrogen generation technologies and establishing hydrogen cities.[28]

In 2021, the South Korean government revisited its support for eco-friendly vehicles and announced a KRW 365.5bn (approximately USD 305.5m) subsidy scheme to support deployment of 15,185 units – KRW 126.2bn more than was committed in 2020.[29] In addition, the South Korean government has set out its goals to subsidise hydrogen projects more widely, so investors may also seek government support where this is available. More on this below.

[22] https://www.hyundai.com/worldwide/en/company/newsroom/-0000016613
[23] https://www.kedglobal.com/newsView/ked202101050008
[24] https://fuelcellsworks.com/news/khnp-completes-hydrogen-fuel-cell-power-plant-for-incheon-fuel-cell-co-ltd-in-south-korea/
[25] http://www.koreaherald.com/view.php?ud=20210223000775
[26] https://www.koreatimes.co.kr/www/biz/2021/07/126_307294.html
[27] https://www.kedglobal.com/newsView/ked202109080016
[28] https://english.moef.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948#fn_download
[29] https://news.hyundaimotorgroup.com/Article/Has-South-Korea-changed-its-subsidy-plan-for-green-vehicles-in-2021

Challenges facing hydrogen projects in South Korea

Financial support and incentives

The South Korean government has established a USD 34m Hydrogen Economy Fund (the **"Fund"**) to support matters connected with the generation and use of alternative fuels generally, of which hydrogen is one. However, the Fund is seen as relatively small and so may not be sufficient to profitably support the sorts of projects the country needs to meet its policy objectives. Nonetheless, the South Korean government is working very closely in tandem with major conglomerates and financial institutions in South Korea to encourage the development of the hydrogen sector generally. With a goal of nurturing 1,000 hydrogen specialised companies by 2040, the government will provide incentives for companies wanting to convert into a hydrogen business and to promote technology-sharing between companies.

With regard to hydrogen fuelled automobiles specifically, in August 2020 the South Korean government proposed amendments to the existing Trucking Transport Business Act and the Passenger Transport Service Act. The amendments are focused on promoting the commercial use of hydrogen fuelled transport vehicles. In essence, the amendments state that government subsidies will be available to transport business owners that use hydrogen fuelled vehicles as part of their business.

In order to tackle a lack of investment in hydrogen infrastructure due to short-term profitability of assets, the government is considering a "Build-Transfer-Lease" model under its Green New Deal pursuant to which the private sector would build infrastructure, transfer ownership to government and then lease it back over a 30 or 50-year period.[30]

Research and education

Private South Korean companies are at the forefront of the research and education of the hydrogen fuel technology. However, government institutes such as the Korean Institute of Science and Technology (**"KIST"**) also are involved in research and education. KIST's Centre for Hydrogen and Fuel Cell Research drives the commercialisation of fuel cell systems. The Centre's research currently focuses on renewable water electrolysis, chemical hydrogen storage, as well as fuel cells applicable to transportation, power generation, and portable devices.

Regulation of hydrogen

Specific legislation/regulation

In January 2019, the South Korean government announced the Hydrogen Economy Roadmap (the **"Roadmap"**) to promote the development and use of hydrogen energy.

On 4 February 2020, the South Korean government promulgated the Hydrogen Economy Promotion and Hydrogen Safety Management Act (**"Hydrogen Act"**), which came into force on 5 February 2021.

The Hydrogen Act is now the central legislation regulating the hydrogen industry, while the Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy (the **"Renewable Energy Act"**), which was last amended in March 2017, will be used where an issue is not covered.

[30] https://www.intralinkgroup.com/en-GB/Media/News/January-2021/South-Korea%E2%80%99s-hydrogen-economy-report

Regardless of the legislation, the Ministry of Trade, Industry and Energy (the **"Ministry of Energy"**) is responsible for policy development for the hydrogen economy in South Korea. Its remit encompasses the development of national policies as well as the licensing and registration (and de-registration) of a company as a hydrogen-specialised business (under Articles 11 and 12 of the Hydrogen Act). Furthermore, it can oblige power plant owners to develop their plant into a "Hydrogen Fuel Supply Facility".

Hydrogen production licensing

A licence for the generation of gaseous fuels is required pursuant to the Renewable Energy Act. A company that intends to generate gaseous fuels is required to obtain a licence from a city mayor or district governor, in which the generation facility will be constructed. There is also a general requirement to obtain a licence to apply for the establishment of a fuel cell supply facility, pursuant to the new Hydrogen Act. The Minister of Energy has the authority to require one of the following organisations to submit a plan for the establishment of a fuel cell supply facility:

— the central or regional governments;
— public institutions;
— regional state enterprises; and
— any other organisations determined by the Ministry of Energy.

Connection and distribution system regulation

Pursuant to Article 36 of the Hydrogen Act, companies wishing to produce hydrogen fuel cell or hydrogen related components must receive approval by the local district authority. In particular, foreign companies (or South Korean companies based abroad) that wish to export hydrogen fuel cell related components into South Korea must register their business with the Ministry of Energy, pursuant to Article 38 of the Hydrogen Act.

Transport related regulation

Article 50 the Hydrogen Act deals with the reporting and disclosure requirements of the sales price of hydrogen supplied to automobiles. Transportation of hydrogen is regulated by the Safe Management of the High Pressure Gas Act, which requires transportation of dangerous gases, including hydrogen, to be conducted through tube trailers and specialised pipes.

Financing of hydrogen projects

Article 10 of the Hydrogen Act provides that the South Korean government will subsidise or provide loans for the development of hydrogen related projects (including cooperative efforts with foreign entities). Article 13 permits the establishment of private investment funds for the purpose of investing in the hydrogen related industry. The government will raise the USD 34m Hydrogen Economy Fund and increase the maximum limit on loans to companies investing in hydrogen businesses to USD 8.4m. To obtain government funding, a company is required to qualify as a hydrogen specialisation company; the criteria for such companies is either to earn at least 30% of sales from hydrogen related business or to invest 20% of its research and development budget into developing hydrogen related products. 11 hydrogen-specialised companies were designated under the Hydrogen Act as of June 2021.[31]

Safety regulations

Section 6 of the Hydrogen Act sets forth in detail the safety regulations that a manufacturer of hydrogen related components must comply with. In particular, Article 41 requires that the party must submit an opinion of safety issues by the Korean Gas Corporation.

[31] https://www.iphe.net/republic-of-korea

Secondary legislation and other legal documents

In June 2021 it was proposed to revise the Hydrogen Act to establish "Clean Hydrogen Energy Portfolio Standards" (**"CHPS"**) and a national clean hydrogen certification scheme.[32] Currently, hydrogen fuel cells are supported by the Renewable Portfolio Standards, which require power companies with greater than 500MW installed capacity to increase renewable generation,[33] however a dedicated policy scheme which accounts for hydrogen's unique characteristics, such as variable input fuel prices, was considered more suitable.

Relevant secondary legislation to the Hydrogen Act is yet to be published.

Regulation of hazardous activities

Section 7 of the Hydrogen Act, which governs the handling, import and export of hydrogen related components, such as fuel cells and hydrogen extractors. The Ministry of Energy can designate an organisation to be in charge of hydrogen safety, issue a licence for the manufacture of hydrogen related components, monitor hydrogen manufacturing companies' internal safety measures, and inspect safety of hydrogen related components.

Transport, import and export of hydrogen

The import of hydrogen related components is also regulated by the Hydrogen Act, which states that imported hydrogen related components can be inspected by the Ministry of Energy or the local authority of the relevant city or district.

In September 2019, the South Korean government signed a letter of intent with the Australian government. As Australia is capable of generating a large amount of hydrogen at a cheaper price and South Korean companies have advanced technology in FCEVs, the letter of intent aims to increase imports of hydrogen from, and exports of FCEVs to, Australia. The two countries also agreed to promote cooperation in the hydrogen industry, for example in the research and development of hydrogen liquefaction technology for the storage and transport of hydrogen. Also in 2019 the government concluded memoranda of understanding with each of Norway (for cooperation around hydrogen and shipping[34]), Saudi Arabia (for the provision of LNG from The Kingdom to South Korea, where it will be used to produce hydrogen and the CO_2 subsequently returned to Saudi Arabia)[35] and Israel,[36] along with a letter of intent to investigate development of a large scale liquid hydrogen supply chain from New Zealand to South Korea[37].

Regulatory bodies

The Ministry of Energy is the main government entity responsible for energy matters including the regulation of hydrogen projects. Some regulatory activities are deleted to the local authority of the relevant city or district, such as in relation to land permits.

Ministry of Energy

The Ministry of Energy is primarily responsible for regulating the hydrogen industry. This includes the issuing of licences and registrations (and de-registrations) of companies as hydrogen specialised businesses (under Articles 11 and 12 of the Hydrogen Act). The subsidiary regulations regarding the licensing requirements are currently being developed.

[32] https://www.iphe.net/republic-of-korea
[33] https://www.iea.org/policies/4837-renewable-portfolio-standard-rps
[34] http://www.koreaherald.com/view.php?ud=20190613000650
[35] https://www.energyvoice.com/oilandgas/304486/saudi-arabia-south-korea-hydrogen-carbon-dioxide/
[36] https://fuelcellsworks.com/news/s-korea-israel-sign-mou-on-hydrogen-economy/
[37] https://www.nzhydrogen.org/nz-hydrogen-projects

Additionally, the Ministry of Energy has the authority to specifically instruct facility and plant owners, that are based within certain areas, to develop their facilities into "Hydrogen Fuel Supply Facilities". Such areas are defined under Article 19 of the Hydrogen Act as free economic zones, rest areas on highways, industrial zones, and any other locations to be determined by the Ministry of Energy.

In addition, the Ministry of Energy will be establishing a specialised institute for the promotion of the hydrogen industry and a specialised institute for the distribution of hydrogen and safety management.

The promotion of the hydrogen industry will be carried out by the Hydrogen Convergence Alliance, a private organisation that aims to improve the competitiveness of hydrogen specialised companies.

The Korea Gas Corporation, a state enterprise, will establish a system for the distribution and transaction of hydrogen, and manage adequate pricing for hydrogen.

The Korea Gas Safety Corporation, a state enterprise, will oversee safety management, the inspection of safety standards of hydrogen related components and facilities, and supporting education, advertisement and international cooperation relating to hydrogen safety.

Hydrogen Economy Committee

To successfully implement the policies of the Ministry of Energy, the Hydrogen Economy Act requires the establishment of the Hydrogen Economy Committee (the **"Committee"**). The Committee is comprised of the Ministry of Energy, and seven other government bodies, including the Ministry of Economy and Finance, the Ministry of Science and Information Communication Technology, the Ministry of Environment and the Ministry of Land, Infrastructure and Transport, as well as industry, academic, and civil experts.

The Committee held its first meeting on 1 July 2020. At its first meeting, it resolved to implement six major action plans:

— Develop 500 hydrogen specialised companies by 2030 and a further 1000 by 2040;
— Raise a USD 34m Hydrogen Economy Fund to promote the entry of related companies into the market;
— Establish four major hydrogen production headquarters in the four major districts of South Korea, and 40 smaller production facilities by 2025, to set up necessary infrastructure;
— Establish a hydrogen production system of 100MW by 2030 for the implementation of various hydrogen projects that would be connected to other renewable energy plants;
— Develop hydrogen technology, such as production, storage, transportation and charging; and
— Develop technology for the establishment of a cross-ministry hydrogen infrastructure, including technology for building the infrastructure for domestic production facilities, overseas supply network, and hydrogen-based cities.

The Committee met again in June 2021. The main outcome of that meeting was a proposal to update the Hydrogen Act to establish the CHPS (discussed in section *Secondary legislation and other legal documents*, above). The Committee also announced that to date:

— 11 hydrogen-specialised companies had been identified;
— 658.7MW of stationary fuel cell capacity had been deployed, out of a target of 1GW by 2022 and 10.1GW by 2040;
— 88 refuelling stations had been deployed out of a target of 310 by 2022 and 1,200 by 2040; and
— 106 FCEV buses had been deployed out of a target of 40,000 by 2040.

Upcoming developments

The Ministry of Energy intends to promulgate the subsidiary legislations of the Hydrogen Act. Subsidiary legislations of an Act are usually promulgated in conjunction with the Act and require only a confirmation from the President and a relevant Minister.

The Ministry of Oceans and Fisheries has selected a number of ports to be developed into facilities capable of producing and storing hydrogen as well as handling imports and exports and supplying the fuel to ships and land-based vehicles.[38] The southern ports of Yeosu and Gwangyang as well as the western port of Pyeongtaek-Dangjin will be developed with chosen partner SK Group, and are intended to complete in 2040.[39]

The South Korean government has selected three cities – Ansan, Ulsan and Wanju[40] – as the target for investment in a bid to become "hydrogen-powered cities", with major urban functions fuelled primarily by hydrogen, by 2022.[41]

A consortium of state and private sector bodies led by Korea Maritime & Ocean University and Korean Register are seeking to develop a floating offshore wind project co-located with hydrogen generation.[42] They intend to develop a 1MW demonstrator project by 2022 and a gigawatt-class plant by 2030. The project would incorporate a floating production storage and offloading unit as has been utilised successfully in the oil and LNG sectors.[43]

Implementation of hydrogen drones is underway in South Korea. The government has signed an KRW 831m (approximately USD 737,000) contract with Doosan Mobility Innovation Inc. for the supply of drones which will be utilised for military surveillance.[44] In Sejong City, Dominos's Pizza are also using hydrogen powered drones to support their pizza delivery service.

SK Group, South Korea's third largest conglomerate, announced plans in 2021 to invest KRW 18.5tn (approximately USD 16.6bn) over the following five years to establish a domestic hydrogen energy industry,[45] including completion of the world's largest clean hydrogen production facility.

[38] https://www.globalconstructionreview.com/sk-group-to-spearhead-south-koreas-ambitious-hydrogen-port-plans/
[39] https://www.koreatimes.co.kr/www/nation/2021/07/371_313003.html
[40] https://ihsmarkit.com/research-analysis/south-korea-plans-northeast-asias-largest-hydrogen-hub.html
[41] https://www.weforum.org/agenda/2019/11/south-korea-green-energy-hydrogen-future-city-fossil-fuel-renewables/
[42] https://newenergyevents.com/development-floating-offshore-hydrogen-production-plant-south-korea/
[43] https://www.maritime-executive.com/article/korean-design-for-hydrogen-producing-fpso
[44] http://www.koreaherald.com/view.php?ud=20210517000181
[45] https://www.reuters.com/article/southkorea-hydrogen-sk-hldg-idUSL3N2L01EW

Spain

Author:
Ignacio Grangel

Current status for hydrogen in Spain

Introduction

Hydrogen has been recognised as having a key role in energy transition in Spain under the country's National Energy and Climate Plan (**"NECP"**). Due to the country's significant renewable energy resources, most notably solar and wind, and its ambitious plans to decarbonise the power, transport and industry sectors over the next 10–20 years, the contribution of hydrogen to these sectors is likely to increase.

At present, Spain consumes approximately 500,000 tonnes of hydrogen a year, almost exclusively in industrial uses (70% in refineries and 25% in chemical industries), all of which is from fossil fuels. If Spain can switch consumption to become low-carbon, through the use of zero-emission transport and the integration of hydrogen in the power grid as a storage medium, this will not only assist with the flexibility and resiliency of its energy system but Spain will be in a stronger position to achieve its decarbonisation goals.

Large scale demonstration projects in Spain are in early stages. For example, the Power to Green Hydrogen project led by Enagás, Spain's leading natural gas transmission company and the Technical Manager of Spain's gas system, that was launched in Mallorca in January 2019, will generate at least 330 tons of hydrogen per year using solar PV electricity. The project aims to demonstrate hydrogen use for transportation applications in sustainable urban transport (five buses), rental car fleet (ten vehicles), the feasibility of its injection into the gas grid from a dedicated pipeline transporting pure hydrogen through a Guarantee of Origin System, and its use for commercial (hotels and municipal buildings) and port applications (auxiliary power for ferries and port operations).

The NECP ambitious renewable electricity targets for 2030 and beyond imply that Spain could position itself as an exporter of green energy. As an example, the NECP already identifies a minimum of almost 14TWh of curtailed green electricity that could be generated, stored and exported or otherwise commercialised in the form of hydrogen by 2030.

The European Commission launched the process of the Important Project of Common European Interest (**"IPCEI"**) in order to undertake large-scale transnational projects of strategic importance to the EU and for the achievement of common European objectives. Different hydrogen projects were presented by companies, and the Spanish Ministry put forth a set of hydrogen projects for the first two waves (on technology and industrial application themes), which are now in the pre-notification phase to the European Commission. A third wave is under way and a new set of projects is expected to be proposed for the IPCEI mechanism.

Energy & Industry

At present, the overwhelming majority of hydrogen in Spain is used in industry, mainly refineries and chemical industries – all of which is 'grey' hydrogen. However, Spain has set a target to have about 5TWh from low carbon hydrogen (which is about 25% of the total hydrogen consumed in 2030 in all industries) and there is further scope for decarbonisation with hydrogen by blending hydrogen in the gas grid.

A plant for the production of e-fuels has been announced in Bilbao. In June 2020, Repsol announced its plans to build one of the world's largest plants to manufacture net zero emissions fuels.[1] This is using CO_2 captured in Petronor's refinery and green hydrogen generated from renewable energy through a partnership with other companies, such as Enagás and Petronor.

The Spanish utility group Iberdrola SA, and the fertiliser producer Fertiberia, announced a plan to install 800MW of electrolysers by 2027. The initiative will set up a solar-plus-storage system and a 20MW electrolyser at Fertiberia's ammonia plant in the city of Puertollano, Spain, with ribbon-cutting scheduled for 2021. These companies intend to expand their alliance by developing three more green hydrogen projects for Fertiberia's plants in Spain in 2023–2027. The initiative will require an investment of EUR 1.8bn by 2027.

[1] https://www.repsol.com/es/sala-prensa/notas-prensa/2020/repsol-desarrollara-en-espana-dos-grandes-proyectos-de-reduccion-de-emisiones/index.cshtml

Transport sector

A fleet of 12 cars (Toyota Mirai) are already on the roads in Madrid, fuelled at a newly built refuelling station (the first HRS in Madrid was inaugurated on 28th January 2021). Similar plans are in development at the Green Hysland project in Mallorca (a fleet of ten cars and five new fuelling stations). In addition, Barcelona is in the process of acquiring and rolling out an additional eight urban buses and Madrid is considering similar plans in the near future.

The H2Ports project contemplates the deployment of the first fuel cell-powered reach stacker and terminal tractor in Valencia by the end of 2021. This is the first step in the application of hydrogen in ports.

The NECP contemplates the use of green hydrogen for clean transport alongside battery electric vehicles. In addition, in May 2021, the Spanish Prime Minister announced support for development in the field of green hydrogen within the framework of a comprehensive plan for modernising the automotive industry in Spain, a sector responsible for 10% of national GDP.

Market prospects for hydrogen

The development of a hydrogen market in Spain is at an early stage, with significant space for growth. After launching a national hydrogen strategy by the national government and with input from stakeholders, in October 2020 the Spanish Government published The Hydrogen Roadmap, the national hydrogen strategy in Spain.

This Spanish Hydrogen Roadmap set out the following targets for 2030: the installation of at least 4GW of electrolyser power; 25% of hydrogen consumption in industry covered by renewable hydrogen; 100–150HRS with public access; 150–200FCEV buses; 5,000–7,500 light and heavy freight FCEV vehicles and two commercial train lines powered with hydrogen with an investment of EUR 8.9bn. All of these investments could be undertaken by the private sector with the necessary public support in cases where the need is determined.

Furthermore, it is expected that the development of an economy based on the production and application of renewable hydrogen will accelerate in Spain from the year 2030. The renewable hydrogen economy will imply the constitution of a decarbonised society by 2050 in which renewable energies make up the majority share in the energy mix.

This national hydrogen roadmap establishes the creation of "valleys of hydrogen clusters" which will play a key role where production, transformation and consumption are spatially concentrated, taking advantage of the application of economies of scale, as well as the development of pilot projects linked, among others, to isolated energy systems and to the transport sector. This roadmap also identifies the necessary elements along the value chain in order to help foster the growth of a national hydrogen industry.

Due to the cost premium that green hydrogen and its end users face today and in the medium term, public grant-type funding to help bridge the gap with respect to conventional or competing technologies will be necessary. Early-stage demonstration projects are seeking funding mainly at a European level, although national agencies are increasingly keen to explore funding possibilities and are likely to develop these further. Furthermore, due to the fact that most of the activity has been related to R&D, few well-developed companies or business units dedicated to hydrogen exist, and M&A activity has been insignificant to date. As the market develops and grows, this is likely to result in more commercial and business relationships and increased M&A activity.

Challenges facing hydrogen projects in Spain

Political framework

As noted above, Spain has had a Hydrogen Roadmap in place since October 2020. This Roadmap recognises the complementary role of hydrogen as a necessary energy vector and includes the abovementioned specific objectives related to hydrogen, as well as a system for accounting for renewable gases (e.g. guarantees of origin). The roadmap also provides for different measures regarding financial aspects. For instance, it includes proposals for different hydrogen support mechanisms among the award criteria, and seeks to facilitate the demonstration of innovative technologies based on renewable hydrogen by launching calls within the framework of the Emissions Trading Scheme Innovation Fund. However, there are no specific guidelines on how to implement such measures, so whilst this Hydrogen Roadmap is positive because it sets out the national hydrogen strategy, more concrete measures and their further development are needed.

Legal framework

The publication of the Spanish Hydrogen Roadmap marks an important milestone for the development of this sector.

One of the measures envisaged in this Roadmap is the establishment of a legal basis for Power to X plants (**"P2X"**) and electrolysis facilities although, again, there are no specific indications on how to achieve this. Besides, hydrogen production from renewable sources is hindered since electrolysis is considered as an "energy use" rather than an "energy conversion device". Considering that the price of electricity is key in the production of hydrogen in order to obtain a competitive price, the electricity used by the electrolysers should not pay access tariffs because it is an energy conversion (an intermediate process to transform electricity in another energy) and not a final energy use. To date, however, no steps have been taken to address this legal barrier, other than a Royal Decree[2] which proposes the possibility to eliminate connection charges on a temporary basis. Positively, one of the measures of this Roadmap is the review of the technical and regulatory aspects and the quality of the gases necessary for the injection and use of hydrogen into the gas grid.

Securing end users and reducing costs

The current cost premium for hydrogen technologies compared to conventional technologies remains an obstacle for widespread market uptake. While developing hydrogen at scale remains a key lever for reducing costs, R&D and product development activities also need further support to enable this cost reduction. End users must be identified and engaged with so as to enable large demonstration projects at commercial scale (i.e. multi-MW).

Financial support for deployment

The cost premium requires action by public agencies so as to help remove this barrier and enable hydrogen projects to be implemented. Many in the sector are calling for a funding programme to be put in place for this purpose, with ambitious but progressively decreasing levels of support as technology develops and costs are reduced, thereby incentivising early adopters.

Lack of awareness

Despite the recent surge in interest in hydrogen technologies, they remain largely unknown to potential end users and the public in general. The lack of trained personnel and training programmes may also be considered a challenge. More targeted communication on the benefits of hydrogen will be needed, as otherwise there may be a time investment required in informing potential project partners about the technology, its status and prospects.

[2] https://www.boe.es/buscar/doc.php?id=BOE-A-2021-4239

Regulation of hydrogen

Specific legislation/regulation

In Spain, the guidelines for the development of specific hydrogen legislation are set out in the Hydrogen Roadmap of October 2020. So far, in terms of hydrogen production, it is considered as any other inorganic gas production facility and it is subject to the same conditions regardless of size, which could hinder the development of small projects.

In relation to hydrogen's injection in the gas grid, the PD-01 protocol applies. This document provides the technical specifications for gas circulating inside the grid and makes reference to standard UNE-EN 16726. At present, there is no specific limitation of hydrogen content by volume: it is assessed on a case-by-case basis.

One of the measures foreseen in this Hydrogen Roadmap is reviewing the technical, regulatory aspects and quality of the gases necessary for the injection and use of hydrogen in the natural gas grid.

At national level, the Land Law *(Ley del Suelo)* establishes a basic regulation of land use without prejudice to the competences of the Autonomous Communities to develop different land use regimes. Hydrogen production plants are considered to be chemical facilities for the production of chemical products and inorganic gases such as hydrogen. Therefore, the land use permit must be obtained for this industrial activity. In this sense, the Spanish Hydrogen Roadmap has instructed the modification of the classification as an industrial activity of the production of renewable hydrogen in situ at service stations, but only in such service stations.

Other regulations

There are no land use prohibitions for hydrogen production, but there are for storage of large quantities of hydrogen. If storage is greater than 200,000 tons, an Environmental Impact Assessment (**"EIA"**) is needed.

As a rule, local authorities are in charge of permitting. As such, whilst there may be few variations between installations from one part of the country to another as a practical matter, permitting rules will need to be taken into account for each new project.

It is likely that dedicated hydrogen production plants linked directly to renewable energy installations will be subject to similar requirements to those applicable to said installations, amongst them an EIA.

With regard to the transportation of hydrogen by road, the European Agreement concerning the International Carriage of Dangerous Goods by Road rules apply.

Installations where storage of pressurised hydrogen containers may be located will likely require an ad hoc review by local permitting authorities. Such would normally be the case for refuelling stations where high-pressure buffer tanks (up to 1000MPa) are required.

According to article 1.8 of the Spanish NECP and the RED II, it is mandatory to implement a Guarantees of Origin System, and the Green Certificates in accordance with it, for all renewable gases. In that sense, Green Hydrogen is part of this scheme and the development and the mandate to develop this system are still pending.

Regulatory bodies

There is no specific regulatory body responsible for the regulation of hydrogen projects. Instead, there are a number of regulators which would have responsibilities depending on the activity concerned, including the Councils, Regional Governments and the National Government:

Grant Authority	Permit Requirement
Regional Government	— Administrative authorisation; — Environmental Impact Assessment; — Integrated Environmental Authorisation
Council	— Construction Permit
National Government	— Grid Connection

Upcoming developments

Key projects that are likely to start implementation in the near future (12 – 24 months) are as follows:

— **Green Crane,** a joint Spanish-Italian proposal for large scale hydrogen production, led by TSOs Enagás and SNAM. The hydrogen production hubs are located in areas that will be majorly affected by the energy transition (such as locations with closures of coal mines and coal power plants);
— The **Power to Green Hydrogen** in Mallorca (GREEN HYSLAND funded by the FCH JU) will install a production capacity of more than 330 tons per year for a variety of uses, such as transport (rental car fleet and urban buses), commercial heat and power, as well as demonstrating the feasibility of injection into the gas grid;
— **Hydrogen fuel cell urban buses** in Barcelona and Madrid are expected to roll out in the next few years;
— **A fleet of 12 Mirais** in Madrid has been deployed together with the first hydrogen refuelling station. As we have mentioned previously, this HRS went into operation in January of this year, and it has been the first publicly available hydrogen refuelling station in Spain for refuelling at 700bar;
— The **deployment of demonstration units** (a reach stacker and a terminal tractor) within the **H_2Ports project** in Valencia will also advance the development of fuel cell solutions for port-related activities;
— The **SeaFuel project funded by the Interreg Atlantic Area** aims to use the renewable resources across the Atlantic Area to power the local transport fleet and support the shift towards a low-carbon economy in Tenerife (Spain); and
— **The Sun2Hy project,** led by Enagás and Repsol, focuses on the development of a new photoelectrochemical technology that allows the production of green hydrogen, 100% renewable, at a competitive cost, from solar energy through a direct process without external electrical input (bias free). This new technique can achieve a 90% carbon footprint reduction with respect to existing green hydrogen production technologies.

The first phase of the project, in which the project has been developed a demonstrator at pre-commercial scale (TRL-6), is co-financed by the Centre for Industrial Technological Development and the European Union through the European Regional Development Fund (**"FEDER"**).

The aim of the present project is to demonstrate the first PEC pre-commercial plant in the world with a production capacity of 201 tH_2/year, ensuring supply of Hydrogen Refuelling Stations in the surroundings of Puertollano Industrial Complex (Spain) for the mobility sector (freight buses, trucks and light vehicles). During ten years of operation, a total amount of 25,217.61 $tonCO_2eq$. will be avoided.

Turkey

Authors:
Döne Yalçın
Taner Elmas

Current status for hydrogen in Turkey

Introduction

The Ministry of Energy and Natural Resources (**"MENR"**) organised an international conference on 15 January 2020 to discuss the future of hydrogen in Turkey and to evaluate the development of a national hydrogen-strategy for the Turkish energy market (the **"Conference"**).

The aim of the Conference was to focus on indigenous energy sources, which includes hydrogen production from local coal mines. MENR sees hydrogen as playing an important role alongside renewables and being key to decarbonising the heating sector through the blending of hydrogen with methane in the gas distribution system. That said, the use of low-carbon hydrogen in industrial and heating processes requires more research in order to be a truly viable option in Turkey.

On 24 January 2020, MENR published a *beyaz belge* (or "white paper") to obtain opinions, proposals, and recommendations from hydrogen stakeholders in Turkey on the future hydrogen strategy. The questions asked were:

— What are the areas/technologies where research and development need to be strengthened?
— What is the future of hydrogen in the transport sector and where are there still gaps?
— What kind of strategies do you propose with regards to using hydrogen safely, as a fuel?

The deadline for the submission of stakeholder contributions was 22 June 2020 and the contributions were due to be published in an opinion document, a "blue paper". Following this, the government planned to introduce a further opinion document, known as the "red paper", which was expected to be released in January 2021. It was anticipated that the "red paper" would set out the decisions made by MENR following the consultations. The final phase is an application document, known as the "green paper", which will show the government's method for the application of decisions. It is likely that this will include an approach towards a new legislation for promoting hydrogen developments in Turkey.

Through no specific timeline has been stated, the short-term goal of MENR approach is to prepare test projects to strengthen the organisational structure and research and development of hydrogen potential in Turkey. Unfortunately, none of the papers have been published as of October 2021.

That said, the long-term objectives are the improvement of infrastructure and the preparation of necessary legislation that will govern the production, transmission, distribution, and use of green hydrogen, based on renewable energy resources, for use in the Turkish industrial and transport sectors (vehicles, railways, and shipping). The establishment of reliable and long-term storage of hydrogen and the development of local fuel cell technology for the transport sector is also considered one of the most important parts of the planned roadmap.

In addition, the Minister of Energy and Natural Resources (**"Minister"**) gave a statement on widening the usage of hydrogen in multiple areas, including renewables, heating, and transportation in the Scout Meetings in Energy Workshop. By increasing the use of hydrogen, Turkey aims to take a step towards using clean resources and consequently becoming less dependent on imported energy. Within this scope, in April 2021, Turkish Natural Gas Distributors Association (**"GAZBIR"**) has established the Clean Energy Technology Centre with its own undertaking Gazmer. Accordingly, the Clean Energy Technology Centre is conducting studies and tests for blending natural gas and hydrogen which is aimed to be used in households.

Transportation

The Regulation on Rules and Procedures Regarding Increasing Energy Efficiency in Transportation aims to ensure energy efficiency using environmentally friendly fuels, such as hydrogen. It recognises the importance of using hydrogen in transport as a clean fuel in Turkey. As such, several projects have been developed by universities and institutions, particularly by the Turkish Council for Scientific and Technological Research (**"TÜBİTAK"**) and the Turkish International Boron Research Institute (**"BOREN"**). The majority of hydrogen developments in the Turkish transport sector focus on hydrogen fuel cells.

Two projects, the "Development of Boron-based Hydrogen and Fuel Cell System for Unmanned Aircraft" and "Boron-based Fuel Cell Range Intensifier for Electric Vehicles", were completed by the Competence Centre for Boron and Hydrogen Technologies. In addition, two hydrogen-powered vehicles were developed through a cooperation between BOREN and TÜBİTAK. Bormobil, one of the vehicles, has a top speed of 100km/h and a potential range of 450km, using hydrogen fuel.[1] The second vehicle, which has a battery capacity of 40kWh, has a hydrogen production system and an integrated fuel cell. The hydrogen production system increases the range of the vehicle from 250 to 400km.

The Hydrogen Technologies Association (the **"Association"**) was founded in 2015 with the aim of developing hydrogen technologies through cooperation with a variety of educational institutions and private and public bodies, contributing to research and development projects and providing financial support. The Association stated that, in addition to the above-mentioned electric vehicles, hydrogen-powered private and public vehicles will also be produced.

The use of hydrogen in fuel cells (and other forms) in large road vehicles is currently being considered in Turkey. MENR is considering producing hydrogen from local coal and using it for transportation purposes. According to MENR, the production of hydrogen is still not cost-effective in Turkey. However, hydrogen in transportation may be viable and efficient considering that an ordinary bus in Turkey could travel 1030km on hydrogen produced from one tonne of local coal.

[1] https://fuelcellsworks.com/news/turkey-tubitak-mam-energy-institute-premiers-hydrogen-vehicle/

The use of hydrogen to decarbonise public road transport, especially buses, has gained popularity. The first hydrogen-powered bus project in Turkey was completed as far back as 2012. This project was designed by ICHET in cooperation with other institutes. The bus was used for two days to test and analyse how the technology could be used to help develop Turkey's hydrogen economy. The project was a success, achieving a fuel efficiency of 15%, thus paving the way for future bus projects.

Industry

In 2011, a hydrogen energy production plant was commissioned on the island Bozcaada, as part of the Bozcaada Hydrogen Energy Project. This pilot plant was built in a cooperation between the United Nations Industrial Development Organisation (**"UNIDO"**) and ICHET, with the support of MENR. The cost of the plant was USD 1.5m and was tested for two years.

One year later, the hydrogen production and filling plant, Hidrojen Üretim ve Dolum Tesisi, was built in Halic, Istanbul, with a capacity three times larger than the plant on Bozcaada. The plant in Halic can refuel vehicles that run on hydrogen, i.e. hybrid fuel cell electric vehicles (**"FCHEV"**) and fuel cell electric vehicles (**"FCEV"**). Ferries and ships that use hydrogen as fuel can also use the plant. The plant continues to be operational in this capacity.

The hydrogen used in Turkish industry is mainly produced from fossil fuels, i.e. natural gas, oil, and coal. Hydrogen is currently used in the fertiliser industry, in the production of vegetable oil and petrochemicals, and the production of gas and liquid hydrogen in pressure cylinders for various processes in Turkey.

At the Conference, MENR stated that the development of a local hydrogen industry is one of its priorities and that studies are already underway.

Heating

The MENR have stated that decarbonisation of heating is a key aim of Turkey's energy strategy. To that end, Turkey's natural gas distributors association, GAZBIR, has carried out blending trials on a facility in Konya, in the Anatolia region.[2] This project has trialled a 20% hydrogen blend into the domestic gas network. The MENR's goal is to complete the first set of trials by the end of 2021 and to replace 2–6% of methane gas supplied in the grid with hydrogen.

Market prospects for hydrogen

According to the MENR's statements during the Conference, its approach to hydrogen production has four main aims:

— creating more renewable energy for Turkey;
— ensuring emission-free production in the heat sector;
— producing hydrogen from domestic coal; and
— increasing the use of boron and its use in hydrogen storage.

MENR is determined to increase the use of hydrogen and, as mentioned above, a white paper outlining MENR's approach was prepared to obtain opinions, proposals, and recommendations from hydrogen stakeholders in Turkey, regarding the future strategy of hydrogen energy. The main purpose of this paper is to develop a local hydrogen strategy in two phases: short-term and long-term.

[2] https://www.kallanishenergy.com/2020/07/30/turkey-tests-20-hydrogen-gas-blend-for-heating/

The financing of existing projects varies; some projects are funded by the private sector while others are supported by the Turkish government. However, the private sector also needs government assistance to produce hydrogen due to the high costs currently involved. Although many universities and institutions in Turkey carry out projects using their own funds, support from the State is needed to complete large-scale development and implement projects that use hydrogen as an energy resource.

Challenges facing hydrogen projects in Turkey

Lack of legislation

At present, Turkey has provisions to promote the use of hydrogen, such as the Rules and Procedures Regarding Increasing Energy Efficiency in Transportation, which is discussed below. However, there are no detailed provisions governing the production of hydrogen and the supervision of organisations that carry out hydrogen production. This lack of legislation in Turkey prevents the development of hydrogen energy and creates uncertainties that need to be removed before the hydrogen economy can develop. Accordingly, MENR has stated that the creation of efficient legislation is considered one of the long-term goals of the government.

Cost effectiveness

At present, hydrogen is three times more expensive than traditional fuels, and its use as a common fuel resource depends on technological developments to reduce the cost of hydrogen production.

Inadequate infrastructure

One of the biggest obstacles to the use of hydrogen as energy in Turkey is inadequate infrastructure regarding the production, transmission, and utilisation of hydrogen in the industrial, transport, and heat sectors.

Regulation of hydrogen

Although there are no provisions specifically governing the production of hydrogen (or its associated transport and storage), there are certain provisions that indirectly relate to hydrogen. Various legislation covers the regulation of liquified petroleum gas (**"LPG"**), electricity and natural gas markets, however none specifically define "gas"; as such, it is unclear how hydrogen will be regulated. This lack of legislation is acknowledged by the Turkish government and the preparation of adequate legislation is one of the long-term objectives of the hydrogen strategy being prepared by the MENR.

Legislation overall

The Regulation on Increasing the Efficiency and Use of Energy Resources sets out rules and procedures to promote the use of clean fuels, such as hydrogen. Under Article 30(6) of the Regulation, state institutions and organisations that carry out or support research and development projects relating to hydrogen must give priority to projects involving hydrogen production technologies that use renewable energy sources, such as water, wind, solar and geothermal energy.

The Rules and Procedures Regarding Increasing Energy Efficiency in Transportation came into force on 2 May 2019. Its purpose is to promote environmentally friendly alternative fuels; hydrogen is counted among these alternative fuels.

Action plans regulated and published by the government are essential to the deployment of hydrogen in Turkey. Accordingly, hydrogen energy was mentioned in the National Energy Efficiency Action Plan (the **"Action Plan"**) that was published in November 2017. With regard to the development of public transport in Turkey, the Action Plan aims to promote the use of environmentally friendly, lightweight, electric or hybrid, hydrogenated, natural gas-powered vehicles by 2023.

Regulatory bodies

There are no regulatory authorities that regulate the development, construction and operation of hydrogen projects in Turkey. Studies on the production of hydrogen energy are carried out by BOREN, an affiliated institution of the MENR.

A supervisory authority to oversee the production of hydrogen or other hydrogen projects has not yet been established in Turkey and, as such, the licensing requirements for hydrogen have not yet been defined.

Upcoming developments

The Hydrogen Technologies Lab, which is managed by BOREN, was founded in 2018. Its aim is to put into operation the necessary technological environment to promote the use of hydrogen as a clean energy resource, as well as the research and development of techniques and methods to increase energy efficiency. Accordingly, a cooperation protocol has been signed between 16 universities and public institutions to carry out research and development in the field of hydrogen energy and to initiate projects that will help to develop this technology. Research and development are on-going, and it is not yet known when results will be publicised.

Feasibility studies for the construction of hydrogen production plants in Zonguldak, Samsun, Sinop, and Giresun are underway. There are also plans to build hydrogen production plants on Turkish waterfronts, however there have been no official statements about when the plants may be operational.

In February 2020, two hydrogen-powered vehicles were developed by BOREN and TÜBİTAK. One of the vehicles, Bormobil, is designed to be a domestic car that uses boron for hydrogen storage. The car operates very quietly and has zero emissions but has a top speed of 100km/h. Currently, it has a range of 300km using electricity, but this could be extended to 450km using hydrogen fuel.[3] The second vehicle, which has a battery capacity of 40kWh, has a hydrogen production system and an integrated fuel cell. The hydrogen production system increases the range of the vehicle from 250km to 400km.

The upcoming 23rd World Hydrogen Energy Conference (**"WHEC 2022"**) will be held in Istanbul between 26 and 30 June 2022. According to Prof. Dr. Ibrahim Dincer, Chairman of WHEC 2022, hosting such a conference in Istanbul will attract researchers from every part of the world to promote hydrogen energy systems and share their innovative ideas and future plans.

[3] https://fuelcellsworks.com/news/turkey-tubitak-mam-energy-institute-premiers-hydrogen-vehicle/

Also, he has stated that Turkey is dedicated to increase the share of renewables in its energy supply and considers hydrogen energy systems as a potential solution to this. In conjunction with this intention, Turkey has expanded its research, innovation, and technology development activities to produce, store, and use hydrogen in an affordable, reliable, safe, clean, and sustainable manner.[4]

Potential Steps for Turkey's National Hydrogen Strategy

Understanding the opportunities presented by hydrogen energy to reduce dependence on energy imports plays a crucial role in the construction of Turkey's National Hydrogen Strategy. According to the green hydrogen potential revealed by an analysis examined in the report "Turkey's Prioritized Fields for National Hydrogen Strategy" that was published in February 2021 by the Shura Energy Conversion Centre and Bilkent University Energy Policies Research Centre – approximately 5% of Turkey's total energy consumption can be replaced by hydrogen and this could play an important role in reducing Turkey's import dependency on natural gas and other imported fossil fuels. In addition, it will appear as an alternative in terms of supplying the energy needs of areas that consume intense energy such as heavy industry and transportation.

Hydrogen could also be exported to the EU and other neighbouring countries and regions through the transportation pipelines. According to Cristian Carraretto, Associate Director of Green Economy and Climate Action at the European Bank for Reconstruction and Development (**"EBRD"**), the notable renewable energy record of Turkey is of significant importance for developing renewable hydrogen, and there is a window of opportunity for Turkey to produce green hydrogen with the purpose of exporting to Europe.

Measuring the costs and social, economic, and environmental benefits of hydrogen production will ensure that the many sectors where green hydrogen can be used are fully addressed. Implementation of market-based mechanisms to reduce energy-related CO_2 emissions will increase Turkey's industrial competitiveness.

[4] https://whecistanbul.org/

Ukraine

Authors:
Vitaliy Radchenko
Anatolii Doludenko

Current status for hydrogen in Ukraine

Introduction

Hydrogen is gaining increased recognition in Ukraine as a prospective energy source that will assist the country to meet its decarbonisation targets. The EU has noted Ukraine as among the countries with a high potential for renewable energy, and more specifically for low carbon hydrogen, in its Hydrogen Strategy. Ukraine has been encouraged by the EU to join the Clean Hydrogen Alliance, which it is expected to do soon.[1]

In 2018, the first industry association aimed at the promotion of low carbon hydrogen energy, the Ukrainian Hydrogen Council, was established in Ukraine.[2] As a consequence, institutions engaged in the development of hydrogen in Ukraine are being rapidly advanced.

At the end of 2019, the department responsible for the implementation of low carbon hydrogen technologies in Ukraine was established[3] within the Ministry of Energy and Environmental Protection (as of 27 May 2020, the Ministry of Energy and Environmental Protection was split into the Ministry of Energy of Ukraine (the **"Ministry of Energy"**) and the Ministry of Environmental Protection and Natural Resources). In June 2020, a working group was created within the National Security and Defence Council of Ukraine to discuss the possibility of a hydrogen economy.[4] Furthermore, at the end of July 2020 a scientific-technical council, "Hydrogen Energy", was created within the Ministry of Energy.[5]

The Ministry of Energy in June 2021 joined European Clean Hydrogen Alliance.[6] Furthermore, a number of Ukrainian state[7] and private[8] companies also joined European Clean Hydrogen Alliance.

In July 2021, the USA and Germany announced their plans to jointly create a green fund with the budget of approximately USD 1bn which will be financing, among others, development of production of hydrogen in Ukraine.[9]

1 https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf
2 https://www.epravda.com.ua/rus/news/2017/12/15/632092/
3 https://mind.ua/news/20204107-minekoenergo-stvoryue-novij-pidrozdil-z-vprovadzhennya-vodnevih-tehnologij
4 https://mind.ua/news/20211997-pri-rnbo-stvoreno-robochu-grupu-z-pitan-rozvitku-vodnevoyi-ekonomiki
5 https://hydrogen.ua/ua/events-ua/1073-narada-pro-stvorennya-naukovo-tekhnichnoji-radi-vodneva-energetika-v-minekoenergo-visnovki-dlya-galuzi
6 https://www.kmu.gov.ua/news/minenergo-priyednalos-do-yevropejskogo-alyansu-z-chistogo-vodnyu
7 https://kosatka.media/en/category/elektroenergiya/news/energoatom-prisoedinilsya-k-evropeyskomu-alyansu-chistogo-vodoroda
8 https://ufuture.com/udp-renewables-has-joined-the-european-clean-hydrogen-alliance/
9 https://expro.com.ua/novini/ssha-ta-nmechchina-vipustili-splnu-zayavu-po-pvnchnomu-potoku--2-ta-pdtrimc-ukrani

Despite the above, the practical application of hydrogen in Ukraine is still limited. Hydrogen technology is at a very early stage of its development in Ukraine and, consequently, the respective market has not yet been formed. As a result, no significant M&A activity and investments have taken place in Ukraine so far.

However, the interest in hydrogen from the private and public sectors continues to grow, particularly in the light of a perspective application of a EU Carbon tax to Ukrainian carbon intense industries which could become a significant barrier for export of their goods into the EU (e.g. steel, cement and fertilizer production) making decarbonisation of such industries a top priority. As a result, there are significant plans for development of Ukrainian hydrogen economy and the first projects in the area are starting to be implemented.

As at August 2021, there have been few instances where financial institutions have supported the development of hydrogen projects in Ukraine.[10] However, due to the rapidly growing, world-wide pressure for commercial banks and financial institutions to opt out of financing carbon intensive, fossil fuel energy projects, it is likely that their attention will instead turn to providing debt financing to stakeholders investing in new, low carbon technologies in Ukraine, including hydrogen projects. The promotion of hydrogen technologies will be important, given that the infrastructure required for the development of low carbon hydrogen projects is likely to involve significant capital expenditures.

Market prospects for hydrogen

The potential for hydrogen to enhance the economy is beginning to be recognised in Ukraine and there is a significant and growing interest in the technology.

In connection with this, ambitious plans for development of hydrogen transportation and production opportunities are being discussed by the market players (please see Figure 1 below):

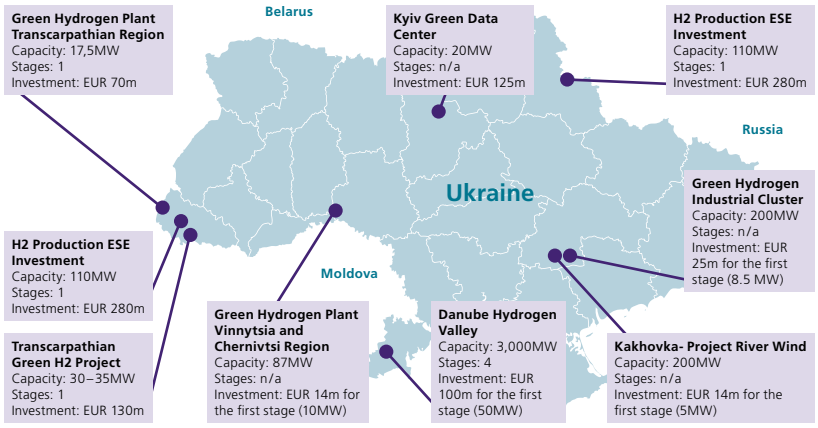


Figure 1: Hydrogen transportation and production opportunities.
Source: Operator of Ukrainian GTS

The storage of hydrogen produced in Ukraine has also been considered as a means to balance the Ukrainian energy system, which is necessary due to the rapid development of renewable energy.[11]

[10] http://www.ukrgasbank.com/press_center/news/12141-ekobank_otkryvaet_put_k_avtomobilyam_na_vodorode_v_ukraine
[11] https://www.epravda.com.ua/projects/greendeal/2020/05/18/660480/

Hydrogen production

Hydrogen production is currently the main area that requires development in Ukraine, as the market is still in its early stages. Ukraine has the potential for substantial hydrogen production – it is estimated that approximately 505,133m m^2 of green hydrogen could be produced in Ukraine, annually[12] – but significant development is still required. There is not yet a demand in Ukraine for such volumes of hydrogen, so production is mainly being considered as an export to the EU. In particular, Hydrogen Europe envisaged a roadmap for the creation of hydrogen electrolysers in Ukraine with capacities of 9,800MW,[13] of which approximately 2,500MW are intended for domestic hydrogen use, mostly for ammonia production and 7 7,300MW for export capacity. The possibility of production of hydrogen using electricity generated by offshore wind is also actively discussed by the market players.[14]

During discussions held by the Ministry of Energy, in early 2020, it was highlighted that low carbon technologies, such as electrolysis and non-green technologies (for example, gasification of coal and biomass) would be the most suitable and profitable methods for hydrogen production in Ukraine.[15]

Despite the above, to date, only one experimental solar power station with an electrolyser has been developed by Ukrainian scientists, which was constructed in 2019 in the Kyiv region of Ukraine.[16]

Nevertheless, production of hydrogen is steadily getting taction and the market players in the energy sector are starting to show their interest in hydrogen technologies. In particular, Ukraine's largest energy group, DTEK, has become the first Ukrainian company to join the industry and research association, Hydrogen Europe[17] and is going to launch its first hydrogen electrolysis pilot project with the capacity of 8.5MW by the end of 2021.[18]

In addition, naturally occurring hydrogen accumulations were discovered in one of the regions of Ukraine in 2019[19] which can, in theory, be extracted. Ukraine does not yet have the technologies required for extraction of naturally occurring hydrogen and so such technologies must be implemented first to capitalise on this discovery.

As for the transportation of the produced hydrogen, the Ministry of Energy of Ukraine considers that it could be feasible for hydrogen to be transported in compressed form via trucks and railways (up to 250km), in liquid form via trucks and railways (between 250 and 1,000km) and in gaseous form via GTS (over 1,000km).

12 https://mind.ua/publications/20205250-mozhlivosti-alternativnoyi-energetiki-dozvolyayut-skorotiti-spozhivannya-tradicijnih-energonosiyiv-udvichi
13 https://www.hydrogeneurope.eu/wp-content/uploads/2021/05/Hydrogen-Europe_2x40-GW-Green-H2-Initative-Paper.pdf
14 https://expro.com.ua/novini/potencal-ofshorno-vtroenergetiki-v-ukran-syaga-250-gvt-potujnost--ve-nan-ukrani-
15 https://www.ntseu.net.ua/stories/549-hydrogen-energy
16 https://www.ntseu.net.ua/stories/549-hydrogen-energy
17 https://www.h2-view.com/story/dtek-joins-hydrogen-europe/)
18 https://metallurgprom.org/en/news/ukraine/7554-dtjek-i-siemens-postrojat-vodorodnyj-jelektrolizer-v-mariupole-za-25-millionov-evro.html
19 https://elektrovesti.net/69285_ukrainskie-uchenye-nashli-prirodnyy-vodorod-v-nedrakh-rovenskoy-oblasti

Use of hydrogen in Ukrainian GTS

There are significant opportunities for the development of hydrogen projects in sectors such as energy and transport. During the first meeting of the scientific-technical council "Hydrogen Energy", it was highlighted that the blending of hydrogen and natural gas within the Ukrainian gas transmission system **("GTS")** is among the most promising methods of hydrogen use in Ukraine.[20]

Blending of hydrogen is also being considered by the Operator of the Ukrainian GTS and is actively promoted by experts, industrial associations, and market players.[21] Promotion of this method is likely to increase as the Operator of the Ukrainian GTS became a member of the European Clean Hydrogen Alliance[22] and executed in July 2021 an Agreement to formalise cooperation on low-carbon hydrogen with EBRD.[23] The operator of Ukrainian GTS has also set up a dedicated think tank focused on decarbonisation of its infrastructure and is currently, among others, developing its hydrogen strategy and R&D program with expected implementation of the first pilot projects after 2025.

Furthermore, in July 2020, Regional Gas Company, the Ukrainian gas distributor, and the National Academy of Science of Ukraine, started studying the effects of using of hydrogen in gas networks on five test sites in Ukraine.[24] The study will be performed until the end of 2025 and on different stages will include static and dynamic tests on the test sites, as well as experiments on existing sections of networks in several consumer clusters with up to 100 households.

Challenges facing hydrogen projects

Legal framework

Currently, the regulatory framework for hydrogen is fragmented due to the so-far narrow application of hydrogen in industry. The regulation of hydrogen is discussed in more detail below.

Financial support and incentives

With regard to hydrogen projects, there have been no instances of the provision of financial support from the government to date.

Furthermore, there are no established incentives for the development of hydrogen projects in Ukraine. In light of the rapid development of renewables in Ukraine, which has raised balancing issues for the Ukrainian energy system, and a transitioning to the competitive scheme for awarding state support to renewables through auctions, some market players have called for the extension of the renewables auctions scheme to include hydrogen storage projects. Such projects will be used to balance the Ukrainian energy system.[25]

At the moment, several Ukrainian companies are exploring potential partnerships with European counterparts in order to unlock financing options for hydrogen projects in Ukraine.[26]

[20] https://hydrogen.ua/ua/events-ua/1073-narada-pro-stvorennya-naukovo-tekhnichnoji-radi-vodneva-energetika-v-minekoenergo-visnovki-dlya-galuzi
[21] https://delo.ua/business/kak-ukraine-razvivat-vodorodnuju-ekonomiku-ek-364696/
[22] https://www.epravda.com.ua/projects/greendeal/2020/06/24/662145/
[23] https://kosatka.media/en/category/gaz/news/operator-gts-ukrainy-stal-chlenom-evropeyskogo-alyansa-s-chistogo-vodoroda
[24] https://www.ebrd.com/news/2021/ebrd-and-ukraine-boost-lowcarbon-hydrogen-development.html
[25] https://kosatka.media/category/gaz/news/rgk-sertificirovala-specialistov-dlya-vodorodnyh-ispytaniy
[26] Іван Гайдуцький у своєму виступі запропонував розповсюдити практику «зелених» аукціонів з ВДЕ також на проекти зі складування енергетичного водню. Ці пілотні проєкти доцільно очікувати від таких структур, як «Нафтогаз України» чи «Укренерго». Представник ДП "ВУГЛЕСИНТЕЗГАЗ УКРАЇНИ" підкреслив важливість просвітництва з метою привернення уваги наших громадян до впровадження водневих технологій.
[27] https://www.energy-community.org/dam/jcr:512b6d58-70a2-4533-9f04-5cb537058b8e/ECA_E4tech_H2_part3.pdf

Research and education efforts

The Ukrainian Academy of Sciences is currently financing 21 hydrogen scientific research and development projects related to the practical aspects of production, storage and usage of hydrogen.[27] The Ukrainian Hydrogen Association and the Institute of Renewable Energy are jointly financing the project "Development of scientific principles on the introduction of technologies for hydrogen with the use of renewable energy sources and prospects for further use for energy needs in Ukraine".[28]

Research in relation to use of the hydrogen in the Ukrainian GTS is also supported by the Public Joint Stock Company "National Joint Stock Company "Naftogaz of Ukraine".[29]

Regulation of hydrogen

Policy and government programmes

Already in April 2019, one of the industry associations in the energy sector presented its roadmap for development of hydrogen in Ukraine until 2035 which envisages development and implementation of effective systems of accumulation, storage, transportation, and usage of hydrogen from various sources, mechanisms of state monitoring, and regulatory framework.[30]

In April 2021, the Ministry of Energy prepared drafts of its own roadmaps for production and use of hydrogen in Ukraine[31] and for usage of hydrogen in automobile transport.[32] In particular, roadmap for production and use of hydrogen in Ukraine provides for three phases for implementing hydrogen, namely:[33]

— First phase (2021–2023), focusing on the assessment of the Ukrainian economy for "green transition" and launch of the hydrogen economy;
— Second phase (2024–2026), including policy prioritisation, hydrogen market and supply chain development and demonstration, scale-up; and
— Third phase (2027–2029), putting together a smart portfolio of policies and strategic hydrogen project development, regulatory reform, and technological development.

The draft of the Ukrainian Green Deal – a document inspired by the European Green Deal which the Ministry of Energy and Environmental Protection of Ukraine was also presented on 21 January 2020. It envisages an increase in the industrial production and use of hydrogen as an energy resource and the replacement of combustion engine vehicles with electric and hydrogen vehicles.[34] However, the Ukrainian Green Deal has not yet been approved, and is under process of revision.[35]

27 https://ecolog-ua.com/news/ponad-try-milyony-gryven-na-vodnevi-proekty-vydilyly-v-nan-ukrayiny
28 https://ecolog-ua.com/news/ponad-try-milyony-gryven-na-vodnevi-proekty-vydilyly-v-nan-ukrayiny
29 http://www.naftogaz.com/www/3/nakweb.nsf/0/11772E471EB0FC90C22581690026DFB6?OpenDocument&Expand=9.2&
У обговоренні доповідей водневої тематики виступив академік НАН України, д.т.н., професор І.М.Карп.
30 https://hydrogen.ua/ua/events-ua/1053-vodneva-energetika-krajini-es-pidtrimali-ukrajinu-ta-jiji-dorozhnyu-kartu-v-gannoveri
31 https://unece.org/documents/2021/03/reports/draft-roadmap-production-and-use-hydrogen-ukraine
32 https://www.ukrinform.ua/rubric-economy/3232781-u-minenergo-rozrobili-tri-dokumenti-dla-pidgotovki-vodnevoi-strategii-ukraini.html
33 https://www.energy-community.org/dam/jcr:512b6d58-70a2-4533-9f04-5cb537058b8e/ECA_E4tech_H2_part3.pdf
34 https://mepr.gov.ua/news/34731.html
https://mineco.gov.ua/files/images/news_2020/02032020/%D0%9A%D0%BE%D0%BD%D1%86%D0%B5%D0%BF%D1%86%D1%96%D1%8F%20%D0%B7%D0%B5%D0%BB%D0%B5%D0%BD%D0%BE%D0%B3%D0%BE%20%D0%B5%D0%BD%D0%B5%D1%80%D0%B3%D0%B5%D1%82%D0%B8%D1%87%D0%BD%D0%BE%D0%B3%D0%BE%20%D0%BF%D0%B5%D1%80%D0%B5%D1%85%D0%BE%D0%B4%D1%83.pdf
35 https://www.ukrinform.ua/rubric-economy/3142287-minenergo-pereglane-koncepciu-zelenogo-energeticnogo-perehodu-buslavec.html

The Ukrainian Energy Strategy for the period until 2035, approved by the Order of the CMU No. 605-p dated 18 August 2017, also recognises that, in the next few decades, combustion engines in cars will be replaced by electric and hydrogen engines.[36] Please note that the Ukrainian Energy Strategy for the Period until 2035 is currently undergoing revision in order to bring it in line with the latest developments in the sector (European Green Deal) and thus, among others, to highlight importance of development of hydrogen economy.

Specific legislation/ regulation

Regulatory framework for hydrogen in Ukraine is fragmented and there is no single legal act regulating hydrogen yet. As such existing laws on energy, transport, and movement of gasses apply to hydrogen projects.

General usage of hydrogen in various technological processes is subject to the technical regulations applicable to:

— equipment and protective systems intended for use in a potentially explosive environment;
— pressure running equipment;
— simple high-pressure vessels;
— water heating boilers running on liquid or gaseous fuels;
— gaseous fuel devices;
— mobile pressure equipment.

Furthermore, in Ukraine, in 2020, the technical committee for standardisation of TC 197 "Hydrogen Technologies" was established, which operates in hydrogen technologies in accordance with the adopted international classification of standardisation. Due to the fact that hydrogen technologies cover various industries, the technical committee also coordinates the activities of national technical committees, whose activities are related to the design, construction, manufacture, operation of technological objects, systems and equipment, the production, and use of hydrogen:[37]

— TC 8 "Pipes and steel cylinders";
— TC 21 "Dynamic and volumetric pumps";
— TC 25 "Fire Safety";
— TC 26 "Operation of aircraft";
— TC 28 Compressors;
— TC 38 "Refined and petrochemical products";
— TC 55 "Methanol, synthesis products";
— TC 80 "Road transport";
— TC 108 "Pipe Fittings";
— TC 133 "Gas natural";
— TC 146 "Materials, equipment, technologies and facilities for the oil and gas industry";
— TC 187 "Explosion-proof equipment";
— TC 318 "Construction of oil and gas production, transportation and storage facilities".[38]

[36] https://zakon.rada.gov.ua/laws/file/text/58/f469391n10.pdf
[37] https://unece.org/documents/2021/03/reports/draft-roadmap-production-and-use-hydrogen-ukraine
[38] https://unece.org/documents/2021/03/reports/draft-roadmap-production-and-use-hydrogen-ukraine

Regulation of hydrogen production

General requirements apply to hydrogen as a "chemical substance" and these are established by the State standard of Ukraine DSTU 2655-94 Hydrogen.

Although the production of hydrogen does not require the obtaining of a respective licence as such, it is worth mentioning that there is a general requirement to obtain a licence to produce hydrogen from household or hazardous waste[39] or to generate electricity from hydrogen (which may be also required for the use of hydrogen storage for balancing the energy system of Ukraine).

The production of hydrogen as "chemical production" will likely require the undertaking of an environmental impact assessment and compliance with its conditions.[40]

Electrolysing facilities are required to obtain a special permit for water usage, as they will most likely be withdrawing water from water sources, using the water, and potentially discharging polluting substances back into the water sources.

When using biomass for the creation of hydrogen, the respective facilities will be also subject to either submitting a declaration of waste or to obtaining a permit for the performance of operations in the sphere of waste treatment.

The operation of hydrogen production facilities may also potentially require obtaining air pollution permits and compliance with thresholds for air pollution.[41]

Use of hydrogen in Ukrainian GTS and gas distribution networks

At the time of writing, the use or transportation of hydrogen is neither foreseen by the Ukrainian GTS in the GTS code of Ukraine approved by the Order of the Regulator No. 2493 dated 30 September 2015, nor by the Ukrainian gas distribution networks in the Code of Distribution Networks approved by the Order of the Regulator No. 2494 dated 30 September 2015.

To be connected to the GTS or gas distribution networks, hydrogen projects must execute connection agreements with the Operator of the Ukrainian GTS or the relevant distribution system operator.

Use of hydrogen for transportation

On 6 July 2021, the Ministry of Infrastructure of Ukraine published for public discussion the draft Law "On Amendment of the Law of Ukraine" "On Automobile Transport" regarding encouragement of usage of transport vehicles with electric engines which, if approved by Ukrainian Parliament, will establish, among others, definition in Ukrainian legislation of a hydrogen vehicle, being a vehicle with an engine which uses energy obtained from hydrogen.[42]

39 https://zakon.rada.gov.ua/laws/show/222-19#Text 14
40 https://zakon.rada.gov.ua/laws/show/2059-19#Text
41 https://ips.ligazakon.net/document/REG9701?an=11&q=%D0%B2%D0%BE%D0%B4%D0%B5%D0%BD%D1%8C&is_no_morph=true&hide=true&snippet_id=snippet_26545
42 https://mtu.gov.ua/news/32930.html

Hydrogen produced from biomass is defined as an "alternative type of gaseous fuel" in the Law of Ukraine On Alternative Types of Fuel.[43] This law establishes the general principles of treatment of alternative types of fuel, including the possibility for implementation of various state incentives for their development. Otherwise, hydrogen is not covered by legislation regulating production and sale of fuel in Ukraine (which also covers various gaseous fuels).

Nevertheless, it is possible to assume that the development of the hydrogen as a fuel for transportation will result in application of similar principles to it. As a result, the provisions applicable to gaseous fuels should be taken into account in this respect. In particular, the Law of Ukraine on the State Regulation of the Production and Circulation of Ethanol, Cognac and Fruit Spirits, Alcohol Beverages and Fuel establishes a requirement to obtain a licence for the production, storage and sale of gaseous fuels.[44]

Regulation of hazardous activities

Hydrogen is considered as a hazardous (flammable)[45] and explosive[46] substance according to the Resolution of the CMU No. 956 dated 11 July 2002. As a result, hydrogen projects may also be subject to a number of other requirements on labour safety.

In particular, hydrogen projects will be subject to the following safety rules:

- fire safety rules in Ukraine (NABB A.01.001-2014);
- safety rules in the production of hydrogen by electrolysis of water (NPAOP 24.11-1.03-78);
- safe operation of piston compressors operating on explosive and toxic gases (NPAOP 0.00-1.14-76);
- safety of gas supply systems (NPAOP 0.00-1.76-15);
- labour protection during operation of pressure equipment (NPAOP 0.00-1.81-18);
- safety during operation of means and systems of automation and control in the gas industry (NPAOP 11.1-1.07-90);
- electrical installations (NPAOP 40.1-1.32-01);
- safe operation and maintenance of automobile gas filling compressor stations (NPAOP 63.2-1.06-02).[47]

Furthermore, the operation of hydrogen projects will include the performance of certain works and the operation of certain equipment which pursuant to Ukrainian law are considered (or are likely to be considered) as creating occupational risks. Performance of such hazardous works (including usage, production, storage, and transportation of hydrogen, as well as gas hazardous works)[48] and the operation of hazardous equipment (including of equipment for usage, production, storage, and transportation of hydrogen)[49] is only allowed under a respective permit. In addition to the above, the performance of welding, storage of containers, cisterns and other vessels with hydrogen must also be performed based on the declaration of compliance with labour safety requirements.

43 https://ips.ligazakon.net/document/T001391?an=30&is_no_morph=true&hide=true
44 https://ibuhgalter.net/ru/articles/333, https://zakon.rada.gov.ua/laws/show/481/95-%D0%B2%D1%80#Text
45 https://zakon.rada.gov.ua/laws/show/956-2002-%D0%BF#Text
46 https://ips.ligazakon.net/document/RE23603?an=221&is_no_morph=true&hide=true
47 https://unece.org/documents/2021/03/reports/draft-roadmap-production-and-use-hydrogen-ukraine
48 https://zakon.rada.gov.ua/laws/show/1107-2011-%D0%BF#Text
49 https://zakon.rada.gov.ua/laws/show/1107-2011-%D0%BF#Text

In addition, hydrogen projects are likely to be considered as "hazardous projects" (in particular, facilities for hydrogen production and hydrogen pipelines).[50] Under the Law of Ukraine On Facilities of High Hazard, the owner of projects that use (produce, process, store or transport) hazardous substances is required to prepare a declaration of safety and assess such projects in order to identify whether the facility qualifies as a highly hazardous project (based on the quantity of a substance and its hazard class).

Construction of hydrogen projects

Law of Ukraine "On Regulation of City Building Activities" provides for three classes of construction projects, depending on possible damage to property and hazard to health and safety of people:

— CC1 (objects with minor consequences);
— CC2 (objects with medium consequences); and
— CC3 (objects with significant consequences).

Considering the classification of hydrogen as a hazardous and explosive gas, the majority of hydrogen projects are likely be classified as having medium (CC2) and significant (CC3) consequence classes and, thus, requiring expert examination of their construction design and obtaining of the construction permit.

Furthermore, the companies (contractors) that will be performing the construction of the hydrogen projects will likely be required to hold a valid construction licence.

Transportation, import and export of hydrogen

Liquid or compressed hydrogen is considered as dangerous cargo and thus additional permitting and licensing requirements to its transportation are applicable.[51]

Transportation of hydrogen across Ukrainian customs border is also subject to additional ecological control.[52]

50 https://ips.ligazakon.net/document/RE12160?an=1&is_no_morph=true&hide=true
51 https://ips.ligazakon.net/document/re16196a?an=13813, https://ips.ligazakon.net/document/reg7879?an=13225
52 https://ips.ligazakon.net/document/MK111178?an=1&q=%D0%B2%D0%BE%D0%B4%D0%B5%D0%BD%D1%8C&is_no_morph=true&hide=true&snippet_id=snippet_262082) (https://ips.ligazakon.net/document/mf16032?an=18383

Regulatory bodies

Since there are no hydrogen-specific provisions yet, mentioned above general provisions concerning the construction and operation of equipment and labour safety will apply to hydrogen.

The Ministry of Energy and the National Commission for State Regulation of the Energy and Public Utilities Sector are responsible for regulating the usage of the hydrogen in the electricity and gas spheres and establishing the relevant regulatory policy.

The Ministry of Environmental Protection and Natural Resources regulates the production of hydrogen in relation to waste treatment, the extraction of natural accumulations of hydrogen, as well as other environmental aspects of hydrogen projects (such as environmental impact assessments).

Upcoming developments

Although it is expected that the detailed regulatory framework for usage of hydrogen in Ukrainian economy will be drafted in the future, no clear framework has been established yet.

This legislation will need to include the following in order to support the development of a hydrogen economy in Ukraine:

— development of support schemes for hydrogen production, as well as systems of guarantees of origin of hydrogen;[53]
— an amendment of the GTS Code for usage of hydrogen in the GTS;[54]
— the adoption of the bill regulating production of the hydrogen from waste and biomass;[55] and
— various technical regulations in relation to hydrogen and production processes.[56]

Ukraine, with the support of the World Bank, is also in the process of preparing its Hydrogen Strategy. In particular, in August 2021 the first meeting of the working group of the Ministry of Energy for development of the Hydrogen strategy[57] was held and the tender for choosing of the experts which will be developing the hydrogen strategy was announced by the World Bank.

53 https://unece.org/documents/2021/03/reports/draft-roadmap-production-and-use-hydrogen-ukraine
54 https://mind.ua/ru/openmind/20204093-zelenyj-vodorod-dlya-ukrainy-kak-spasti-prirodu-i-gts
55 https://www.ntseu.net.ua/stories/549-hydrogen-energy
56 https://mind.ua/ru/openmind/20204093-zelenyj-vodorod-dlya-ukrainy-kak-spasti-prirodu-i-gts
57 https://www.kmu.gov.ua/news/robocha-grupa-z-rozrobki-vodnevoyi-strategiyi-ukrayini-provela-pershe-zasidannya
58 https://blog.liga.net/user/arepkin/article/33656
59 https://en.interfax.com.ua/news/investments/682339.html

Nevertheless, industry associations are already researching and developing hydrogen deployment across Ukraine, looking towards 2035 for deployment.[58] It is also worth noting that various hydrogen related projects are starting to be unveiled in Ukraine, namely:

— During a meeting with the President of Ukraine on 6 August 2020, Norwegian company NBT announced its plans to build **a wind power plant with a capacity of 800MW and electrolysis-based hydrogen production facilities with a capacity of 200MW in Zaporizhzhia** region of Ukraine.
— On 20 August 2020 National Nuclear Power Generation Company of Ukraine and the H2 LLC executed a memorandum of cooperation on the **construction of a computing data centre and hydrogen plant near Zaporizhia Nuclear Power Plant.**[59] National Nuclear Power Generation Company of Ukraine has also announced its plans to produce hydrogen.[60]
— Renewable power plants developer has announced that it received all of the permitting documents for setting up of the R&D site for production of "green" hydrogen.[61]
— Design of the wind power plant with capacity of 72MW which will be producing hydrogen is being developed.[62]
— RAG (Austria's largest storage facility operator) in a partnership with other European companies is pursuing a long term strategy including production of renewable hydrogen in Ukraine.[63]

60 https://minfin.com.ua/ua/2021/07/28/68764417/
61 https://expro.com.ua/novini/kness-rozpochina-budvnictvo-maydanchiku-z-virobnictva-zelenogo-vodnyu
62 https://expro.com.ua/novini/grupa-kompany-mcl-gotu-proekt-ves-z-virobnictvom-zelenogo-vodnyu-u-rvnensky-oblast
63 https://www.energy-community.org/dam/jcr:512b6d58-70a2-4533-9f04-5cb537058b8e/ECA_E4tech_H2_part3.pdf

United Kingdom

Authors:
Dalia Majumder-Russell
Charlotte Rihoy
Kristy Mitchell

Current status for hydrogen in the UK

Introduction

Hydrogen is expected to have a substantial role in the decarbonised UK energy system over the coming decades. Total UK consumption of hydrogen is expected to increase from 0.7m tonnes (Mt) in 2020 to between 3–19Mt by 2050.[1]

The importance of hydrogen to the UK's future energy system and industry is reflected in government policy. In November 2020, the UK government published its Ten Point Plan for a Green Industrial Revolution,[2] which proposed a target of having 5GW of low carbon hydrogen production capacity by 2030 (and 1GW by 2025). Building on this, one month later, the Energy White Paper set out the UK's strategy for the energy transition over the next decade, which amplified the role that the government sees hydrogen playing in its energy mix.[3] In August 2021, the future role of hydrogen was consolidated in the long-awaited and first ever UK Hydrogen Strategy,[4] which reinforced prior commitments but also set forth a roadmap for how these commitments are intended to be achieved over the 2020s (see further at paragraph *The UK Hydrogen Strategy* 2021 below).

At present, virtually all hydrogen is used in the UK as an industrial feedstock in the chemical industry and in oil refineries, but there is potential for a shift towards green hydrogen across a range of sectors, most notably in the following areas.

Transport sector use

Whilst batteries have a role to play in decarbonising passenger vehicles, hydrogen (hydrogen fuel cells or similar) is seen as a potential solution for larger road vehicles, marine and rail transport which needs longer range and refuelling times comparable to internal combustion engines. The UK has a number of policy initiatives to investigate the role of hydrogen in transport.

[1] http://www.h2fcsupergen.com/wp-content/uploads/2020/04/2020_04_H2FC_Supergen_Hydrogen_Fuel_Cells_P_Dodds_DIGITAL_W_COVER_v05.pdf
[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf
[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf
[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

For example, the UK government has committed to invest GBP 3m in 2021 to establish a multi-modal hydrogen transport hub in Tees Valley focusing on hydrogen research and demonstrations.[5] Furthermore, Network Rail's cross-industry Traction Decarbonisation Network Strategy considered areas for deployment of overhead electrification, battery and hydrogen trains.[6] It now plans to showcase its low-carbon train technologies at COP 26 in Glasgow, including a hydrogen-powered HydroFLEX train.[7] The challenge for rail freight is that current alternatives to overhead electrification, such as hydrogen or batteries, do not have sufficient power on their own to pull heavy freight trains, so bi-modes may be an alternative way to reduce emissions.

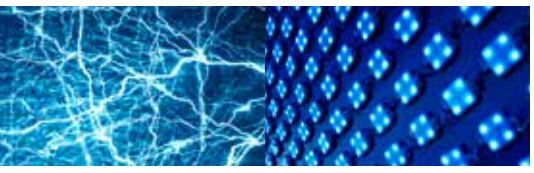
Hydrogen use is also popular in the context of decarbonising public road transport, particularly buses. Wrightbus already manufactures zero emission hydrogen buses (which use hydrogen fuel cells)[8] and has committed to introduce 3,000 buses in the UK by 2024.[9] In the Hydrogen Strategy, the government also highlights that up to GBP 120m of funding will be provided by the Zero Emission Bus Regional Areas scheme to begin delivery of 4,000 new zero emissions buses, either hydrogen or electric, and supporting infrastructure. These developments have garnered interest from numerous local authorities keen to use hydrogen-powered transport partly as a way of improving local air quality as well as creating local jobs.

Industry

UK industry uses around 0.7Mt of hydrogen every year as a feedstock for a number of processes. At present, this is primarily produced from natural gas (i.e. grey hydrogen). However, with the development of carbon capture technology over the coming decade, this hydrogen can be decarbonised by capturing the carbon dioxide emissions using the steam reformation method. Alternatively, there may be some industrial processes which are situated in locations suitable for green hydrogen (i.e. hydrogen made by electrolysis, often using renewable energy power). In addition to feedstock, such hydrogen would also be used for heating in many industrial processes such as in cement production and in the chemicals industry. One such example is the HyNet project in North West England which proposes to develop a hydrogen cluster in which blue hydrogen is produced to supply a range of industrial sites, with the carbon emissions of these sites directly captured.

Heating

The UK has an extensive gas network providing natural gas to more than 80% of homes as well as to commercial buildings for heating. Decarbonising heating is key for the UK's overall net zero aims, therefore a number of pilot heating projects have been undertaken so far. For example, the HyDeploy project led by Cadent, in partnership with Northern Gas Networks and others, is testing an injection of up to 20% hydrogen into the natural gas network feeding 100 homes and 30 faculty buildings. The results of this study are key to demonstrate the viability of blending the existing gas supplies (methane) with hydrogen. As part of the Hydrogen Strategy, the government has also committed to deliver a hydrogen for heat neighbourhood trial by 2023, and a village scale trial by 2025 to gather more evidence in relation to the safety and feasibility of hydrogen heating. These trials intend to inform the government's 2026 strategic decision on the future of hydrogen for heat. In terms of hydrogen appliances, the government expects to consult on the case for enabling or requiring new natural gas boilers to be easily convertible to use hydrogen.



[5] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1009448/decarbonising-transport-a-better-greener-britain.pdf
[6] https://www.networkrail.co.uk/wp-content/uploads/2020/09/Traction-Decarbonisation-Network-Strategy-Interim-Programme-Business-Case.pdf
[7] https://www.networkrail.co.uk/stories/world-environment-day-2021/
[8] https://airqualitynews.com/2020/05/01/wrightbus-announce-plans-for-3000-hydrogen-buses/
[9] https://www.route-one.net/news/wrightbus-owner-plans-3000-hydrogen-buses-by-2024/

Market prospects for hydrogen

The hydrogen market in the UK is at an early stage with significant prospects for growth over the coming years. The Committee on Climate Change have advised that hydrogen will be a key enabler for the UK to meet net zero targets. To date, much of the funding has come from the public sector. In March 2021, the UK government's R&D body, UK Research and Innovation, awarded GBP 171m of funding across nine hydrogen projects.[10] Furthermore, in May 2021, the UK government announced a GBP 166.5m funding package to drive forward the technologies and development needed for a green industrial revolution. As part of this package, GBP 60m is allocated to support the development of low carbon hydrogen in the UK and scale up efficient solutions for producing hydrogen through electrolysis.[11] The Hydrogen Strategy also outlines several other pots of funding that are or will be in place to support the range of commitments therein, such as the GBP 240m Net Zero Hydrogen Fund.

The UK government continues to work on developing business models that support investment in hydrogen projects and, alongside the publication of the Hydrogen Strategy, launched a consultation on proposed models.[12] Whilst many in the industry had anticipated that the preferred business model for hydrogen will be based on the offshore wind Contract for Difference (**"CfD"**) scheme – and the contract will be with a government owned counterparty – the consultation sets out a number of options as well as giving an indication of the government's preferred approach (and reasons behind it). Namely, the consultation states that the hydrogen CfD will be a variable price support model whereby the reference price will comprise, at least initially, the highest of two proxies (methane gas price and sales price achieved by the producer). Project eligibility is yet to be determined and is subject to a separate consultation. Similarly the government is developing the standard against with low carbon hydrogen projects will be measured. The government's ambition is to finalise the hydrogen business model in 2022 so as to enable first contracts to be allocated from Q1 in 2023.

Because of the relatively nascent status of the hydrogen projects there has been little M&A activity in the sector and relatedly, little by way of private financing to date. This is expected to change once the UK government clarifies the legal frameworks for hydrogen projects.

Challenges facing hydrogen projects in the UK

Reducing the cost and securing demand

As with any emerging technology, production and processing of decarbonised hydrogen is more expensive than current processes for producing grey hydrogen. Accordingly, development of hydrogen at scale is seen as a key requirement for reducing overall costs. Some projects predict that the cost of delivering green hydrogen at scale by 2050 could be cost-competitive with the current methane reformation processes. In part, the key variable for determining the price projections also depends on the production method, the electricity, gas or biomass feedstock price, the carbon price, and also the seasonal temperature variations which would vary demand for hydrogen heating. Current forecasts estimate that in 2050 the value of hydrogen in the UK would be in the range of GBP 428bn, while the global market value could be at least GBP 380bn.[13]

[10] https://www.ukri.org/news/ukri-awards-171m-in-uk-decarbonisation-to-nine-projects/
[11] https://www.gov.uk/government/news/166-million-cash-injection-for-green-technology-and-60000-uk-jobs
[12] https://www.gov.uk/government/publications/business-models-for-low-carbon-hydrogen-production
https://www.gov.uk/government/consultations/design-of-a-business-model-for-low-carbon-hydrogen
[13] http://www.h2fcsupergen.com/wp-content/uploads/2020/04/2020_04_H2FC_Supergen_Hydrogen_Fuel_Cells_P_Dodds_DIGITAL_W_COVER_v05.pdf

Overcoming the current price uncertainties and lack of demand forecast is therefore key for developing successful hydrogen projects. In this regard, the certainty of long-term contracts is seen as critical for minimising some of the perceived risks.

Legislative framework

In common with many jurisdictions, the UK does not have a well-defined legislative framework for hydrogen projects in the various sectors. While the Hydrogen Strategy outlines a roadmap of key archetypes and milestones that the government expects to see in terms of the production and use of hydrogen across the 2020s, it suggests that an initial network regulatory framework is not expected to be in place until 2025 at the earliest. Until then, networks are envisaged to be delivered through existing frameworks. This creates a number of gaps and uncertainties which need to be addressed before the hydrogen economy can flourish.

Regulation of hydrogen

Legislation overall

There is very little legislation that specifically relates to hydrogen. Instead, hydrogen projects must navigate the existing legislative landscape that applies to gasses more generally. Hydrogen is captured under the definition of "gas" in the Gas Act 1986 (the **"Gas Act"**) and is therefore regulated as part of the gas network.

The UK gas market is regulated by the Gas and Electricity Markets authority, operating through the Office of Gas and Electricity Markets (**"Ofgem"**). Anyone engaging in gas supply, gas shipping or gas transportation, or who participates in the operation of gas interconnectors, or provides smart metering in respect of gas must have a licence to do so under the Gas Act. The licences include measures relating to the safe operation of the gas network and provisions relating to price controls. An entity wishing to transport hydrogen (or carry out another activity regulated by the Gas Act) through gas pipelines may therefore require a licence and as part of this must demonstrate a credible plan to commence licensed activities and permit a risk assessment to be carried out by Ofgem as part of the process for obtaining the licence.

Further, a gas licensee must also comply with various industry codes, such as:

- The Uniform Network Code – sets out the common rules governing the gas transportation arrangements between licenced gas transporters and shippers, as required under their licence. Every licensed gas transporter must have its own network code, incorporating the Uniform Network Code, and governing the terms on which it will transport gas. It includes a Transportation Principal Document, which sets out the gas transportation arrangements between gas shippers and transporters and an Offtake Arrangements Document which sets out arrangements between different transporters.
- Independent Gas Transporter Uniform Network Code – sets out the common rules applying to independent gas transporters. It aims to harmonise the network code arrangements of Independent Gas Transporters, who operate extensions to the gas network such as those serving new housing developments.
- Supply Point Administration Agreement – this is a multi-party agreement to which all gas transporters and suppliers are required to comply with. It facilitates supply point administration, being the change of gas supplier.
- Retail Energy Code – this enables end consumers to switch energy suppliers.

Injection into the gas grid – blending hydrogen into the existing gas networks

Pursuant to the Gas Safety (Management) Regulations 1996, the concentration of hydrogen that can be injected onto the UK gas network is 0.1%. As mentioned above, this is being tested to increase the hydrogen blend to up to 20%. If successful, the regulations will need to be amended to allow for this higher blend.

Real estate and consenting regulation

Major hydrogen projects are likely to be nationally significant infrastructure projects which require a development consent order under the Planning Act 2008. For smaller projects (or pipelines) such consents may be instead regulated through the Town and Country Planning Act 1990.

In addition to ensuring the relevant consents are obtained, land rights need to be secured the same as for other infrastructure. As such access rights would be needed from production and storage facilities to ensure they are fit for the purpose of large-scale industrial transportation which may be through private contracts or under the compulsory acquisition powers that may be available. In the case of re-purposing existing infrastructure, variations to existing rights are likely to be needed to reflect the necessary technological upgrades and/or regulatory issues.

In relation to storage of hydrogen, an Environmental Impact Assessment may be required if hydrogen is to be stored on site or if there are pipelines carrying hydrogen pursuant to the Town and Country Planning (Environmental Impact Assessment) Regulations 2017.

Health and safety laws

Hydrogen, like other gasses is heavily regulated from a health and safety perspective. The Health and Safety Executive (**"HSE"**) requires compliance with the following regulations:

- Gas Safety (Management) Regulations 1996 – concerns the flow of gas through the network. All gas transporters must prepare and submit a safety case to HSE. This identifies the hazards and risks, explains how they are controlled, and describes the system in place to ensure that controls are applied. The gas transporter will be audited to ensure compliance with their safety case
- Pipeline Safety Regulations (1996) – concerns pipeline integrity. These regulations set out requirements in respect of pipeline design, construction, installation, operation, maintenance and decommissioning. For example, pipelines should be equipped with emergency shut down valves and its design should take account of the need for maintenance access.
- Storage of Hydrogen is regulated by The Planning (Hazardous Substances) Regulations 2015 and/or the Control of Major Accident Hazards Regulations 2015 (**"COMAH"**), depending on the quantities involved. COMAH sets a high bar of requiring operators to take all measures necessary to prevent a major accident and limit consequences for human health and the environment. The operator must have in place various strategies, including safety plans, emergency plans and a Major Accident Prevention Policy.
- Under the Hazardous Substances Regulations, consent is required to store two or more tonnes of hydrogen, and a further consent is required where storing five of more tonnes of hydrogen.
- The Dangerous Substances and Explosive Atmosphere Regulations 2002 sets out requirements for the use of equipment and protective systems in potentially hazardous environments, including those where hydrogen is produced or stored.

Transport of hydrogen by road

The European Agreement concerning the International Carriage of Dangerous Goods by Road ("ADR") regulates the transport of hydrogen, which is classified as a dangerous good under Annex 5 of the ADR. Hydrogen transport is excluded through ten tunnels in the UK, based on its ADR classification.

Drivers transporting hydrogen must be appropriately trained, and vehicles must meet specifications required for hazardous cargoes.

The Pressure Equipment (Safety) Regulations apply to the design and manufacture of tanks used to transport hydrogen.

Regulatory bodies

There is no specific regulatory body which is responsible for the regulation of hydrogen projects. Instead, a number of regulators would have responsibilities depending on the activity in question.

Regulatory Body	Role
Local Authority Town and Country Planning Authority	— Regulates the use of land — Undertakes Environmental Impact Assessment — Usually has the role of the hazardous substance authority in relation to storage
Health & Safety Executive	— Assesses local authority decisions and signs off driver training
UK Vehicle Certification Agency	— Approves hydrogen transport vehicles
Oil and Gas Authority	— Regulates new pipelines and decommissioning
Ofgem	— Regulates the gas network

Upcoming developments

The UK Hydrogen Strategy 2021

In August 2021, the UK government published its long-awaited and first ever Hydrogen Strategy for the UK. As highlighted throughout this chapter, the Hydrogen Strategy reinforces prior commitments (such as the ambition for 5GW of hydrogen production capacity by 2030) but also provides clarity on plans for the near future to develop a hydrogen economy in the UK, taking a "whole-system" approach. In particular, it sets out (amongst other things):

— a detailed roadmap of key archetypes and milestones that the government expects to see in terms of production, networks and use of hydrogen in the early, mid and late 2020s to reach its 5GW goal, as well as an indication of the intended direction from the mid-2030s and beyond;
— the way forward to developing a hydrogen business model and revenue mechanism, namely, launching a consultation on the proposed models with the ambition to finalise this in 2022;
— a commitment to a "twin-track" approach for both natural gas based "blue" and electrolytic "green" hydrogen production methods, and a proposal to develop a UK low-carbon hydrogen standard to clarify what "low-carbon" really means;
— that work is ongoing with the Health and Safety Executive to assess the potential for 20% hydrogen blending into the gas network, and a call for evidence on the future of the gas system is to be launched later in 2021; and
— methods and indicative metrics for tracking progress against the Strategy's key outcomes.

The government expects that 20–35% of the UK's energy consumption in 2050 can be met with hydrogen and that it can be used in sectors ranging from heating to heavy industry, land, air and maritime transport. However, while the Hydrogen Strategy was welcomed by many in the industry, legal analysis and the development of new laws and an industry framework is yet to come with new legislation likely to be needed. This is in addition to navigating the HSE and environmental regulations, whether as part of consenting such projects or in trying to get them built.

Hydrogen Projects in development

There has been a number of hydrogen projects developing over the course of 2021. Notably, the following have been successful in securing public funding to progress demonstration of the role that hydrogen can play in the UK's energy, transport, industrial and heating sectors:[14] [15]

Dolphyn Project: led by Environmental Resources Management, this project is developing the design of a 2MW prototype of the technology that combines offshore wind power with seawater to produce green hydrogen, that can then be piped back to shore. Initial designs include a 10MW floating offshore wind turbine, together with a water treatment unit and electrolysers for localised hydrogen production.

HyNet: led by a core consortium of Progressive Energy, ENI UK, Cadent Gas, Essar Oil and others, HyNet involves the development of a hydrogen production facility in the north west of England to be part of the UK's first net-zero industrial zone using carbon capture and storage technology. Gigastack: led by ITM Power Trading Ltd, in collaboration with Orsted, Phillips 66 and Element Energy, the project is to demonstrate its capacity to provide large volume, low-cost and zero-carbon hydrogen, through gigawatt-scale polymer electrolyte membrane (**"PEM"**) electrolysers. It will use the electricity generated by Ørsted's Hornsea One offshore wind farm to generate renewable hydrogen for the Phillips 66 Humber Refinery.

Acorn: led by Pale Blue Dot Energy, this hydrogen production plant is focused on the delivery of an energy and cost-efficient process for hydrogen production, using natural gas produced in the North Sea, with carbon capture and storage technology for the associated emissions.

HyPER: led by Cranfield University, in collaboration with Gas Technology Institute and Doosan, this project is working to design and build a pilot-scale hydrogen supply system based on new technology involving steam (the "sorption enhanced steam reforming process") that may be capable of bulk hydrogen production. Construction commenced in April 2021.

South Wales Industrial Cluster ("SWIC"): led by a partnership of utilities, power generation and heavy industry companies, SWIC aims to decarbonise various sectors in the region such as energy, oil, chemicals, steel and cement. To that end, collaborators, including RWE, Shell, Tarmac, SIMEC Atlantic Energy and Tata Steel, are working to devise options to support regional hydrogen deployment as well as carbon capture technologies.

Northern Endurance Partnership: led by oil and gas majors such as BP, Shell, Eni, Total and Equinor, this project aims to create an offshore carbon dioxide transport and storage network and develop a large-scale blue hydrogen production plant that will connect to and decarbonise industrial sites throughout the Humber region.

[14] https://www.gov.uk/government/news/90-million-uk-drive-to-reduce-carbon-emissions
[15] https://www.ukri.org/news/ukri-awards-171m-in-uk-decarbonisation-to-nine-projects/

United States of America

Authors:
Dalia Majumder-Russell
Charlotte Rihoy

Current status for hydrogen in the US

Introduction

Hydrogen is an emerging key technology in the US and has the potential to be a multi-billion dollar industry.[1] Hydrogen regulation in the US is dealt with at two main levels – US-wide federal regulation and individual state regulation. The US has historically experienced changeable political attitudes towards low-carbon technologies at federal level, and approaches between states differ greatly. These are discussed in more detail in the *"Policy Landscape"* section. Long-term policy thinking is required to develop and deploy nascent technologies, such as low-carbon hydrogen, on a commercial scale. The official re-signing of the Paris Agreement on behalf of the US in January 2021 demonstrates support for the decarbonisation agenda, of which hydrogen is recognised as having the potential to play an important part.

At present, about 95% of hydrogen produced within the US is polluting grey hydrogen. However, an August 2021 report by GlobalData estimates that low-carbon hydrogen production in North America is expected to almost triple by 2030 to around 1.4m tons per annum (**"mtpa"**).[2] Other research suggests the potential for low-carbon hydrogen to generate revenues of between USD 130–170bn per year by 2050.[3] To put this into context, in 2018 the total revenue of the United States' oil and gas industry came to around USD 181bn. Further, the *Road Map to a US Hydrogen Economy*, developed by a coalition of US energy sector players, estimates that hydrogen could account for 14% of US energy demand by 2050.[4]

[1] https://www.forbes.com/sites/energyinnovation/2019/10/07/how-hydrogen-could-become-a-130-billion-us-industry-and-cut-emissions-by-2050/#280a67b12849
[2] https://store.globaldata.com/report/gdge00366ei--north-america-hydrogen-market-overview-demand-policies-deals-and-key-players/
[3] https://www.forbes.com/sites/energyinnovation/2019/10/07/how-hydrogen-could-become-a-130-billion-us-industry-and-cut-emissions-by-2050/#280a67b12849
[4] https://www.fchea.org/us-hydrogen-study

The US is well placed to produce blue hydrogen using steam methane reformation combined with carbon capture, usage, and storage. This is due to the US's significant storage capacity – estimated as being 3,000mGt of greenhouse gas emissions or about 600 years' worth of current US emissions.[5] At present, however, only about 0.25mtpa worth of completed blue hydrogen production capacity exists in the US, with a further >0.1mtpa in feasibility study stage. Deployment of green hydrogen production is even less advanced, with about 0.2mtpa of production capacity in feasibility study stage.[6]

To achieve the level of hydrogen generation and deployment required to match ambitions, increased investment in research and development is crucial, as well as the introduction of a supportive regulatory framework at federal and state level. Due to variation among national and state policies, infrastructure needs, and community interest, each state and region of the US has, to a greater or lesser extent, its own specific policies and road maps for implementing hydrogen infrastructure. The need for a harmonised approach, at least in some areas, will be important in realising hydrogen's potential. For example, the majority of hydrogen activity currently in the US is used at, or near to, where it is produced.[7] If hydrogen is to be transported across state borders, state cooperation will be needed to ensure that the appropriate infrastructure is in place and that regulation of hydrogen transport between states is not mismatched. An August 2021 statement by Bakken Energy and Mitsubishi Power Americas announced the intention to do just that, with the companies confirming their intention to acquire and redevelop a synthetic natural gas plant in North Dakota into a blue hydrogen production facility, with the aim of connecting the hub by pipeline to other hubs throughout the US.

At state level, California, Texas, and Louisiana are recognised by the US Department of Energy as being the major hydrogen-producing states.[8] California in particular has made significant progress in the development of low-carbon hydrogen as a new energy source.

The *Road Map to a US Hydrogen Economy* has identified that hydrogen can play a role in five major sectors of the US economy:

— as fuel for buildings;
— as transportation fuel;
— as feedstock for industry and long-distance transport;
— as industrial fuel; and
— for power generation and grid balancing.[9]

The majority of low-carbon hydrogen projects in the US to date relate to the transportation sector.

5 https://www.fchea.org/us-hydrogen-study
6 https://hydrogen-central.com/globaldata-hydrogen-production-america-triple-2030-1-4-million-tpa/
7 https://afdc.energy.gov/fuels/hydrogen_production.html
8 https://afdc.energy.gov/fuels/hydrogen_production.html
9 https://static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/5e7ca9d6c8fb3629d399fe0c/1585228263363/Road+Map+to+a+US+Hydrogen+Economy+Full+Report.pdf

Transport

Transport accounts for around a third of US carbon emissions.[10] The US is among the leading countries in moving towards broad commercialisation of fuel cells and hydrogen energy in transport, with over 9,000 fuel cell electric vehicles (**"FCEV"**) currently on the road – around 25% of the global FCEV stock.[11] Statistics as to the current number of refuelling stations in the US differ – partly depending on whether private refuelling stations are included in the numbers – but the majority of refuelling stations are currently located in California.[12] In addition, fuel cells are being deployed in industrial vehicles with roughly 23,000 fuel cell-powered operational forklifts reported in April 2021 across the US.[13]

The state of California is leading the way in hydrogen mobility. As of September 2021, the majority of FCEVs on the road in the US are located in the state, along with 48 hydrogen fuel cell buses.[14] California also ranks alongside industry-leaders Japan, South Korea, and Germany in terms of the deployment of hydrogen fuelling infrastructure. Some North-Eastern states are rolling out hydrogen fuelling stations, but California is currently most advanced and reported to have 31 strategically located commercial stations state-wide.[15] Further, there are a number of prototype heavy-duty fuel cell electric trucks in operation in California and Arizona.

Feedstock for industry and long-distance transport

About 95% of the hydrogen currently consumed in the US serves as a feedstock or reactant in industrial processes, for example within refining, ammonia, and methanol plants.[16] With a switch to low-carbon "green" hydrogen, there could be a significant reduction in domestic carbon emissions in these industries. Hydrogen could also be applied in other industries, such as steel production. The Yara/BASF ammonia plant in Freeport, Texas, has developed a pilot using low-carbon hydrogen. Opened in 2018, it showcases a sustainable production process using by-product hydrogen from nearby petrochemical plants instead of natural gas from steam methane reforming. In August 2021, Mitsui and CF Industries – one of the world's largest ammonia producers – signed a memorandum of understanding to carry out various feasibility studies in respect of ammonia produced using blue hydrogen production in the US.[17]

Industrial Fuel

The industrial sector is one of the biggest consumers of energy in the US and is responsible for around 23% of overall domestic greenhouse gas emissions.[18] At present, nearly all hydrogen used in the industrial sector is "grey" hydrogen. Low-carbon hydrogen is an attractive means of decarbonising such industrial processes, which are difficult to electrify.

10 https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions
11 https://www.ieafuelcell.com/fileadmin/publications/2021-Deployment_status_of_fc_in_road_transport.pdf
12 A 2021 report on the Deployment Status of Fuel Cells in Road Transport estimates that the US had 63 stations as at the end of 2020 (https://www.ieafuelcell.com/fileadmin/publications/2021-Deployment_status_of_fc_in_road_transport.pdf), while the Department of Energy's website states that there are 48 refuelling stations located in the US, 47 of which are in California (https://afdc.energy.gov/stations/states)
13 Best Hydrogen Fuel Cell Stocks In 2021 | Fuel Cells Works
14 https://www.autoweek.com/news/technology/g32203425/10-things-about-hydrogen-fuel-cell-vehicles-in-america/
15 https://www.californiahydrogen.org/resources/hydrogen-faq/
16 https://cafcp.org/sites/default/files/Road%2BMap%2Bto%2Ba%2BUS%2BHydrogen%2BEconomy%2BFull%2BReport.pdf
17 https://www.upstreamonline.com/hydrogen/mitsui-teams-up-with-fertilizer-heavyweight-to-explore-us-blue-ammonia-developments/2-1-1051748
18 https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions

Power generation and grid balancing using hydrogen

Hydrogen could help decarbonise the power system, particularly as it can provide strategic opportunities for storing large amounts of energy over longer durations, for example, when seasonal storage of energy is needed. In doing so, it can offer long duration discharge cycles that other technologies currently lack. The University of California, Irvine (**"UCI"**), in collaboration with SoCalGas, is running a demonstration project through its Advanced Power and Energy Program (**"APEP"**) to utilise excess renewable power by converting it to hydrogen and blending it into the natural gas system. In 2016, UCI engineers successfully implemented the first power-to-gas hydrogen pipeline injection project in the US. SoCalGas is exploring ways that their existing infrastructure could be leveraged to enable other power-to-gas opportunities, including developing a "hydrogen home" demonstration project, which will convert solar power into low-carbon hydrogen which can then be stored, blended, or used to power a fuel cell within the home. Further, SoCalGas are conducting research with a view to increasing hydrogen blending on the grid up to 20%.[19]

The APEP 2021 annual report highlights the steps that have been taken to create a 'Hydrogen Ecosystem' for the UCI campus. The aim is to generate green hydrogen through electrolysis which is then stored and subsequently blended with the natural gas powering the campus at times of high demand, thus displacing a proportion of the carbon emissions which would otherwise have been generated through natural gas use.[20]

Hydrogen's role in supplying micro-grid type power has also been acknowledged. In particular, supplying communities with the highest risk of shut-offs during seasonal weather-related issues, such as high temperatures or wildfire-related power interruptions.

Market prospects for hydrogen

Federal Investment

On 7 July 2021 the Department of Energy announced USD 52.5m of funding[21] for 31 projects to advance next-generation clean hydrogen technologies and to support the *Hydrogen Energy Earthshot*, the first in a series of initiatives with a stated aim of accelerating breakthroughs in more abundant, affordable, and reliable energy solutions within the decade. The *Hydrogen Energy Earthshot* seeks to reduce the cost of clean hydrogen by 80% to USD/kg in 1 decade.[22] An associated 700,000 jobs and USD 140bn in revenue are estimated to be gained by 2030 if the *Hydrogen Energy Earthshot* goals are achieved.

[19] https://www.utilitydive.com/news/socalgas-announces-net-zero-emission-goal-by-2045-but-some-stakeholders-re/597232/
[20] Advanced Power and Energy Program (APEP), UC Irvine
[21] https://www.electrive.com/2021/07/08/us-doe-awards-52-5m-to-31-hydrogen-projects/#:~:text=The%20US%20American%20Department%20of,breakthroughs%20in%20the%20hydrogen%20sector.
[22] https://www.energy.gov/eere/fuelcells/hydrogen-shot

The American Jobs Plan[23] also suggests pairing investment in 15 low-carbon hydrogen demonstration projects with a new tax credit for low-carbon hydrogen production facilities where construction begins before 2026. This would mirror other tax incentive schemes like 45Q, which has incentivised carbon capture and storage projects in the US since its introduction.

Further to this, the Fiscal Year 2022 Budget proposes that USD 197.5m is requested for supporting efforts to enable the widespread adoption of hydrogen and fuel cell technologies. The Budget sets out that the production of clean hydrogen is a key priority for the Office of Energy Efficiency and Renewable Energy in conjunction with enabling diverse end uses, including:

— grid integration and stationary energy storage;
— transportation;
— chemicals;
— industry; and
— backup power.

This Budget Request is an increase of USD 47.5m on the amount enacted in the 2021 fiscal year, up 31.7%,[24] and underlines a shift from early-stage research in fuel cells to accelerating research, development and demonstration to bring about fuel cell systems that operate at a much lower cost than those at present. This Request also highlights a move from early-stage materials research to accelerated, target-driven research, development, and demonstration in hydrogen technologies. This research focus emphasises a reduction in the cost of electrolysers, alongside increased funding to demonstrate the use of green hydrogen as feedstock or as an agent to decarbonise the production of steel and ammonia.[25]

California

State and local governments in California have worked to establish market development and incentivise consumer adoption of hydrogen. They have successfully implemented a portfolio of policies to boost the market. One such example is the California Low-Carbon Fuel Standard (**"LCFS"**) which created a market for tradeable credits pushing low carbon fuels.

The Volkswagen Zero Emission Vehicle (**"ZEV"**) Investment Plan is an example of a public-private tie-up to promote consumer adoption of hydrogen across the state of California. As a form of reparations for its violation of emission control requirements, in 2016 Volkswagen agreed to invest USD 800m over 10 years into zero-emission infrastructure in California. The programme will include public education, brand-neutral marketing programmes and increased access to ZEVs for consumers.[26]

Another example of public-private cooperation in hydrogen deployment is the contract between Swiss manufacturer Stadler and the San Berdino County Transportation Authority for the hydrogen powered "FLIRT H2" train planned to be opened in 2024.[27]

On the purely private side, Chevron and other partners are investing USD 20m in a start-up aimed at producing green hydrogen as part of an innovative waste disposal process.[28] The first facilities are planned to be built at landfill sites in California.

23 https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/
24 doe-fy2022-budget-in-brief.pdf (energy.gov)
25 doe-fy2022-budget-in-brief.pdf (energy.gov)
26 https://afdc.energy.gov/fuels/laws/HY?state=CA
27 https://railway-news.com/stadler-wins-us-flirt-h2-hydrogen-contract/
28 https://ravensr.com/

In 2021, Californian legislators began lobbying their assembly leaders to commit USD 300m for hydrogen refuelling infrastructure;[29] a process which as of October 2021 is ongoing. This is in addition to the USD 115m of funding approved by the California Energy Commission (**"CEC"**) in 2020, which will seek to fund an additional 134 hydrogen refuelling stations in the state.[30]

Whilst these types of policies have been successful to date, in order to achieve a self-sustaining market, California will need to move towards establishing new, market facing policy mechanisms that focus on attracting both private capital and new market players.

Texas specific incentives

The size and geography of Texas has already allowed renewable energy to thrive, ranking first in the US for both installed and under construction wind capacity, and fifth for the same in solar energy. Excess renewable energy could be used to generate green hydrogen. Due to the existing scale of energy production, and status as the largest producer of hydrogen, Texas has therefore been identified as having significant potential to produce green hydrogen in the H2@ Scale Initiative.[31] The US Department of Energy aims to assist Texas in the designing, building, and operation of the first dedicated renewable hydrogen network in the US. This funding totals USD 10.8m, with the project expected to continue for three years.[32] As seen at state and federal level across the US, the cost of hydrogen as a fuel remains the greatest anticipated market challenge to significant production expansion.[33]

A further facilitating factor for hydrogen expansion in Texas is that it has approximately 1,600 miles of dedicated hydrogen pipelines; this has been posited as available for potential expansion. This is alongside the three hydrogen-specific underground storage fields in Texas which have a combined capacity of roughly 6bn cu ft.[34]

For these reasons, Texas has been tipped against California in a 'race' to become the hydrogen capital of the US.[35]

Louisiana specific incentives

Alongside Texas, Louisiana has displayed potential to help the Gulf Coast become a hydrogen production hub. This is on the basis of plentiful storage potential, in addition to already being a platform for a significant amount of hydrogen supply and infrastructure through the state's hydrogen consumption in the refining and chemicals sectors. It has been suggested that Louisiana could become part of a pipeline network to transport carbon captured from blue hydrogen.[36]

Transport sector ambitions

In particular, there is potential for investment in the transportation sector. The US has a large long-haul trucking industry compared with other markets. On average, Americans drive more than 12,000 miles per year, per vehicle – nearly twice as far as people in other developed countries.[37] There is therefore a need for long distance capability, with such vehicles having a projected sale growth of 1% per year over the next decade.[38] Such long distances and preferences for large vehicles favour FCEVs over battery powered EVs.

29 https://www.forbes.com/sites/arielcohen/2021/06/17/california-legislators-push-300-million-hydrogen-plan/?sh=28488ee05cfb
30 https://www.energy.ca.gov/news/2020-12/energy-commission-approves-plan-invest-115-million-hydrogen-fueling
31 Between the Coasts: Texas — Fuel Cell & Hydrogen Energy Association (fchea.org)
32 DOE-Backed Hydrogen Project Underway in Texas (powermag.com)
33 How The Lone Star State Is Building A Green Hydrogen Future (forbes.com)
34 Texas well-suited to become leading US producer of low-cost hydrogen: panelists | S&P Global Platts (spglobal.com)
35 California And Texas Vie To Be America's Hydrogen Capital (forbes.com)
36 Could Louisiana be key in building a hydrogen economy? (1012industryreport.com)
37 https://cafcp.org/sites/default/files/Road%2BMap%2Bto%2Ba%2BUS%2BHydrogen%2BEconomy%2BFull%2BReport.pdf
38 https://static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/5e7ca9d6c8fb3629d399fe0c/1585228263363/Road+Map+to+a+US+Hydrogen+Economy+Full+Report.pdf

Challenges facing hydrogen projects

Costs

As is the case in a number of other countries, one of the main challenges facing hydrogen in the US is cost. At present, the costs of hydrogen throughout the whole supply chain are not competitive against fossil-fuel and more carbon-intense alternatives. Costs to hydrogen buyers may be lowered if:

— breakthroughs in technology reduce costs or improve the efficiency of electrolysis;
— electricity prices drop;
— an import/export market for hydrogen develops; or
— alternative zero-carbon hydrogen production technologies are commercialised and surpass electrolysis in their cost-effectiveness.

The US is developing large-scale renewable power that forecasts for the costs of electricity production to be as low as USD 20 per MWh in 2030. A large network of US companies with expertise in fuel cells, electrolysers, reformers and carbon capture and storage are already working to bring equipment and production costs down.

A 2020 study carried out by researchers at Massachusetts Institute of Technology (**"MIT"**) has suggested that solar-powered electrolysis for hydrogen production could reach a low price of USD 2.50/kg by 2030 in US states with good solar resources. The research goes as far as to suggest that green hydrogen generation could become cost-competitive, with the ability to maintain stable prices, if geological hydrogen storage prevails over the next decade. The study does note, however, that natural gas without carbon capture may still be a cheaper alternative in 2030, at a price of around USD 1/kg. [39]

Policy landscape

The future deployment of hydrogen in the US over the next decade will depend on the policy landscape at both federal and state level for encouraging the development of low-hydrogen projects. Support and policy certainty would help address challenges such as:

— capital requirements to build foundational hydrogen infrastructure;
— regulatory barriers and lack of appropriate codes and standards (regulation is addressed in more detail, below); and
— funding requirements for further research and development.

Whilst multiple state agencies have overlapping authority to regulate hydrogen depending on its application, there is currently no comprehensive hydrogen strategy for the United States. However, the Department of Energy's Hydrogen Program Plan[40] has been published with the intention of attempting to realise the potential of hydrogen use through committing to research and development, in addition to increasing demonstrations and deployments with the private sector. The Hydrogen Program Plan is a strategic framework incorporating the research, development, and demonstration efforts of the Offices of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, Electricity, Science, and Advanced Research Projects Agency. Ultimately, this aims to advance the production, transport, storage, and use of hydrogen throughout the economy and across the US.[41]

[39] https://www.pv-magazine.com/2020/08/25/solar-powered-hydrogen-under-2-kg-by-2030/
[40] https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf
[41] U.S. Department of Energy Hydrogen Program Plan

Storage related challenges

To ensure that green hydrogen is competitive in the US, substantial reductions in storage costs are necessary. Though the Gulf Coast offers opportunities to overcome such storage issues, for hydrogen to achieve greater uptake, inexpensive storage and pipelines must be established beyond this region. Though currently the transportation and storage of hydrogen are of low immediate concern, with 85% of hydrogen produced and consumed on-site, this is a point of increasing importance. To instigate greater use of hydrogen on an industrial scale, transportation and storage costs will increase and could become a substantial barrier to this growth. Geological features are likely to provide storage at the lowest cost and are already being utilised to an extent: for example, in 2017 in Texas, Air Liquide commissioned the world's largest hydrogen storage facility. Salt cavern storage has also been posited beyond the Gulf Coast.[42]

When looking at hydrogen for vehicular transportation, storage is a significant technical barrier to project development, placing a potentially significant limitation on the take-up and public acceptance of FCEVs. In response to such a challenge, it is clear that a key theme in facilitating the growth of hydrogen generally across the US, as well as specifically in California and Texas, is the development of infrastructure to support hydrogen usage. This has especially been seen in the drive for the building of refuelling stations.

Key challenges to hydrogen storage are:

— weight and volume;
— efficiency;
— durability;
— refuelling time;
— cost;
— codes and standards. This involves codes and standards that are applicable for hydrogen storage systems and interface technologies. Improvement in these areas will allow for greater implementation and commercialisation to ensure both safety and public acceptance, which at present has not been established. Specifically, a standardisation of the hardware and operating procedures is needed in addition to these applicable codes and standards; and
— life-cycle and efficiency analysis, as currently there is a lack of analysis of the full life-cycle cost and efficiency for hydrogen storage systems.[43]

Infrastructure and Accompanying Investment needed

Currently, the US has an underdeveloped physical infrastructure in relation to hydrogen. In the 'Roadmap to a U.S. Hydrogen Economy' report from October 2020, it was considered that the US lags behind China, Japan, and the European Union in the infrastructure needed for hydrogen projects, and that further investment is required. This was an important point moving into 2021, influencing the President's Fiscal Year 2022 Budget Request, with increased funding moving forwards and the ground-level investment provided for hydrogen refuelling discussed further under *Regulation of Hydrogen and Upcoming Developments*.

[42] Decarbonized Hydrogen in the US Power and Industrial Sectors: Identifying and Incentivizing Opportunities to Lower Emissions (rff.org)
[43] Hydrogen Storage Challenges | Department of Energy

The 'Roadmap to a U.S. Hydrogen Economy' report stressed the need for hydrogen production to be increased and the transport infrastructure to carry it to end users, alongside incentives to stimulate private-sector investment, codes and standards to regulate the growing supply chain, and research into techniques that are in the early stages of development. The report sets out 4 phases for hydrogen development over the next decade, adopting a phased approach that is designed to expand into new hydrogen-use based off of current infrastructure. The number of fuel cell vehicles required to reach the report goals will need to grow from a stipulated 2,500 fuel cell vehicles at the time of the report to almost 1.2m by 2030, alongside fuelling stations increasing from around 100 to over 4,300 in the same time period. The use of blending within existing pipelines is considered necessary to achieve this.[44]

Regulation of hydrogen

Each state in the US has its own specific policies in relation to hydrogen. As mentioned previously, California and Texas are generally more advanced in their low-carbon hydrogen policies and, as such, have been selected as the key examples in this section.

Federal Policy

Energy Policy Act 2005 (the "EPA"): The EPA addresses energy production in the US at federal level, including renewable energy. Title VIII of the EPA (also known as the Spark M. Matsunaga Hydrogen Act of 2005) is, amongst other things, to:

— enable and promote comprehensive development, demonstration, and commercialisation of hydrogen and fuel cell technology in partnership with industry;
— make critical public investments in building strong links to private industry, institutions of higher education, National Laboratories, and research institutions to expand innovation and industrial growth;
— build a mature hydrogen economy that creates fuel diversity across the massive transportation sector in the US;
— sharply decrease the dependency of the US on imported oil, eliminate most emissions from the transportation sector, and greatly enhance US energy security; and
— create, strengthen, and protect a sustainable national energy economy.

Energy Independence and Security Act 2007 (the "EISA"): While not specifically an act that regulates the production of hydrogen, the EISA aims to further the EPA by encouraging, amongst other things:

— Increased production of clean renewable fuels;
— Promotion of research on and deployment of greenhouse gas capture and storage options; and
— Improved energy performance of the Federal Government.

EISA sets out the need for the Secretary of Energy to report on the use of geothermal energy to produce hydrogen and also provides amendments to the EPA allowing for the Secretary of Energy to competitively award bi-annual "prizes" for the advancements in technologies, components or systems related to hydrogen production, storage, distribution and utilisation.

[44] Can the US Catch Up in the Green Hydrogen Economy? | Greentech Media

45Q Tax Credit: The American Jobs Plan, a USD 2tn infrastructure proposal announced on 31 March 2020, includes a revised and expanded section 45Q Tax Credit. This offers a tax credit per tonne of carbon dioxide captured and stored – relevant to the production of blue hydrogen. Currently, the section 45Q Tax Credit is limited to a term of 12 years from the placed-in-service date of the facility. Certain proposals within the American Jobs Plan would extend such a term to 20 years, or perhaps longer, and others would expand or increase the number of credits and the breadth of taxpayers who could utilise this. A proposal of particular interest for hydrogen is the idea of turning clean energy tax credits into 'direct pay' credits that are treated as payment of tax. This would result in a cash pay-out to the taxpayer to the extent that these credits exceed the tax liability.

State Policy level regulation

California

The **Renewable Portfolio Standard ("RPS")** for power generation is a market-based policy requiring utilities to deliver 50% of their retail electricity from clean, renewable sources by 2030. Since 2002, when the RPS programme was created, nearly 200 renewable energy generation projects have been built in California.[45]

The **California Energy Commission** is the state's primary energy policy and planning agency, established by the Warren-Alquist Act in 1975. Through their Clean Transportation Program, they are supporting the adoption of zero-emission hydrogen fuel cell electric cars by expanding California's network of hydrogen refuelling stations. They are investing in an initial network of 100 public hydrogen stations.

The **Low Carbon Fuel Standard** evaluates transportation fuels, including hydrogen. It is designed to decrease the carbon intensity of California's transportation fuel pool and provide an increasing range of low-carbon and renewable alternatives, which reduce petroleum dependency and achieve air quality benefits.

California has joined 9 other states – Connecticut, Maine, Maryland, Massachusetts, New York, New Jersey, Oregon, Rhode Island and Vermont – in the **Zero Emission Vehicle Deployment Support** memorandum of understanding. This supports the deployment of ZEVs through involvement in the ZEV Programme Implementation Task Force. Annually, each state reports on the number of hydrogen fuelling stations, as well as broader ZEV infrastructure and registered ZEVs, to ensure that there are 3.3m ZEVs and an adequate fuelling infrastructure by 2025 within the signatory states.

[45] https://www.ucsusa.org/resources/californias-renewables-portfolio-standard-program#:~:text=California%27s%20Renewables%20Portfolio%20Standard%20(RPS)%20Program&text=The%20California%20state%20legislature%20passed,%2C%20and%20biopower%2C%20by%202030.

There are a wide number of "zero-emission" laws, incentives and regulations surrounding transport in California. These can be found within broader zero-emission laws, incentives, and regulations, as well as also being hydrogen-specific. This has occurred at both state and County level. A few key Californian examples of those which specifically include hydrogen:

— the **Hydrogen Fuelling Station Evaluation** involves the CEC being required to annually report on progress towards establishing a hydrogen fuelling station network that can meet the needs of vehicles being used in California. The review determines the remaining time and cost required to set up a network of 100 publicly available hydrogen fuelling stations and whether funding from the Clean Transportation Program is required to assist in achieving this goal. The CEC allocates up to USD 20m per year to fund the number of stations deemed necessary based on the California Air Resources Board report which examines the specifics of current and future projections of fuelling station availability;
— as highlighted above, the **Clean Transportation Program** is administered by the CEC. This program provides financial incentives for businesses, vehicle and technology manufacturers, workforce training partners, fleet owners, consumers, and academic institutions which have the goal of developing and deploying alternative and renewable fuels and advanced transportation technologies. One of the funding areas is hydrogen vehicles and the corresponding refuelling infrastructure;
— the **ZEV Promotion Plan** ensures that all California state agencies must support and facilitate the rapid commercialisation of ZEVs in California. This includes the supporting infrastructure, whereby by 2025 there will be 200 hydrogen fuelling stations in California, as well as State agencies working with their stakeholders to ensure that hydrogen fuelling is affordable and accessible to all drivers;
— an example of County incentives is the **Alternative Fuel Infrastructure Grant** of Santa Barbara County which provides grants for the installation of the alternative fuel infrastructure within the County which can cover 80% of the project cost up to USD 150,000. Hydrogen fuelling stations come within the eligible projects for this; and
— a further County example is the **Alternative Fuel and Advanced Vehicle Rebate** in San Joaquin Valley. The 'Drive Clean! Rebate Program' provides rebates of up to USD 3,000 for the purchase or lease of eligible new vehicles, which includes hydrogen fuel cell vehicles.

There are a number of "zero-emission" incentives and regulations surrounding transport in California. One such example is the **Zero Emission Transit Bus Requirement**. This requirement established that, by 2040, all public transit agencies must transition to 100% zero-emission bus fleets.

The **California Hydrogen Business Council ("CHBC")** is the leading advocate for the hydrogen and fuel cell industry in Sacramento, California. The CHBC's policy mission is to advocate for public policies that recognise hydrogen and fuel cell technologies as a clean, zero emissions energy source that can be utilised across sectors for a wide array of applications.

Texas
As in California, Texas has a broad range of zero-emission laws, incentives, and regulations, in addition to those that target hydrogen uptake specifically.

The Texas Commission on Environmental Quality (**"TCEQ"**) will establish the **Authorization of Governmental Alternative Fuel Fleet Grant Program**, which provides grants for the purchase or lease of a new alternative fuel vehicle as well as for the purchase, lease, or installation of alternative fuelling equipment; this includes hydrogen within the definition of alternative fuel.

The Texas Department of Transportation, through the **Provision for Establishment of Hydrogen Program**, is permitted to seek funding from private and public sources to acquire and operate hydrogen vehicles and to establish and operate publicly accessible fuelling stations.

The TCEQ administers the **Texas Clean Fleet Program ("TCFP")** as part of the **Texas Emissions Reduction Plan**. The TCFP offers grants to fleets to replace existing fleet vehicles with alternative fuel vehicles or hybrid electric vehicles for entities that operate at least 75 vehicles and commit to placing 20 or more qualifying vehicles in service for use in the Clean Transportation Zone. These alternative fuel vehicles must reduce emissions of nitrogen oxides or other pollutants by at least 25% as compared to baseline levels, as well as replace vehicles that meet operational and fuel usage requirements.[46]

[46] Alternative Fuels Data Center: Hydrogen Laws and Incentives in Texas (energy.gov)

Regulatory bodies

As a result of the structure of the US legal system, the regulation of hydrogen and the relevant regulatory bodies differ state by state. On a federal level however, there are some relevant regulatory bodies, with those most significantly and extensively in a position to influence the development of the hydrogen industry and infrastructure being:

— The **Department of Energy** is a cabinet-level department of the US Government led by the US Secretary of Energy which focuses on policies regarding energy and safety in handling nuclear material.
— The **Federal Energy Regulatory Commission ("FERC")** is the US federal agency that regulates the transmission and wholesale trading of electricity and natural gas, and also regulates the transportation of oil by pipeline. Pursuant to the Natural Gas Act, FERC regulates the siting, construction, and operation of interstate natural gas pipelines and storage, as well as the rates and terms of service that these pipelines offer. The FERC has not used this jurisdiction to regulate exclusively hydrogen pipelines, and may not have the ability to do so under existing statute, but could potentially regulate the transportation of hydrogen if transported in a blended stream with natural gas. With the legislation at present, an Act of Congress will be required to ensure that hydrogen is within the scope of the FERC. Further, such an Act could accordingly separate infrastructure development responsibilities between the FERC and the Department of Transport through the Pipeline and Hazardous Materials Safety Administration.[47]
— The **Occupational Safety and Health Administration ("OSHA")** creates the Occupational Health and Safety Standards, including for compressed gases and hydrogen. Title 29 of the C.F.R. Subpart H, as created by OSHA, covers the installation of hydrogen systems. Consequently, this regulates a wide variety of aspects of hydrogen, including location, containers and piping characteristics, safety relief devices, equipment assembly, marking, and testing.[48]

The **United States Environmental Protection Agency ("EPA")** regulates substances that could impact human health and the environment, which includes hydrogen. Importantly, it is interesting to note that in the EPA's regulation of hydrogen, hydrogen itself was not necessarily the focal point of the regulatory process. As such, it has been suggested that with the growth of hydrogen the EPA will likely need to revisit this regulatory approach.[49]

The **Pipeline and Hazardous Materials Safety Administration ("PHMSA")** is centred around creating national policy, conducting research, and setting and enforcing industry standards, taken together with the intention of protecting human health and the environment through promoting the safe transportation of energy and other hazardous materials. As of December 2020, it regulated approximately 700 miles of hydrogen pipelines. As with the EPA, it can be considered that, given the primary focus of the regulations is not specifically hydrogen, certain aspects of hydrogen itself are not fully contemplated in some parts of the existing regulations' design requirements.[50]

47 Laying the regulatory groundwork for hydrogen in the United States | Utility Dive
48 Federal Hydrogen Regulation In The United States: Where We Are And Where We Might Be Going | Vinson & Elkins LLP - JDSupras | Utility Dive
49 Federal Hydrogen Regulation In The United States: Where We Are And Where We Might Be Going | Vinson & Elkins LLP - JDSupra
50 Federal Hydrogen Regulation In The United States: Where We Are And Where We Might Be Going | Vinson & Elkins LLP - JDSupra

Upcoming developments

California focused key upcoming projects

Key projects that are recently kicking off or likely to start implementation:

Bloom Energy: California-based Bloom unveiled on 14 July 2021 that they will begin offering electrolysers alongside hydrogen-powered fuel cells to tap the green hydrogen market. Bloom's core product is its Energy Server, which converts natural gas into electricity through an electrochemical process without combustion, reducing carbon emissions. In 2019, Bloom stated that its Energy Servers could be upgraded to run on hydrogen, or a blend of hydrogen and natural gas. Having announced in June 2020 the intention to begin offering electrolysers to make renewable hydrogen, 13 months later it unveiled an electrolyser to "supercharge the path to low-cost, net-zero hydrogen". This is expected to produce the lowest cost clean hydrogen through electrolysis and intends to assist hard-to-decarbonise heavy industries in achieving net-zero emissions through the Bloom Electrolyser's use of solid oxide technology delivering better efficiency by operating at high temperatures. This is a flexible concept that could entail unique advantages for deployment across a broad variety of hydrogen applications through the use of multiple energy sources, including intermittent renewable energy and excess heat. Orders are currently being accepted, with commercial shipment expected in Autumn 2022.[51]

SGH2 Energy Global: part of the Solena Group, it was announced on 4 June 2021 that they have agreed to sell 3,850 tonnes a year of carbon-negative green hydrogen to refuelling stations across southern California; these stations are run by two of the state's largest station owners and operators. It is claimed by SGH2 that this is the first and only long-term green hydrogen off-take agreement in the world to date. This carbon-negative hydrogen is expected to be produced from biogenic waste and biomass. Moving forwards, a plasma-enhanced gasification plant is scheduled to open in the summer of 2023, owned jointly by SGH2 and the City of Lancaster. This will produce up to 11,000kg daily at full operation for a baseload of 350 days per year. Critically, SGH2 has announced that its green hydrogen would be cost-competitive with grey hydrogen, therefore making it the cheapest source of green hydrogen. SGH2 is said to be in negotiations with major global energy companies to launch similar projects in Northern California, as well as across parts of Europe, Australasia, and South Africa.[52]

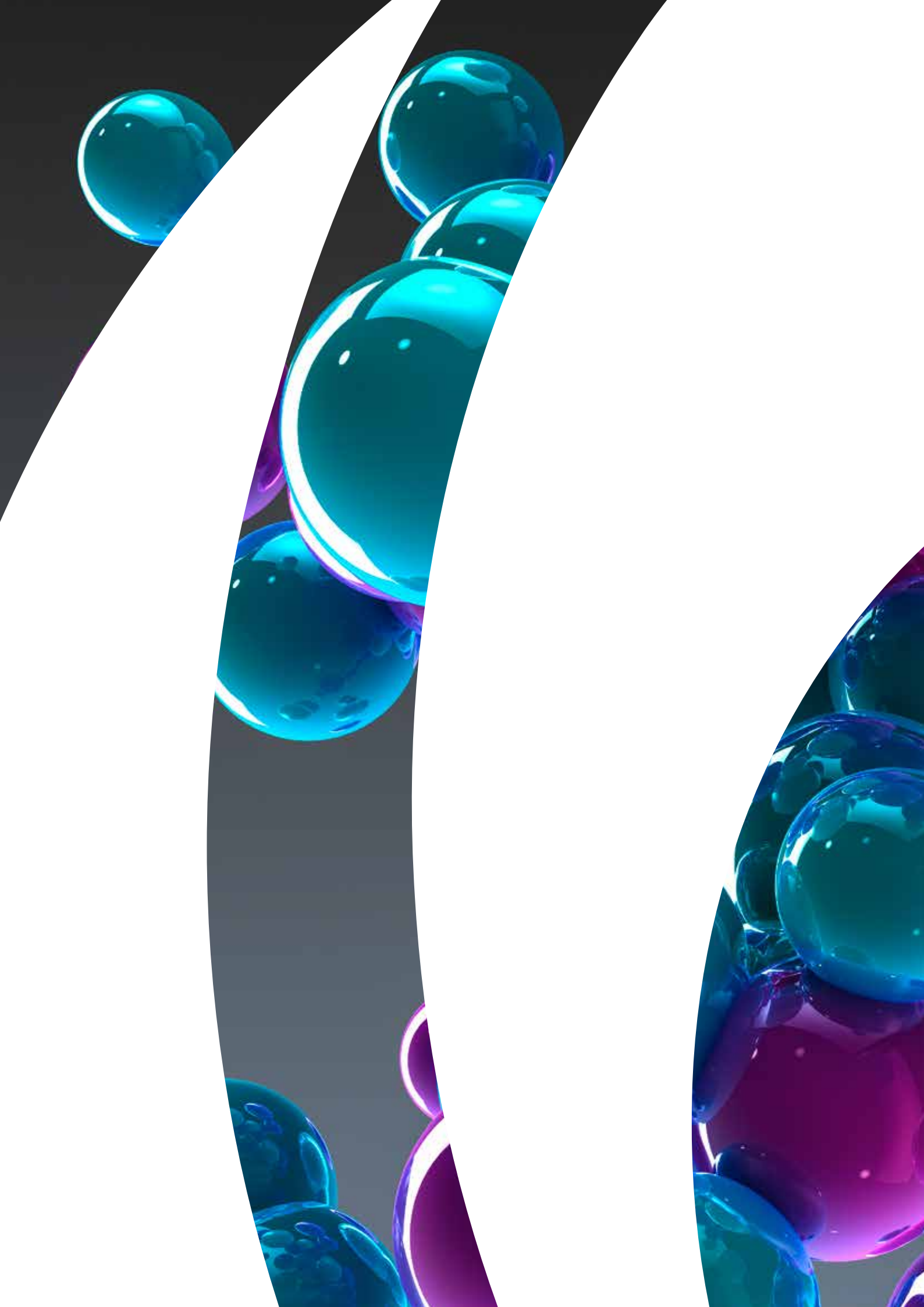
[51] Bloom Energy Unveils Electrolyzer to Supercharge the Path to Low-Cost, Net-Zero Hydrogen – Bloom Energye
[52] World's largest 'green hydrogen' offtake deal signed in California by waste-to-H2 start-up | Recharge (rechargenews.com)

Shell: In December 2020, the CEC awarded USD 7.3m to Shell Hydrogen (as part of the wider Equilon Enterprises LLC) to deliver 8 of the 51 Shell hydrogen refuelling stations that have been proposed, expanding the hydrogen refuelling infrastructure. This has occurred alongside continued strong support from Toyota and Honda for fuel cell electric vehicle sales in California, and the development of the hydrogen refuelling network to facilitate the adoption of lower carbon transportation options, as noted throughout this Chapter.[53]

Intermountain Power Project: The Utah coal-fired power plant is converting to turbines that will use natural gas blended with 30% hydrogen, a proportion that will rise to 100% hydrogen over the coming decades. This generation capacity of 840MW could become a source of increasingly low-carbon energy as it is fuelled by hydrogen which is stored in very large underground caverns. This is provided that the systems to use renewable energy to convert water to hydrogen via electrolysis and store it for later use can combine in a cost-effective way. To meet the goals at Intermountain, Siemens Energy has announced a US Energy Department grant-funded project to study how its electrolysers could be combined with hydrogen compression, storage, and power plant controls technology.[54]

[53] Shell to Expand California Hydrogen Refuelling Infrastructure | Shell United States

[54] https://www.greentechmedia.com/articles/read/how-siemens-energy-is-targeting-the-u.s-green-hydrogen-opportunity



The Hydrogen Rainbow

Different legal regimes for different "colours" of hydrogen

From the perspective of investors in the sector, it is important to recognise that while the molecules are indistinguishable, hydrogen is classified according to the way that it is produced, and categorised by colour. Different legal regimes may apply to hydrogen production and usage depending on how it is produced, and particularly whether it is produced using renewable or non-renewable input fuels.

Most commonly we hear of "grey", "blue" and "green" hydrogen, produced using methane gas, methane gas with carbon capture and storage technology and renewable energy, respectively. However, for completeness there are also other colours in the hydrogen rainbow, some of which are detailed on this page.

Blue – blue hydrogen is generated from the same process as grey hydrogen, but the carbon dioxide is captured and stored instead of being released into the atmosphere

Brown / black – brown/black hydrogen is extracted from fossil fuels, mainly coal

Grey – grey hydrogen is the most common form and is generated through steam reformation of methane gas

Green – green hydrogen is produced via electrolysis using electricity generated by renewable sources such as wind and solar

Pink – pink hydrogen is generated via electrolysis using electricity generated from nuclear power

Purple – purple hydrogen is made using nuclear power and heat through combined chemo thermal electrolysis splitting of water

Red – red hydrogen is produced through the high-temperature catalytic splitting of water using nuclear power thermal as an energy source

Turquoise – turquoise hydrogen is produced by a process known as "methane pyrolysis" which involves natural gas being passed through a molten metal. This process also produces solid carbon.

White – white hydrogen is naturally-occurring geological hydrogen found in underground deposits and produced through fracking

Yellow – yellow hydrogen is produced via electrolysis using electricity generated by solar power

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