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The Promise of Hydrogen: An International Guide

October 2020

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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.

As energy lawyers, we are accustomed to the emergence of new technologies. Nevertheless, each emergent technology's unique characteristics need to be respected. It would be complacent to think that hydrogen can be treated like natural gas, or other energy sources, for the purposes of legal and regulatory frameworks, investment cases, financing structures, operational requirements, revenue stream arrangements and the panoply of other elements that need to be considered to formulate an effective commercialisation model.

The term "hydrogen economy" is not new, but the role that hydrogen can, and is expected, to play in the economies of many of the jurisdictions covered in this guide demonstrates the revitalised ambitions of this subsector. But this guide also highlights the fact that progress is not equal in all places. What are still an emerging suite of technologies and an immature web of policy and regulatory frameworks in some jurisdictions, are developing quickly into a supportive system ready to welcome private sector investment in other countries. What is clear is that the promise of hydrogen developments and uses is rapidly evolving as governments and market players are waking up to its benefits and potential.

With many countries committing to having major low-carbon hydrogen projects underway by 2030 and committing to achieve net zero targets, investors have to take a truly global perspective on the sector.

This guide sets out the ease (or otherwise) of developing hydrogen projects across the jurisdictions covered – highlighting the status of hydrogen developments in each country; considering the market prospects and opportunities ahead that are key for our clients who are seeking to enter or expand in this sector; what challenges need to be overcome in order to reach national and international goals and how the national and international specific legislation and regulations in each jurisdiction facilitates this growing sector.

Overarching Context: The Paris Agreement and Net Zero

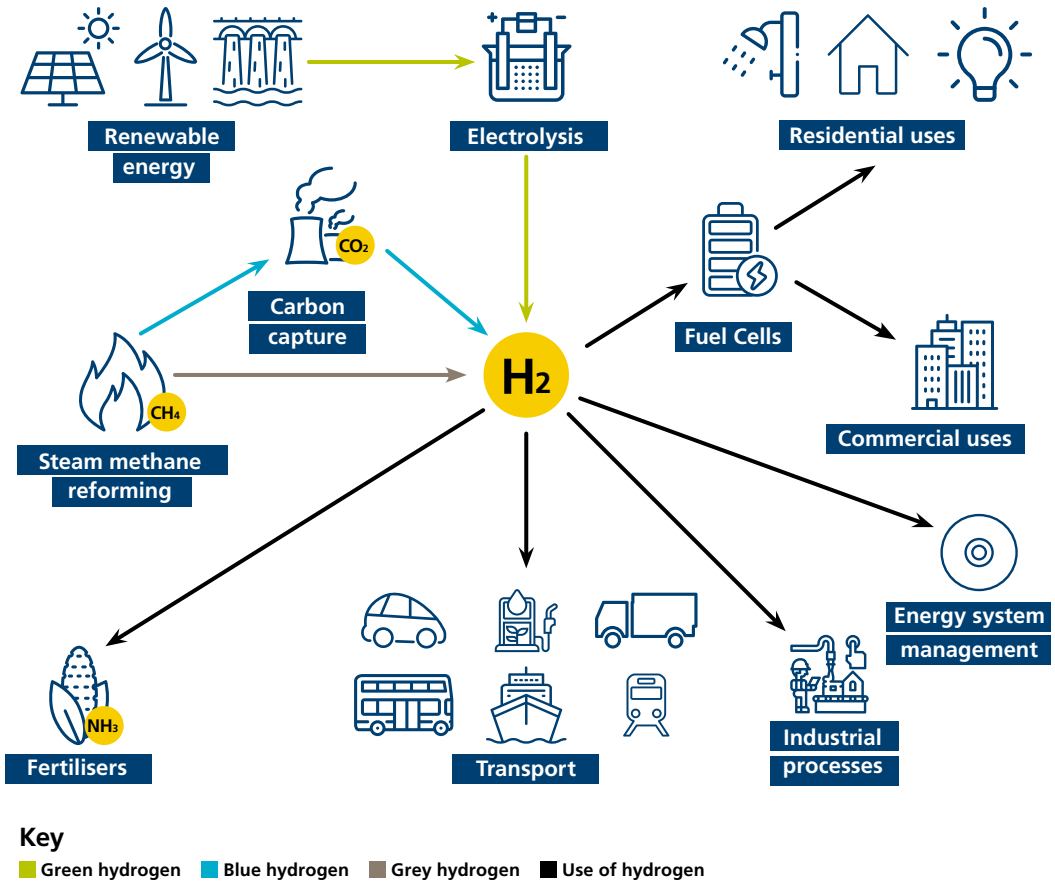
Supranational policies and frameworks helpfully guide the longer term direction and developments at national levels. In this case the supranational commitment is made through the Paris Agreement by 189 countries, representing 97% of global emissions[1].

All of the countries covered in this guide are signatories to the Paris Agreement (albeit the US has notified the United Nations of its intention to withdraw from the Paris Agreement). The Paris Agreement is one of the most ambitious international agreements within the United National Framework Convention on Climate Change **("UNFCC").** It commits signatories to responding to the threat of climate change by keeping any global temperature rise this century to well below 2 degrees Celsius above pre-industrial levels, and better still, to pursue efforts to limit the temperature increase to 1.5 degrees Celsius above those levels. Since then, a number of countries have adopted legally binding targets to reach "net-zero" in terms of their greenhouse gas emissions by 2050. Alongside national governments, similar commitments are being made by major businesses and investors, who are also seeking to decarbonise their products and processes.

The countries covered in this guide have or are in the process of creating legal frameworks to support their vision. For many this vision includes hydrogen playing a key role in achieving their Paris Agreement climate change ambitions and net zero targets in a number of sectors, most notably in transportation, heating and industry.

[1] https://cait.wri.org/

Different Legal Regimes for Different "Types" 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. References to the following colours are for hydrogen produced in turn: "grey" from methane gas, "black" from coal or "brown" from lignite. Currently around 95% of the hydrogen produced in the world is grey or brown, 76% from natural gas and 23% from coal[2]. "Blue" hydrogen is produced using methane gas with carbon capture and storage technology. This type of hydrogen is seen as carbon neutral but not strictly renewable. "Green" hydrogen is produced through electrolysis, which is the process of splitting up water (H_2O) into hydrogen and oxygen, using renewable energy (for example, wind or solar energy). There are a number of other "colours" of hydrogen that are less relevant from an investors perspective and are not covered in this guide.

It is understood that a move away from grey hydrogen will be necessary to meet the decarbonisation targets many countries have set out. However, blue hydrogen's attraction comes from the scale of production that it offers and the ability to use carbon capture storage technologies to prevent the emission of carbon dioxide into the atmosphere. Many of the jurisdictions covered in this guide are focusing on the advancement of green and blue hydrogen.

[2] IEA World Energy Outlook, 2019

Green Hydrogen

Green hydrogen is typically made through electrolysis – which in its simplest terms requires an electrolyser to break down water (H_2O) into hydrogen and water using renewable sources such as wind, solar and hydro to generate the electricity used for the process.

An example is the Austrian, Hydrogen eMoblity AG, which announced green hydrogen produced from gasification of wood at previously unattainable production price and energy efficiency.

While there are a number of demonstration projects being developed, at present the high cost (of the energy hungry) electrolysis is a significant barrier. As a result, just 2% of global hydrogen production is currently produced by electrolysis. However, green hydrogen perceived as the ultimate goal and there are new national and supranational policies emerging that promote the use of electrolysers.

Blue Hydrogen

Blue hydrogen is seen by many as an enabler in the commercial development of low-carbon hydrogen projects. It's success depends in part on the role of carbon capture usage and storage (CCUS), which in turn suits some countries (such as the UK, Netherlands, Norway and parts of the US) better than others which do not already have storage infrastructure to exploit.

A number of hydrogen plus CCUS projects and business models are under consideration and covered in the guide. For example, the UK is specifically developing business models for hydrogen and CCUS projects over the coming years.

The UK is not alone at having spotted the blue hydrogen opportunity. In the Netherlands, led by a consortium comprising state owned companies, the Porthos project focuses on the capture of CO_2 within the port of Rotterdam from existing hydrogen production facilities with a view to producing large-scale blue hydrogen and reduce emissions by 2030. The captured CO_2 will be transported and stored in a depleted gas field in the North Sea.

Taxonomy may seem a geeky subject, but classification and legal precision are crucial. In particular, the lack of harmonisation and classification is a common complaint whether from financial institutions, developers or investors seeking to understand and compare opportunities in the sector. There are some developments in this area. For example, the EU Taxonomy[3] published in March 2020, considers what should be treated as "low carbon" or "renewable". In this case, for the manufacture of hydrogen, hydrogen is considered renewable where:

- the level of direct CO_2 emissions from manufacturing of hydrogen are 5.8 tCO_2e/t
- electricity use for hydrogen produced by electrolysis is at or lower than 58 MWh/t
- average carbon intensity of the electricity produced that is used for hydrogen manufacturing is at or below 100 gCO_2e/kWh.

In practice, investors, developers, financiers and advisors seeking to invest in renewable hydrogen projects should note that this narrows the options to "green" and "blue" hydrogen.

[3] https://ec.europa.eu/info/sites/info/files/business_economy_euro/banking_and_finance/documents/200309-sustainable-finance-teg-final-report-taxonomy_en.pdf

Sector-specific Legal & Regulatory Challenges

Transportation
Hydrogen has the potential to play a significant role the transportation sector. While batteries are seen as a viable technology for passenger vehicles, as seen through the uptake of electric vehicles **("EV")** globally, hydrogen-based mobility is a complimentary option. Hydrogen can be applied in a wide range of sectors such as local public passenger transport, heavy-duty road transport and commercial vehicles, as well as in marine, rail, and possibly, even in aviation. The guide has highlighted several jurisdictions (notably Korea and Japan) where fuel cell technology **("FCEV")** shows significant prospect for use in road and rail transport.

What is a hydrogen fuel cell?
Fuel cells, and in particular, hydrogen fuel cells, are key for a number of hydrogen applications. In a fuel cell, the chemical reaction is used to generate electricity.

In a hydrogen fuel cell, the chemical reaction involves combining hydrogen and oxygen to generate electricity, heat, and water. The chemical reaction in a hydrogen fuel cell continues for as long as there is sufficient fuel and therefore it does not have range limitations common with battery technologies. Because there are no moving parts, the fuel cells operate silently.

Fuel cells are used in a number of application today. These tend to be mixed fuel cells (i.e. a mixture of chemical compounds, which often include hydrogen). For example, fuel cells are used in providing back up power in facilities like hospitals, retail and data centres, as well as, increasingly, in a variety of transport.

Whilst some countries such as Singapore focus on the uptake of battery powered electric vehicles, other countries such as Germany are creating a network of hydrogen refuelling stations to encourage the uptake of hydrogen vehicles, or hydrogen-hybrid vehicles. As of January 2020, there a 86 hydrogen refuelling stations in Germany, and an expansion of 15 stations per year is envisaged to accommodate the increased use of hydrogen in transport.

This raises a number of legal issues for companies seeking to enter the hydrogen mobility sector. Despite the first hydrogen refuelling station having been installed over ten years ago, only a few of the countries we surveyed have specific legislation for hydrogen refuelling. In this uneven landscape, while in countries such as Germany, Denmark, the UK and the Netherlands authorities can look to existing rules, in other countries, a number of different authorities may need to be involved to develop the legal and regulatory framework for hydrogen. Further, without existing rules it is more difficult to navigate the permitting and regulatory regimes, with the process slowed down if the authorities are less familiar with the issues.

The opportunity to educate, create, and harmonise some of the standards may be afforded through the focus on the roll out of hydrogen buses. Many of the countries we surveyed focus on public transport as the key area for using hydrogen in the mobility sector. The UK has already seen the rollout of zero emission hydrogen buses and has committed to introducing 3,000 buses by 2024. Similarly, Japan is aiming to have 1,200 fuel-cell buses on the road by 2030. More than for decarbonisation purposes, hydrogen fuelled public transport is gaining popularity due to the added benefits of also improving local air quality thus also bringing public health benefits. Given that contracting for public transport and associated infrastructure often involves a governmental authority as the counterparty (whether for the land rights, the leases of the transport etc.) buses could be the catalyst for the build-up of the administrative knowledge and processes.

With a number of governments are focusing their R&D efforts and providing grant funding to those developing the mobility sector options, questions arounds eligibility, stability and sufficiency of such funding are often asked. For example, if state funding is available to encourage individuals to purchase hydrogen fuelled vehicles, issues of state aid and procurement will need to be carefully considered and managed. Assuming this can be done purposefully and effectively, hydrogen fuel transport could mirror the rapid uptake seen in EVs in some countries.

Though at an earlier stage of development, hydrogen technologies could also be used in shipping and aviation, though our experts agree that significant changes to the existing practices would be needed in these areas.

For further consideration of hydrogen use and opportunities in the automotive sector, please see the Automotive chapter.

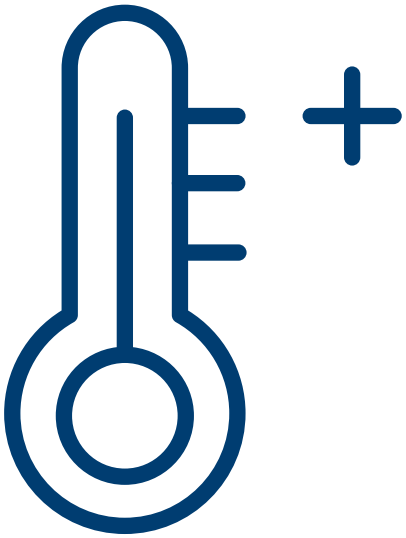
Industry

Unsurprisingly the guide underscores the significant hydrogen demand in industrial processes. The International Energy Agency **("IEA")** estimates that the total global demand for hydrogen will be around 40m tonnes per year over the coming decade[4]. This includes using hydrogen in various industrial processes including oil refining, ammonia production, and steel production. The hydrogen used in these industries is generally "grey", and as such there is a large opportunity to decarbonise this sector by transitioning to blue or green hydrogen. One such example is the HyNet project in North West England which proposes to develop a hydrogen cluster in which 10 large industrial sites would be converted to use 100% green hydrogen.

Clearly the challenge with adapting and retrofitting existing infrastructure to produce low carbon hydrogen is not without its challenges. As with much else in this developing sector, first of its kind projects act as path finders in the administrative, permitting and regulatory processes. As such the time and complexity is a burden that needs to be addressed to facilitate further developments, and attract outside investments and financings. As it is already used in the manufacturing process, there are fewer novel technical barriers to consider. Nonetheless, the cost of production, based on current technology, is inevitably higher, which combined with the economic and regulatory challenges that require thorough understanding and review, are delaying unlocking what is a sector clearly suited for this transformation.

For further consideration of hydrogen use and opportunities in the industrial processes, please see the Industry chapter.

[4] IEA (2019), The Future of Hydrogen, IEA, Paris https://www.iea.org/reports/the-future-of-hydrogen



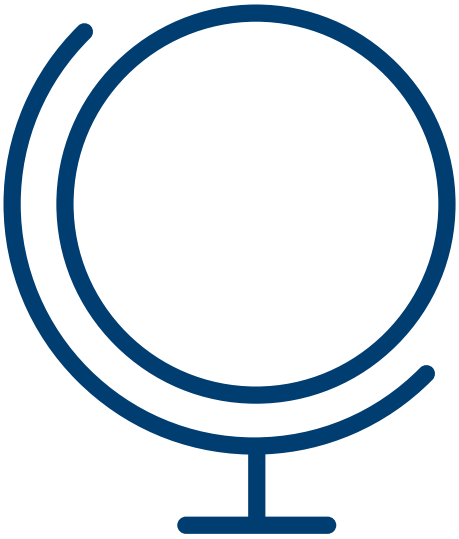
Heating

A number of countries have identified hydrogen as part of their plan for decarbonising heating. In the UK, for example, the gas network provides natural gas to over 80% of residential homes and commercial buildings for heating. Decarbonising this network could be paramount to achieving net zero aims. A number of countries, such as Portugal, Germany and France, have initiated pilot projects to test the blending of hydrogen into the gas grid. With some, such as the Netherlands, which intends to eliminate the use of natural gas in the built environment by 2050.

Several demonstration projects are currently testing the blending of up to 20% of hydrogen into the existing gas grid from a technical and engineering perspective. What is less clear is how the technical and safety tests about the limitations of hydrogen blending, link with the current legal frameworks. At present, while there is a harmonised legal regime for ownership and operation of the gas networks (though the EU Third Package Directive), the design of the legislation is firmly centred around methane gas and gas quality standard (based on calorific value; Wobbe Index). However, blending hydrogen changes the calorific value of gas carried in the grid. The existing ways of regulating gas transmission, the payment terms for the various entities involved as well as questions of gas quality standards impacted by blending and deblending hydrogen into/out of the grid each requires further consideration. As identified in our guide, in a number of jurisdictions, the gas transmission rules were drafted into law decades ago, well before the opportunities for heating with hydrogen, let alone having a 100% hydrogen gas network, were contemplated.

If the ambition is to enhance the prospects of using hydrogen networks for heating, further work and studies are needed to link the safety and technical integrity requirements in all parts of the heating chain, including at the end user interface, with the current regulatory frameworks. The final picture is also likely to be hugely dependent on the country and region specifics may vary in terms of their own seasonality of demand and levels of available infrastructure.

Further Challenges Identified in this Guide



Lack of administrative practice and guidance adds to the costs and complexity of authorisations
While some jurisdictions, such as Austria, South Korea, and Japan are centralising the permitting processes and simplifying the requirements on operators seeking to develop hydrogen projects, in many other jurisdictions the complexities in the permitting regimes are yet to be addressed. As we have seen with other emerging technologies, the lack of past projects for guidance can result in inconsistencies in approach between the responsible authorities as well as lead to complex, protracted discussions before authorities are able to interpret the existing rules and grant the necessary permits.

The burden on the investors to engage stakeholders in the process is thus extended to capacity building of not just the public but also the competent authorities, which adds to the cost and time involved in the process of developing hydrogen projects.

Faster deployment can facilitate reduction in costs
Following on from the above, a key challenge in the hydrogen market today is cost and the need for the creation of a sufficiently large marketplace to achieve economies of scale. While electrolysis using electricity from renewable energy sources may be the more environmentally sustainable method of producing hydrogen, currently it can be two to three times more expensive compared to hydrogen produced with natural gas or fossil fuels (without CCUS).

As we have learnt from other new technologies, costs fall when there are enough projects to form a critical mass of investment. National policies are key for attracting more projects to be developed and thus driving down costs. Recognising this, the European Commission published an ambitious strategy in July 2020. This seeks critical mass investment to make hydrogen more cost effective. Estimated costs today for fossil-based hydrogen are around EUR 1.5/kg for the EU, for fossil-based hydrogen with carbon capture and storage around EUR 2/kg, and for renewable hydrogen EUR 2.5–5.5/kg. The strategy notes that carbon prices

in the range of EUR 55–90 per tonne of CO_2 would be needed to make fossil-based hydrogen with carbon capture competitive with fossil-based hydrogen today. The costs of renewable hydrogen are going down, however. For example, electrolyser costs have already been reduced by nearly 60% in the last ten years and are expected to halve in 2030 compared to today with economies of scale. Electrolyser costs are predicted to decline from EUR 900/kW to EUR 450/KW or less in the period after 2030, and EUR 180/kW after 2040.

Absence of a facilitative legislative framework and need for reform

Reflective of the nascent yet developing array of hydrogen technologies, legislative frameworks have not always caught up with development ambitions. As such, another key challenge that has emerged in this guide is the lack of a clear legal and regulatory framework for hydrogen. The majority of countries rely on their existing gas regulations to regulate hydrogen. Due to the different nature and use of hydrogen these frameworks are not always appropriate, and market players would benefit from the introduction of a clear regulatory framework to encourage the development of a hydrogen economy.

From a lack of clear legislation, the counterbalance is practice not totally suited to new ways of working. Although most hydrogen is produced and consumed on the same site, or transported short distances by road or pipeline[5], for transporting hydrogen over longer distances is restricted. The flammable characteristics of hydrogen require extreme care when handling (and transporting it). Hydrogen is a colourless, odourless and flammable gas, and its large scale use has commonly been perceived as risky because of how easily it may leak and ignite in relatively low temperatures. Much of how hydrogen storage and transport is treated has developed over time from industrial uses of hydrogen, and the understanding of hydrogen as a fuel source by relevant stakeholders and authorities is therefore important in their decisions on whether to authorise the activity in these newer contexts.

A unified vision for hydrogen on Europe? The European Hydrogen Economy

Several countries have adopted national hydrogen strategies but the EU has set out a transnational hydrogen strategy applicable across all member states, many of which are covered in guide. The long awaited Hydrogen Strategy for a Climate-Neutral Europe (the **"Strategy"**) sets out the EU-wide vision for decarbonising a range of sectors across Europe. The Strategy estimates that hydrogen is expected to provide at least 13% of the final energy mix by 2050 in Europe. Following in the footsteps of several European national hydrogen strategies, this Europe wide strategy is expected to encourage the development of a hydrogen economy across Europe.

On the back of this EU-wide framework, a number of other jurisdictions explored in this guide await the pending publication of a roadmap or strategy for the implementation of hydrogen in their countries. These strategies will help set out a clear path for accelerating the deployment of a hydrogen economy in the respective countries. As we have seen in other sectors (eg renewables), the EU-wide direction can stimulate the national legislative systems to create further local policy and thus investors greater certainty in venturing into this sector. This is the expectation for countries, such as Poland where the Polish Ministry of Climate intends to publish the Polish Hydrogen Strategy setting out its vision for the development of hydrogen in Poland.

Market Prospects

There are a number of ambitious hydrogen strategies being released across the globe sending signals to investors regarding the openness of such countries to developing hydrogen projects, and stimulating public awareness and acceptance. In countries where we have seen new technologies like hydrogen take off, the strategies need to be supported by availability of capital. At present, while projects may fall below the capital requirements of large banks and institutional investors, many of the projects are relying on public support measures and government level financing initiatives that encourage the uptake of hydrogen. For example, the French Government intends to include support measures for hydrogen projects in the French economic recovery plan to be presented in Autumn 2020. The Minister of Economy has indicated a possible increase of investment up to several billion euros in hydrogen[6].

In early 2020 the UK government announced a GBP 90m fund to tackle emissions from homes and heavy industry. GBP 70m of this includes funding for two of Europe's' first-ever large scale, low carbon, hydrogen production plants: on the river Mersey and in Aberdeen, as well as for developing technology to harness offshore wind off the Grimsby coast to power electrolysis and produce hydrogen.

With state sponsored support, it is therefore important to consider the state aid requirements to achieve the right balance of support and retaining value to consumers. Further, given that many of the public grants are managed by state entities and local authorities, appropriate public procurement steps is key to projects' success. Indeed, navigating the pathway of successfully bidding for, securing and maintaining government support and funding has been identified as a key challenge by many countries listed in this guide.

[6] France's previous hydrogen strategy, presented in 2018, limited investment to EUR 100m.

Conclusion

The last 12 months has seen a flurry of announcements and plans being published. A plethora of hydrogen applications is poised to emerge that will help business and nations to decarbonise a range of sectors and unlock new market opportunities. Beyond the energy, transport and heating opportunities, countries are looking to low-carbon hydrogen to help improve air quality in cities, produce local jobs, improve energy security, as well as providing much needed grid stability services to offset some of the issues associated with increased levels of intermittent generation. Being an energy vector, hydrogen is a platform that spans across a number of industries and legal disciplines. As energy lawyers working across the globe, we now that the reasons why a given hydrogen project will succeed in a given location will be uniquely dependent on the factors that are most important in that scenario, be it clean air or back up power.

The demand for hydrogen has grown more than threefold since 1975 and continues to rise.[7] Whilst this is almost entirely supplied from fossil fuels at present, the R&D and demonstration efforts are finding and refining yet more ways of producing low-carbon hydrogen that can help decarbonise a range of sectors. For example, during the year of 2019, the fuel cell electric vehicle market almost doubled[8], owing to expansion in markets such as Japan and China. The same trajectory is true for other modes of transport be it passenger vehicles, heavy-duty vehicles, public transport and even railways. Beyond transport, the grey hydrogen demand in industry presents a significant opportunity to decarbonise this sector. Where not used on site, the pipeline networks are being put to use by blending different levels of hydrogen into the gas networks. These are just some of the examples our experts highlight in this guide. From Saudi Arabia to Japan to California, the range of legal frameworks, business and financing models, operational requirements and many other factors are being tested as we write.

Plainly, hydrogen has an important and increasing role to the global, national and local economies. It remains to be seen which countries will lead the way in uncovering the promise of the hydrogen opportunity. From our experience, countries which support the development of commercially sound business cases and establish enabling regulatory frameworks to support the development of this technology are the likely early winners in this race. Further as the costs of electrolysis decrease and a symbiotic relationship develops between renewables and hydrogen production and offtake, new business models will emerge and new products will be created. The consensus across the guide's contributors is that hydrogen will play a key role as an energy vector and a core pillar in the energy transition we are experiencing. This may just be the beginning.

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

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[7] https://www.iea.org/fuels-and-technologies/hydrogen
[8] https://www.iea.org/fuels-and-technologies/hydrogen

Focus on Hydrogen in the Automotive Sector

Authors: Martin Wodraschke, Gerd Leutner, Laura Capata, Viviane Lacombe

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.

Whilst the current chapter will focus on the automotive sector, it is now a statement of the obvious that technological breakthroughs based on the use of hydrogen also happens in other areas of the transportation field. Trains, in particular, 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 in the end of 2019 that it is investing JPY 4bn on 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]. And the UK is fast catching up, too, introducing in 2020 "Hydroflex", 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]

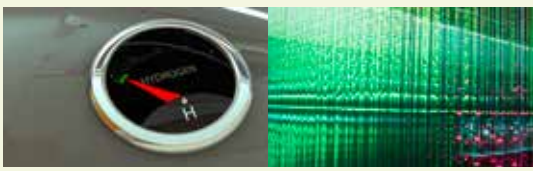
Major automotive players in the EU and around the world are gearing up towards the hydrogen drive, already planning and implementing significant investments in the innovative technology of the future in car manufacturing, particularly hydrogen based fuel-cell electric vehicles **("FCEVs").**

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

Hydrogen Technology in the Automotive Sector

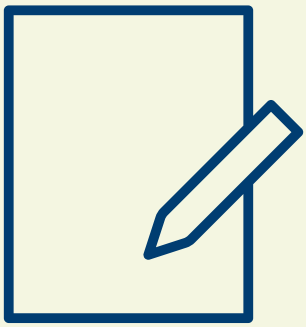
Hydrogen fuel cell cars are powered by an electric motor and are therefore classified as e-cars[6]. As revealed by latest hydrogen technology deployed by car manufacturers (BMW, Toyota), the new technology can be integrated into existing models with minimal design changes, however at a significant cost.

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 (i.e. if the electricity used in the process comes from renewable energy sources).[7] Still, the advantages remain unchallenged: compared to battery based electric cars, hydrogen technology provides fast refuelling, long range and less raw material consumption for batteries – significant incentives for future demand and for vehicle manufacturers to push ahead with this technology.



[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

Pros and Cons of Hydrogen Technology



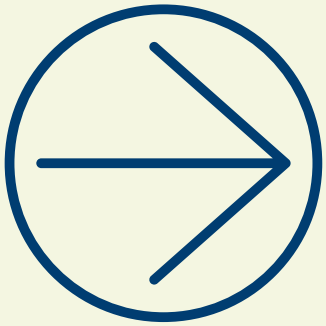
Hydrogen-powered vehicles have been praised for their positive effects on the environment. The hydrogen technology is believed to result in less pollution (compared to typical lithium-ion batteries from electric cars, which have a limited lifecycle and are hard to recycle) and reduce dependence on fossil fuels, while using a widely available resource – hydrogen. Moreover, compared to battery-powered electric cars, hydrogen e-cars are said to offer consumer benefits in terms of fast refuelling (estimated at five to ten minutes) and longer range.[8]

Despite undoubted benefits, sceptics point towards the difficulties of turning hydrogen technology into large scale production, emphasising the high costs associated with the manufacturing, operation and infrastructure of the technology (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) and the dependence of large scale production on available fuelling infrastructure.[9] As detailed below, private and public funding is becoming increasingly available to mitigate this issue and make hydrogen e-cars more affordable.

Others also point out that hydrogen onboard a vehicle may pose a safety hazard, due to possible tank failures (e.g. leaks or ruptures)[10] and undesired chemical reactions. Both research studies and input from the car industry[11] 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[12], contrary to gasoline which is also an extremely flammable fuel[13] which can leak out and pool beneath the damaged vehicle, creating a ready source of fuel for a prolonged burn[14]. Secondly, the risk of a leak and an explosion by a hydrogen tank is also nowadays lesser, since it is now made out of Kevlar, a material resistant to bullets[15], thus confirming the high safety of the tanks storing the fuel (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 opine that hydrogen fuel cell vehicles are safer than cars with internal combustion engines[16], with only some concern for particular cases where safety becomes an issue, such as accidents in parking garages, workshops, or tunnels.[17]

8 https://hydrogeneurope.eu/revolution-mobility
9 https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html
10 https://courses.engr.illinois.edu/npre470/sp2019/web/readings/Hydrogen%20safety%20issues.pdf
11 https://www.bmw.com/en/innovation/how-hydrogen-fuel-cell-cars-work.html
12 https://www.sciencedirect.com/science/article/abs/pii/S036031990900202X
13 https://www.computerworld.com/article/2852323/heres-why-hydrogen-fueled-cars-arent-little-hindenburgs.html
14 https://www.computerworld.com/article/2852323/heres-why-hydrogen-fueled-cars-arent-little-hindenburgs.html
15 https://www.forbes.com/sites/jamesmorris/2020/07/04/why-hydrogen-will-never-be-the-future-of-electric-cars/
16 https://www.computerworld.com/article/2852323/heres-why-hydrogen-fueled-cars-arent-little-hindenburgs.html
17 https://www.sciencedirect.com/science/article/abs/pii/S036031990900202X

Towards an Effective Framework for Hydrogen in the Automotive Sector in the EU and Globally



In an effort to frame the transition towards a green energy strategy, in 2020 the European Commission launched a Hydrogen Strategy for Europe to be further implemented by the European Clean Hydrogen Alliance[18]. 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 deployment of hydrogen technology in the automotive sector, with limited rules that bear only an indirect impact (e.g. environmental rules on green-house-gas **("GHG")** intensity of hydrogen, technical requirements to be followed by refuelling stations).[19]

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 contains 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.[20]

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.[21]

Nevertheless, 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).

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

19 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

20 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.

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

Hydrogen Vehicles around the World

Hydrogen infrastructure is available only in a limited number of cities and countries globally. Across Europe there are less than 200 hydrogen refuelling stations, and these are not spread equally geographically.[22] With a goal to operate 100 hydrogen stations in seven German metropolitan areas and along the connecting arterial roads and motorways in 2021, Germany is at the forefront of hydrogen technology in the EU, but other countries are catching up.

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

Notable examples include:

— **Belgium** *(please see relevant chapter).*

— **Czech Republic** *(please see relevant chapter).*

— **Denmark:** In 2012, the Danish government was announcing a new Energy Plan 2020 that will establish a range of initiatives for a nationwide hydrogen infrastructure and fuel cell electric vehicles, with the overall aim of reaching 100% fossil fuel independence by 2050.[23] In 2019, Denmark was boasting the most dense network of stations for CO_2-free fuel, with Hyundai and Toyota as the main suppliers for the market;[24]

— **France**[25]**:** the world's first hydrogen-powered bus rapid transit **("BRT")** system has been deployed in the city of Pau in the south of France, with eight buses built by Built by the Belgian manufacturer Van Hool in a project launched by French public transport operator, Keolis, in partnership with local transport operator Société de Transport de l'Agglomération Paloise *(please see relevant chapter).*

22 https://h2.live/en
23 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
24 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
25 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market

— **Germany**[26]**:** in April 2020, the German Government funded WSW Mobil GmbH for the purchase of 10 fuel cell buses and refuelling infrastructure and the Obergische Verkehrsgesellschaft **("OVAG")** for the procurement of a hydrogen fuel cell bus and a hydrogen storage unit *(please see relevant chapter).*

— **Italy** *(please see relevant chapter).*

— **The Netherlands**[27]: in September 2019, Keolis won the largest electric bus contract in its history in what is claimed to be Europe's largest electric bus fleet, with 300 vehicles operating in the provinces of Overijssel, Flevoland and Gelderland from December 2020 onwards *(please see relevant chapter).*

— **Poland** *(please see relevant chapter).*

— **Portugal** *(please see relevant chapter).*

— **Slovakia** *(please see relevant chapter).*

— **Spain** *(please see relevant chapter).*

— **Sweden:** in 2017, Sweden launched the Nordic Hydrogen Corridor, a partnership now including Hydrogen Sweden (Vätgas Sverige), Statkraft (Europe's largest producer of renewable energy), the green hydrogen fuel distributor Everfuel and the car producers Hyundai and Toyota. The total budget for implementing hydrogen road transport means in Sweden was approximately EUR 20m, the initiative being co-financed by the Connecting Europe Facility **("CEF").** Other Government supported initiates exist;[28]

— **United Arab Emirates** and **Saudi Arabia** *(please see relevant chapter).*

— **UK** *(please see relevant chapter).*

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[29];

— 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[30];

— 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 programme to trucks and vans in association with Volvo);[31] 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 at the end of.[32]

26 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
27 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
28 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
29 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
30 https://www.cnet.com/roadshow/news/bmw-hydrogen-fuel-cell-x5-production-toyota/
31 https://electrek.co/2020/04/22/daimler-ends-hydrogen-car-development-because-its-too-costly/ and https://www.autocar.co.uk/car-news/motor-shows-frankfurt-motor-show/bmw-i-hydrogen-next-concept-previews-fuel-cell-range
32 https://autovistagroup.com/news-and-insights/renault-introduce-hydrogen-commercial-vehicles-year-end

Heavy-duty vehicles also continue to thrive, with the following global players:

— in 2016 Nikola Motor Company introduced a hydrogen-powered electric semi-trailer Class 8 truck and in 2019 was already reported to have many orders for this truck; [33]

— United Parcel Service **("UPS")** began testing of a hydrogen powered delivery vehicle in 2017; [34]

— 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; [35]

— Toyota Kenworth has a long track record of developing trucks using fuel cell technology and in 2019 it added ten T680s to be used at the Port of Los Angeles and throughout Southern California; [36]

— in July 2020, the 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 total of 1,600 units by 2025. In 2019, Hyundai formed, for its future development, Hyundai Hydrogen Mobility **("HHM"),** a joint venture with Swiss company H2 Energy; [37]

— in 2017 Tesla was launching its Semi prototype truck based on hydrogen technology, however in 2019 was still reported to limit its use for its own internal operations, while continuing efforts to develop durable hydrogen technology for commercial trucking [38]; 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 [39].

33 https://www.teslarati.com/tesla-semi-rival-nikola-get-1-million-us-department-of-energy-fuel-cell-research/ and https://www.foxnews.com/auto/nikola-hydrogen-powered-semi-truck-revealed
34 https://www.cnet.com/roadshow/news/ups-begins-testing-hydrogen-fuel-cell-delivery-truck/
35 https://www.ballard.com/about-ballard/newsroom/market-updates/ballard-and-kenworth-fuel-cell-truck-validation-program-moves-to-next-stage and https://www.trucks.com/2017/05/04/us-hybrid-hydrogen-fuel-cell-truck/
36 https://energypost.eu/hydrogen-fuel-cell-trucks-can-decarbonise-heavy-transport/
37 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/
38 https://www.teslarati.com/tesla-semi-rival-nikola-get-1-million-us-department-of-energy-fuel-cell-research/ and https://www.teslarati.com/tesla-semi-dublin-supercharger-sighting-lathrop-fremont-factory/
39 https://fuelcellsworks.com/news/the-kirchhoff-group-starts-manufacturing-the-worlds-first-refuse-and-sweeper-vehicles-with-hydrogen-fuel-cells/

What About the Funding?

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

At EU level,[40] the European Commission is funding two research projects (H2ME1 and H2ME2) that aim to see an additional 49 hydrogen filling stations and more than 1,400 cars, vans and trucks run on hydrogen within the EU by 2022. These projects have had budgets of EUR 70m and EUR 100m, respectively, 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, governments have already initiated incentive schemes for renewable and low-carbon hydrogen mobility, notable examples including, amongst others:

— **Belgium** *(please see relevant chapter).*

— **Czech Republic** *(please see relevant chapter).*

— **Denmark:** in 2019 alone a national reserve of more than EUR 17m for large-scale energy storage projects was implemented and the funding allocated to two P2X projects (Power-to-Product **("P2X")** refers to technologies that use (surplus) electricity, ideally from fluctuating renewable energy sources, to synthesise (gaseous) chemical products, like hydrogen or hydrocarbons.). With the private investments that follow the public funding nearly EUR 67m in total will be directed at industrial hydrogen production in Denmark;[41]

— **France:** remains committed to invest in hydrogen mobility, with call for projects launched in 2018 and in 2019 and continuing in 2020, which raised interest translating into over EUR 450m potential investment projects.[42] The most recent funding available in 2020 includes grants worth EUR 80m for projects selected in the "Hydrogen mobility ecosystems" call for proposals *(please see relevant chapter).*

40 https://www.wardsauto.com/alternative-propulsion/europe-nurturing-hydrogen-vehicle-market
41 https://hydrogeneurope.eu/sites/default/files/Press%20release%20-%20Hydrogen%20and%20P2X%20on%20the%20rise%20in%20Denmark.pdf
42 https://fuelcellsworks.com/news/france-11-hydrogen-mobility-projects-selected-for-public-funding/ and https://fuelcellsworks.com/news/france-ademe-supports-10-new-hydrogen-mobility-projects/

— **Germany:** in 2020, the State allocated EUR 2.3m in funding to WSW Mobil GmbH for the purchase of ten fuel cell buses and refuelling infrastructure and an additional EUR 1.08m for the purchase of a storage unit to supply hydrogen to the fuel cell buses. Similarly, the Oberhessische Verkehrsgesellschaft **("OVAG")** will receive EUR 1.23m for the procurement of a hydrogen fuel cell bus and a hydrogen storage unit.[43] Moreover, as part of the plan to reboot the economy during the coronavirus pandemic[44], the German government announced in June 2020 an investment of EUR 7bn over the coming two years[45] into the production of green hydrogen[46]. Additionally, EUR 2bn will be invested in fostering international partnerships. The southern state of Bavaria has set up a hydrogen research centre and has involved carmakers Audi and BMW, along with Siemens and energy supplier Bayernwerk[47] *(please see relevant chapter).*

— **Italy** *(please see relevant chapter).*

— **Poland:** R&D initiatives continue with the aid of public and private funding. Poland benefits by over EUR 11m in funds for research into development of new e-mobility technologies[48] *(please see relevant chapter).*

— **Portugal** *(please see relevant chapter).*

— **UK:** the Hydrogen for Transport Programme **("HTP")** sets out the next steps to develop the UK hydrogen vehicle market, providing up to GBP 23m of new grant funding until 2020 to support the growth of refuelling infrastructure alongside the deployment of new vehicles. The HTP was launched on 17 August 2017 by the Office for Low Emission Vehicles **("OLEV")** to provide funding via open competition for both Hydrogen Refuelling Stations **("HRS")** and hydrogen fuel cell electric vehicles **("FCEVs")** in two stages. Stage 2 commits almost GBP 14m funding to five projects which will serve to enhance and expand the UKs refuelling network and increase station utilisation with new vehicles[49] *(please see relevant chapter).*

— **The Netherlands:** in addition to the public funding for hydrogen technology deployed in public transport, the Dutch Government plans to allocate EUR 35m a year from 2021 to scale up projects. Support may also come from EU funds such as the Connecting Europe Facility, as well as the European Hydrogen Alliance initiated by the European Commission[50] *(please see relevant chapter).*

— **Japan** was the first country to adopt a "Basic Hydrogen Strategy". To this end, in 2014 the government began investing in R&D. At present, almost all hydrogen and fuel cell technologies are highly dependent on public funding[51] *(please see relevant chapter).*

— **United Arab Emirates** and **Saudi Arabia** *(please see relevant chapter).*

— **USA:** in 2019 Nikola Motors was awarded by the US Department of Energy a USD 1.7m grant to help the startup advance its research into fuel cell membrane electrode assembly technology[52]. States are reported to allocate yearly significant funds for hydrogen technology – for example, Assembly Bill 8, enacted in 2013, includes a provision to fund at least 100 hydrogen stations with a commitment of up to USD 20m per year and the Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program supplies funding for these hydrogen stations *(please see relevant chapter).*

Undoubtedly, fuel cells 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.

43 https://www.fuelcellbuses.eu/public-transport-hydrogen/german-ministry-transport-releases-millions-euros-funding-purchase
44 https://www.dw.com/en/germany-and-hydrogen-9-billion-to-spend-as-strategy-is-revealed/a-53719746
45 https://reneweconomy.com.au/germanys-covid-recovery-targets-green-hydrogen-and-evs-in-boost-to-energy-transition-32666/
46 https://www.dw.com/en/germany-and-hydrogen-9-billion-to-spend-as-strategy-is-revealed/a-53719746
47 https://www.dw.com/en/germany-and-hydrogen-9-billion-to-spend-as-strategy-is-revealed/a-53719746
48 https://ec.europa.eu/regional_policy/en/newsroom/news/2020/05/20-05-2020-e-vehicle-r-d-gets-cash-injection-in-poland
49 https://ee.ricardo.com/htpgrants
50 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
51 https://www.s-ge.com/en/article/global-opportunities/20201-c5-japan-hydrogen-market
52 https://www.teslarati.com/tesla-semi-rival-nikola-get-1-million-us-department-of-energy-fuel-cell-research/ and https://www.energy.gov/sites/prod/files/2016/11/f34/fcto_state_of_states_2016.pdf

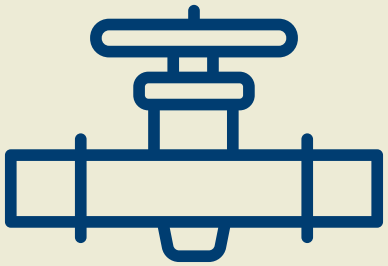
Focus on Hydrogen in the Industrial Sector

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 Sector



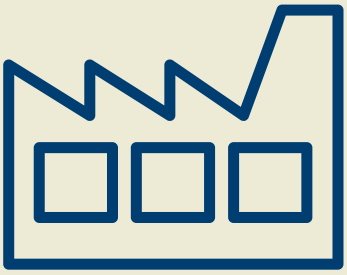
High-intensity heat generation is required for a number of reasons: melting, drying, gasifying, facilitating chemical reactions, and so on.[3] Heat can be used directly, in furnaces, or indirectly, for example to produce steam which is then used for heating.[4] At present, the primary source of energy in high-temperature industrial heating is fossil fuels (coal provides 65%, with natural gas supplying 20% and oil 10%.)[5] Excluding the chemicals and iron and steel sectors, industrial high-temperature heat generation accounts for around 3% of carbon dioxide emissions in the energy sector.[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://webstore.iea.org/download/direct/2803
6 https://webstore.iea.org/download/direct/2803
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 are placing emphasis for the roll out of hydrogen projects at scale. However, for other 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] Either way, 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

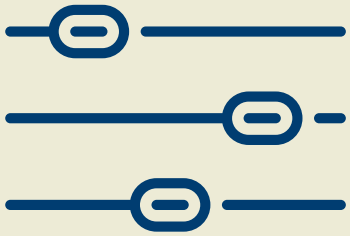
[13] https://webstore.iea.org/download/direct/2803 and Li, J. et al. (2014), "Study on using hydrogen and ammonia as fuels: Combustion characteristics and NOx formation", International Journal of Energy Research, Vol 38, pp. 1214–23.

[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

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 stakeholders low-carbon hydrogen projects may need to take into account.

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 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 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

What About the Funding?

In several 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 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.

— **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.

— **UK:** in February 2020, the Department for Business, Energy and Industrial Strategy 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.[22] 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. Hydrogen produced at this plant will be used at a nearby Unilever manufacturing site, as well as Pilkington's Greengate glassworks – this will be the first time, globally, that hydrogen is used in glass manufacturing.[23]

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

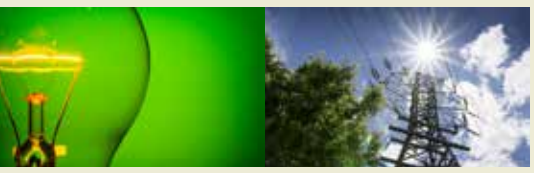
Hydrogen Industrial Clusters

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 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.

Austria

Authors: Johannes Trenkwalder, Irene Ng, Marco Selenic

Current status for hydrogen in Austria

Introduction

Hydrogen has been deemed an important source of energy for Austria and the Austrian government has initiated an "Austrian hydrogen strategy", which is spearheaded by the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology. The Austrian government has ambitious plans to incorporate hydrogen into its climate and energy strategy and has expressed that hydrogen will play a major role in achieving climate neutrality in Europe by 2050. The current environment minister recently stated that the new hydrogen strategy will be announced by the end of 2020.

In the past few decades, Austria has consciously shifted away from relying on fossil fuels and placed a greater emphasis on renewable energy sources. In 2016, according to the statistics released by the Austrian government, 262.8 petajoules of energy were generated from biofuels and other renewable energy sources as compared to 154.7 petajoules in 2005. The current Austrian government plans to continue this trend of incorporating renewable energies as part of its energy plan, with hydrogen as a cornerstone of its sustainable energy strategy. The Austrian Chancellor has announced the government's ambitions for Austria to be the number 1 country in Europe for hydrogen.

Several large Austrian companies, such as Austrian Power Grid, VERBUND and Voestalpine, have already undertaken initiatives to promote and establish hydrogen as a key source of energy. These companies are partners of the EU-funded H2FUTURE project **("H2FUTURE"),** which aims to investigate the generation of green hydrogen from electricity that is derived from renewable sources.

Currently, Austria is focused on the production of green hydrogen on a large scale and is investing in the relevant infrastructure to allow for both public (for example, public transportation or logistics companies) and private hydrogen refuelling.

Power-to-Gas will be a topic of particular importance in the future to enable better energy storage and thus use of electricity from renewable energy sources.

Energy & Industry

Hydrogen is seen as a substitute for other natural gases. Currently, the direct supply of hydrogen into the natural gas network is limited to a maximum of 4% by volume, although an increase is likely. However, energy supplying companies, such as Wien Energie, have noted that almost no pure hydrogen (which is much more valuable than gas) is fed into the grid. Wien Energie has also stated that, until there is a real renewable electricity surplus, one should not expect larger quantities of hydrogen in the gas grid. Nonetheless, Wien Energie has expressed that hydrogen offers the possibility to resolve energy storage issues, whereby surplus electricity generated in summer can be stored in this manner for subsequent use in the winter, when there is a seasonal gap in supply.[1]

Hydrogen has multiple applications for industrial use as well. Voestalpine has reported that as part of H2FUTURE, its largest pilot plant which produces CO_2-free hydrogen has successfully started operation at its site in Linz.[2] In 2019, OMV and VERBUND jointly evaluated the possibility of constructing a facility for hydrogen production using electrolysis. VERBUND has also commented that the Green Hydrogen produced from such a facility could then be used for subsequent chemical production processes.[3]

The Hydrogen Center Austria **("HyCentA")** has also been involved in numerous hydrogen related projects in Austria. Completed projects include a pilot, produced in 2017, that involved the development of a new modular-connected high-pressure proton exchange membrane **("PEM")** electrolyser, which has the flexibility to generate hydrogen from renewable or surplus electricity according to its different load profiles. There are other hydrogen projects under development by HyCentA which are due for completion in the near future. These include:

— the "Renewable Gasfield" project (due for completion in November 2021) and
— the "HYTECHBASIS 4 WIVA" project (due for completion in March 2022), which aims to advance industrialisation by developing the next generation of PEM fuel cells and high pressure electrolysis technology.[4]

Transportation

Some of Austria's largest petrol companies have begun to offer hydrogen as fuel at their gas stations. Since 2012, OMV – Austria's largest petrol company – has made hydrogen fuelling stations publicly available in Vienna. OMV's gas stations currently allow for hydrogen vehicles to refuel. Further OMV is also looking to set up more hydrogen refuelling stations throughout Austria. According to the Chancellor, the Austrian government's goal is to ensure that hydrogen gas stations will be available nationwide by 2025.

1 https://positionen.wienenergie.at/beitraege/wasserstoff-und-energiewende/
2 https://www.voestalpine.com/group/de/media/presseaussendungen/2019-11-11-h2future-weltweit-groesste-gruene-wasserstoffpilotanlage-erfolgreich-in-betrieb-gegangen/
3 https://www.verbund.com/de-at/ueber-verbund/news-presse/presse/2019/07/01/omv-verbund-photovoltaik
4 http://www.hycenta.at/projekte/#realisierte_projekte

Specialist hydrogen companies, such as Hydrogen eMobility AG **("Hydrogen eMobility"),** assist Austria in achieving its hydrogen goals. For transportation, Hydrogen eMobility intends to construct hydrogen fuelling stations in three stages:

— fuelling stations for buses for public transportation;
— fuelling stations for logistics companies; and
— fuelling stations for cars. [5]

Since 2018, hydrogen-powered buses have been tested in Austrian cities, such as Graz. [6]

Austria's national railway company, ÖBB, is also researching a hydrogen and electric hybrid propulsion system for its trains. The development of such a prototype train began in 2015, and ÖBB has plans to test regional trains that will be propelled by hydrogen.[7]

In 2020, Wiener Linien (the public transportation company operating in Vienna) announced that it will conduct tests for hydrogen-powered buses and plans to operate 10 hydrogen-powered buses in Vienna by 2023.[8] Wiener Linien also has plans for a joint Hydrogen Strategy together with Wiener Netze and Wien Energie, whereby the former is tasked with providing the relevant hydrogen gas stations and the latter has been entrusted with procuring hydrogen that is required in the future. An Austrian hydrogen hybrid car which fuses the strengths of hydrogen and battery technology was also presented in Graz, in February 2020.[9]

Market prospects for hydrogen

With strong support from the Austrian government and interest from numerous large Austrian companies, there are strong market prospects for hydrogen. The Climate and Energy Fund (the ***"Klima- und Energie Fonds"***), which is set up by the Austrian government to provide financial support to companies engaging in sustainable energy technologies and climate research, has supported numerous hydrogen related projects in Austria.[10] Some of the projects funded by *the Klima- und Energie Fonds* are:[11]

— UpHy I – the upscaling of green hydrogen for mobility and industry;
— H2Pioneer – which aims to pave the way for green hydrogen for early adopters in the light industry;
— Renewable Gasfield – looking at the production of green hydrogen by means of PEM electrolysis; and
— HyTruck (Hydrogen Truck Austria) – aims to demonstrate an emission-free fuel cell solution for the commercial vehicle market.

5 http://www.hydrogen-emobility.com/en/home-en.html
6 https://www.kleinezeitung.at/steiermark/graz/5509113/Nach-EBussen_Graz-bekommt-jetzt-auch-WasserstoffBusse
7 https://konzern.oebb.at/en/
8 https://www.techandnature.com/wie-wasserstoff-zuge-alte-dieselstrecken-umweltfreundlich-machen/ and https://www.wien.gv.at/presse/2020/06/03/sima-premiere-fuer-wasserstoff-bus-test-bei-den-wiener-linien
9 https://investinaustria.at/en/news/2020/02/hydrogen-hybrid-car-from-austria.php
10 https://www.klimafonds.gv.at/ueber-uns/
11 https://www.klimafonds.gv.at/projekte/

Apart from the *Klima- und Energie Fonds,* alternative financing options are available for hydrogen projects. The Fuel Cells and Hydrogen Joint Undertaking **("FCH JU"),** which is a public-private partnership, supports research and development in fuel cell and hydrogen energy technologies in Europe. The FCH JU organises an annual event, Programme Review Days, that gives an overview of the progress of projects funded by the FCH JU, with the aim of promoting these projects among the wider market.[12]

More recently, in July 2020, Hydrogen eMobility, announced that it has developed a technology that allows for the production of green hydrogen, through the drying and gasification of wood, that can be achieved at a previously unattainable production price and with maximum energy efficiency. According to the company, the technology produces pure green hydrogen with a resource-saving fuel efficiency of more than 97%, while ensuring that the price of the hydrogen produced will be approximately a third lower than the current costs from fossil fuels.[13]

With strong backing from the Austrian government, there are good market prospects for hydrogen. Additionally, numerous Austrian companies have publicly announced their commitment to increase the amount of hydrogen available for both commercial and private consumption, for example, through the construction of additional hydrogen gas stations.

Challenges facing hydrogen projects

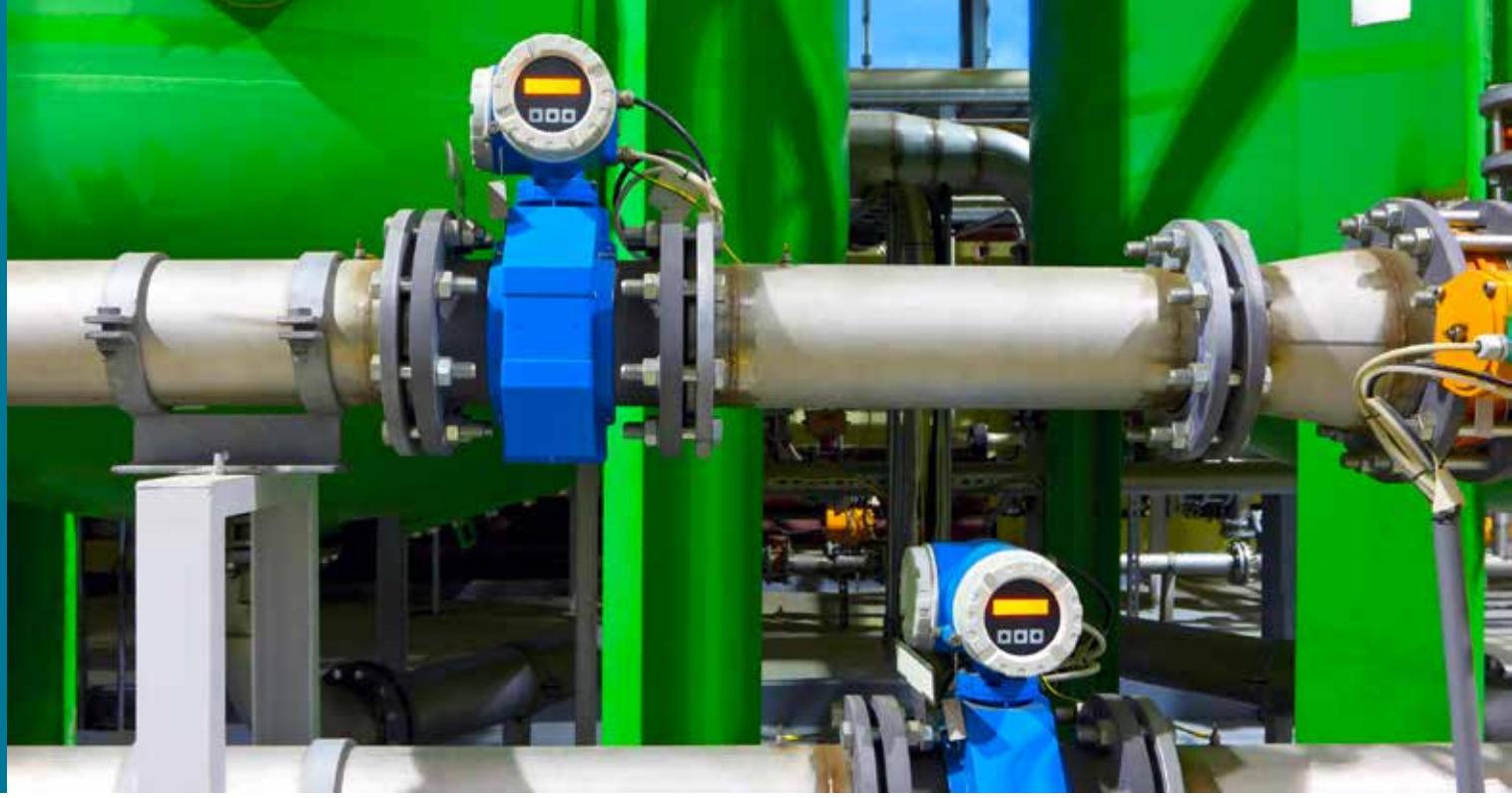
Legal framework

Currently, there is no legal framework that exclusively deals with hydrogen. With regards to general storage and conversion facilities, in particular power-to-gas facilities, the current legal framework in Austria is still very rudimentary, although first steps have been taken to change this. Nevertheless, there are still numerous unresolved legal issues and associated uncertainties regarding hydrogen. For this reason, an initial paper compiling the legal problems and subsequent proposed changes has been prepared by several stakeholders from the hydrogen community.[14] More detail on this, below.

In March 2019, the Austrian government launched its Hydrogen Initiative and presented a roadmap for developing a new hydrogen strategy. Part of the strategy included considerations on the adjustments to the legal framework which were expected to be reflected in the Renewable Expansion Act (or *"Erneuerbaren-Ausbaugesetz"*). Unfortunately, this process has been delayed due to premature parliamentary elections. It is to be expected that the new hydrogen strategy and the new draft of the Renewable Expansion Act will address the regulatory shortcomings in the hydrogen sector.

Reducing Costs

Although the Austrian government is strongly focusing on green hydrogen as a cornerstone of its strategy to become climate neutral by 2040, the costs of implementing the widespread use of hydrogen (whether as fuel cells for mobility purposes, as green hydrogen, or in other uses) are currently still too high.



Infrastructure

If hydrogen is to play a significant role in the road to climate neutrality, investments in the corresponding infrastructure will be necessary, for example, the strengthening of the transmission and distribution networks and an increase of storage capacities.

Regulation of hydrogen

Legislation

There is currently little legislation that explicitly deals with hydrogen and related topics. Accordingly, it is necessary to resort to general public and energy law provisions when implementing hydrogen projects, however, as discussed below, this can be problematic.

Currently, the scope of application of the Gas Industry Act 2011 (or *"Gaswirtschaftsgesetz 2011"*) is limited to natural gas or biogenic gases processed to natural gas quality. Thus, the current provisions of the Gas Industry Act do not explicitly include other types of gas, such as hydrogen and synthetic natural gas. However, this could be remedied by Art. 1 Sec 2 of the Gas Directive 2009, the scope of which extends to other types of gas in a non-discriminatory manner. As the Gas Industry Act falls short of the EU law requirements in this respect and does not fully implement them, it can be argued that EU law is directly applicable.[15] In this sense, the Gas Industry Act could be seen to also apply to hydrogen.

[12] Brief MEZ 22 juni 2020 Rijksvisie marktontwikkeling voor de energietransitie.
[13] Brief MEZ 22 juni 2020 Rijksvisie marktontwikkeling voor de energietransitie.
[14] Brief MEZ 22 juni 2020 Rijksvisie marktontwikkeling voor de energietransitie.

Generation
The licensing process for the construction and operation of a hydrogen production unit and compliance with the respective conditions in the operating license (or *"Betriebsanlagengenehmigung"*) must be taken into account. The licence will also depend on the production plant and land use planning zone in question. A hydrogen plant with production capacity exceeding 150,000 tonnes per year, would be considered as a plant causing significant environmental impact. In such a case, a simplified environmental impact assessment, as per the Environmental Impact Assessment Act 2000 (or ***"UVP-G 2000"***) is necessary; additionally, the provisions of the Austrian Trade Act (or "*Gewerbeordnung*") and any land use plans *("Flächenwidmungsplan")* have to be considered.

Storage
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.

Transport and Distribution
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. 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

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. Anyone acting in the Austrian gas market as a gas supplier or gas trader must have a licence under the Gas Industry Act.

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, for example, can be prevented. It is therefore imperative that the gas being fed in complies with the relevant guidelines of *Österreichische Vereinigung für das Gas- und Wasserfach* **("ÖVGWF")** and thus, is compatible with the grid.

[15] *De Bruyn,* Power to Gas - Eine rechtliche Analyse, Jahrbuch Energiewirtschaft 2017, 169.

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 systems 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

The agenda of the Austrian Government envisages an expansion and support programme for "green gas" (biomethane, green hydrogen and synthetic gas based on renewable electricity) with the aim of feeding 5 TWh into the gas grid by 2030.

Further, a new Austrian hydrogen strategy is due to be announced at the end of 2020. The following cornerstones are currently being developed as part of the strategy:

— Developing hydrogen technology specifically for the economic and transport sectors to make Austria the number one 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
— Making 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

Today, more than ever, hydrogen is in the spotlight. This recent interest is certainly a consequence of the increased attention on the reduction of greenhouse gas emissions and the impact of adverse climate change.[1] In order to meet the European targets for reducing greenhouse gas emissions, a deep decarbonisation of energy systems and a large-scale switch from fossil fuel energy to renewable energy is required 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.

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.[2] 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.[3]

[1] https://www.energiesparen.be/sites/default/files/atoms/files/20191030-Vlaamse_prioriteiten_waterstof_vanuit_energetisch_perspectief.pdf
[2] https://www.waterstofnet.eu/_asset/_public/WaterstofNet_brochure_ENG.pdf
[3] 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.[4]

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

— Firstly, 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.[5]

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.

[4] https://www.energiesparen.be/sites/default/files/atoms/files/20191030-Vlaamse_prioriteiten_waterstof_vanuit_energetisch_perspectief.pdf
[5] 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.[6] 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

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

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.

Besides, one will have to take the Royal Decree of 14 May 2002 on the transport permit for gaseous products and others by pipeline into account.

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.

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

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.[7]

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

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 (0.019 mJ) 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 0,5 bar. 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

The transport of hydrogen is also governed by the previous 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.

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.

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

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. WaterstofNet (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:

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) fourteen 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: Johannes Trenkwalder, Irene Ng, Marco Selenic

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.

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.

Market prospects for hydrogen

With regard 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, the are no hydrogen powered vehicles in the sector but the aim is that, by 2030, this figure will increase to 2.7%.

It is expected that some of the projected production shall be accommodated 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.

Since the market is still under development, there are no clear private financing options determined 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, 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

There is a lack of regulatory framework for hydrogen in Bulgaria. Other than general provisions regarding the issuance of certificates of origin for renewable energy production and the draft ruling on charging stations for hydrogen vehicles, there is currently no 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.

Financial support and incentives

At present, there is general lack of specific financial support for the introduction of hydrogen projects in the market. 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

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.[1] 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.

Currently, there is a draft bill on the design, construction, exploitation and control of hydrogen fuelling stations, that also covers the applicable methods of hydrogen storage.

Regulation of hydrogen

Specific legislation/ regulation

There is no specific legislation adopted in Bulgaria for the regulation of hydrogen projects nor does the Energy Strategy of Bulgaria or the Integrated Plan provide for the development of a specific framework. It is therefore likely that Bulgaria will follow EU regulations in the sector. 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.

[1] http://www.bas.bg/en/2019/02/08/scientists-from-bas-and-higher-education-institutions-are-developing-new-methods-for-using-and-storing-clean-energy/

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 grids and awarded with certificates of origin for the electricity generated from them.

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.
Local Planning and Construction Authority; Municipality Architect	— 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.

Chile

Authors: Sebastián Barros E., Reginald Horn S.

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. Ahead of the UN Climate Change Conference COP26, the Chilean government announced that Chile would be carbon neutral by 2050.[1] However, at present Chile is at an early stage regarding hydrogen production due to technical barriers, an underdeveloped legal framework and a lack of clear financial support mechanisms.

At present, hydrogen production in Chile is 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.[2] 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.[3]

Low carbon hydrogen is expected to have a role across a range of sectors, most notably in:

Public transport

Hydrogen (specifically hydrogen fuel cells or similar) is seen as a potential solution for larger road vehicles in the Chilean public transport system.[4] 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.

[1] More information available online 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 at: https://www.4echile.cl

[3] 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

[4] More information available at: https://www.energia.gob.cl/rutaenergetica2018-2022.pdf

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 4,200 kg/h of hydrogen. This hydrogen is supplied through a pipeline to the nearby oil refinery *Empresa Nacional de Petróleo* **("ENAP"),** which has a hydrogen demand of 3,003 kg/h. This hydrogen production plant uses steam reforming methane with a thermal efficiency of 85%. It also distributes around 4,500 kg/month of hydrogen to external customers.[5]

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 Corporation de Fomento a la Produccion **("CORFO")**[6] 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. This project is directed by Alset Global[7] and it is already at the testing stage.[8]

[5] 4eChile, Idem.
[6] https://www.corfo.cl/sites/cpp/convocatorias/2017desarrollo_de_sistema_de_combustion_dual_hidrogeno-diesel
[7] More information available online at: http://alset.at/
[8] Exchange rate throughout this report USD 1 = 0,0013 USD.

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.

Green hydrogen

Regarding green hydrogen production, the World Energy Council identified Chile as the "hidden champion" in the race to develop a green hydrogen economy. In addition, a "National Green-Hydrogen Strategy" is being developed by the Ministry of Energy as a result of a public-private partnership process that will create a public report which will guide future public policies. The report is expected to be released in late 2020.[9]

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; the overall hydrogen production per year could reach 25m tons.[10]

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. To date, much of the funding has come from the public sector and foreign entities such as GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in cooperation with public entities in Chile.[11]

Because of the nascent status of the hydrogen projects there has been no 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 for hydrogen projects.

Challenges facing hydrogen projects in Chile

Legislative framework

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.

[9] More information available at: https://www.energia.gob.cl/mini-sitio/hidrogeno-verde
[10] More information available online at: https://www.senado.cl/senadores-conocen-las-ventajas-del-denominado-combustible-del-futuro-el/senado/2020-06-26/103338.html
[11] Website information: https://www.giz.de/en/html/index.html

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. However, there remains a need for more engagement of public and private funds in the development of the hydrogen sector across the board.

Research and education

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.[12] 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;
— 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.

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

Transport

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.

In addition, international maritime shipping is regulated by the IMO's International Maritime Dangerous Goods Code **("IMDG").**

Health & Safety

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

The National Service of Geology and Mining issued a Supreme Decree which establishes a mining safety regulation 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.

Environment

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.

In conclusion, the regulatory framework of hydrogen is 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. In particular, provisions are lacking regarding high pressure vessels, cryogenic fluids (i.e. liquid hydrogen), flammable atmospheres, hydrogen production, explosion mitigation, ventilation needs, handling and transfer of hydrogen, and various foreseeable uses within the green hydrogen value chain.[13]

[13] A complete study of actual Chilean hydrogen regulation has been uploaded online, at: https://www.4echile.cl

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
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.

Upcoming developments

There have been several hydrogen related projects announced recently. Notably, the following measures show the progress being made in advancing the role that hydrogen can play in Chile's energy, transport, industrial and heating sectors:

4EChile has published several articles and scientific papers showing the prospects and potential of hydrogen in Chile, including a complete study of current Chilean legal framework of hydrogen.[14]

In January 2020, the **"Cavendish Mission"** program was inaugurated. It consists of a series of four workshops that will provide a space for discussion, learning and convergence of initiatives to support at the local level the development of green hydrogen projects. The program is promoted by the Solar and Energy Innovation Committee of public entity CORFO, the Chilean Hydrogen Association and local private entity Innovation Club. The initiative seeks to encourage and prepare the public, private and academic sectors for a series of international activities and events that will take place during 2020. The purpose of these being to promote the economic agenda of the country and seeking to contribute towards the Chilean National Hydrogen Strategy.[15]

The Ministry of Energy intends to publish the **Chilean National Hydrogen Strategy** in late 2020, which will be a key strategic document for the development of hydrogen in Chile.

[14] Please refer to the following articles: (i) "*Tecnologías del Hidrógeno y Perspectivas para Chile*"; and, (ii) "*Proposición de Estrategia Regulatoria del Hidrógeno para Chile*"; both available online at: https://4echile.cl/

[15] More information available online at: https://www.comitesolar.cl/mision-cavendish-buscan-potenciar-desarrollo-de-hidrogeno-verde-en-chile/

China

Author: Vera Zhang

Current status for hydrogen in China

Introduction

In 2018, China's annual hydrogen production exceeded 20m tonnes, and it 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%). It is likely that fossil fuel-based hydrogen will continue to be the main form of hydrogen produced in China over the next decade.

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.

The National Alliance of Hydrogen and Fuel Cell (or the China Hydrogen Alliance, **"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 international, major players from the energy industry are also members of NAHFC, for example 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.[1]

In August 2020, NAHFC worked alongside the Hydrogen Council to produce the research report titled "Path to Hydrogen Competitiveness – A Cost Perspective", a Chinese version of the Hydrogen Council's 2019 report. The report highlighted that developments in technology, among other areas, will assist in reducing the costs associated with hydrogen production and stated that this is an area in which China has much to offer.[2]

[1] http://www.h2cn.org/en/about.html#survey
[2] http://www.h2cn.org/en/dynamics_detail/736.html

Transport

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 were 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

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 produced from fossil fuels, such as coal, natural gas, and petroleum, accounts 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%.

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 90 bn.

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 2,000 mu (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. 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.

Challenges facing hydrogen projects in China

High costs, difficulties in storage and lack of hydrogen infrastructure

Since hydrogen needs to be produced twice, 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 are not perfect, 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 put into use.

Legislative framework

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

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, 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 successively 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.

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.

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 the Government Work Report of the State Council 2019, it is clearly stated 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.

Primary legislation

The draft "Energy Law of the People's Republic of China" issued on 10 April 2020 is narrow in its scope and only mentions hydrogen within the definition of "energy". Therefore, the importance and potential of hydrogen is yet to be fully reflected in China's legislation.

Generation

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.

Energy supply

On 9 April 2020, the National Energy Administration issued the "Matters Concerning the Preparation of the 14th Five-Year Plan for Renewable Energy Development", which pointed out that combining new technologies, such as energy storage and hydrogen energy, could increase the proportion of renewable energy in regional energy supplies.

Transportation

On 19 September 2019, the Central Committee of the Communist Party of China and the State Council issued the "Outline for Building a Powerful Transportation Country", requesting that the construction of hydrogen refuelling station facilities be expedited.

On 10 February 2020, the Ministry of Industry and Information Technology issued a relevant decision on the access of NEVs, requiring FCVs to have on-board hydrogen system leakage test instruments and equipment.

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.

Also in June 2020, the General Office of the Ministry of Housing and Urban-Rural Development released the national standards, "Technical Specifications for Hydrogen Refuelling Stations (Draft for Partial Amendments)" and "Technical Standards for Automobile Refuelling and Hydrogen Refuelling Stations (Draft for Comments)", to solicit comments. Though these are still in draft form, the standards outline, amongst other things, the technical requirements for hydrogen pipelines and storage systems and the content of liquid hydrogen to be used at refuelling stations. It is not known when the standards may be finalised or when they are expected to come into force.

Foreign Investment

In terms of foreign investment, the "Catalogue of Industries Encouraging Foreign Investment (2019 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 to invest in hydrogen energy projects in China may enjoy preferential treatment, for example on taxation or land.

Subsidies

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

It is no surprise that 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.

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 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, the country will 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 in China 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.

Czech Republic

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Current status for hydrogen in Czech Republic

Introduction

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

Energy & Industry

There are 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.

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

Transport

The transportation industry is the cornerstone of the hydrogen economy in the Czech Republic and a number of hydrogen initiatives (albeit small in size) 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 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 5 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

Transport

The NAP CM provides 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 to 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 a number of key factors which will need to be addressed. 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 as being 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 decrease in the price of hydrogen vehicles.

The NAP CM also includes a general ambition to increase the share of hydrogen fuelled good 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 timings have 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

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., 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 the 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.

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 as well as 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

Regulatory shortcomings are a key barrier to greater development of hydrogen projects in the Czech Republic. Some of the potential regulatory issues involve, without limitation, a lack of regulation concerning:

— the parking of hydrogen fuelled cars;
— 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.

Instead developers of hydrogen projects must rely on existing energy and planning legislation as well as on laws regulating the production, transport, use and store of gases.

Financial support and incentives

Despite the existence of a number of general national funding programmes which may potentially be used for financing hydrogen projects, the absence of a specific hydrogen fund represents a challenge facing potential hydrogen projects and the development of 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 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

According to the 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 use and 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 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

There is no dedicated hydrogen legislation in the Czech Republic. Existing provisions of the Czech legal framework primarily relates to the use of hydrogen in transportation, although this area is underdeveloped.

Primary legislation

Legislation that would apply 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 legal framework. Stakeholders must therefore follow general rules regulating industrial specific areas (e.g. transportation and energy), which may not be suitable for the development and implementation of hydrogen technology. The laws which would apply to hydrogen projects will depend on the way of production, management, disposal and use of hydrogen and therefore include laws such as the Energy Act, Chemical Act, Act on Protection of Public Health, Health and Safety regulations, transport regulations as well as legislation relating to management of dangerous gases. Moreover, hydrogen has only been recognised as an alternative fuel since 2017 under the Czech Act no. 311/2006 Coll., on Fuel Substances, as amended.

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, in particular, Ministerial Decree no. 268/2009 Coll., on technical requirements of constructions, as amended, which to a limited extent addresses 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

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. programs "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.

In respect of licensing, given there is no specific hydrogen licensing regulations the generic licences covering a particular activity 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 regard to the ambitious goals set out in the NAP CM and the initiatives of certain regional municipalities in the Czech Republic, these investments will be made primarily in transportation with the aim of decreasing the carbon footprint of this sector.

While there are a number of projects being discussed, many of these are not sufficiently developed as yet. As such the main one to highlight would be the Usti-nad-Labem hydrogen station.

In February 2020 Usti-nad-Labem announced the construction of its first hydrogen station. Construction will start in 2021 and will be funded under the Operational Program "Transport". The total funding is expected to be CSK 31m, with completion of the station expected by the end of 2021.

France

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Current state of 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 of 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, the law instituted a system of guarantees of origin for hydrogen of renewable origin[3]. The issuance of the law-decrees provided for by the Energy and Climate Law have been postponed due to the COVID-19 crisis. The Minister in charge of Energy specified in April 2020 that the texts should be published soon.

[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

In addition, the Multiannual Energy Program (the **"PPE"**), published on 23 April 2020, for the periods 2019–2023 and 2024–2028, provides for an increase in financial support for the hydrogen sector. The hydrogen plan referred to above is set out in the PPE with the following measures:

- *"Set up support for the development of decarbonated hydrogen to the price of EUR 50m per year and launch calls for projects on mobility and hydrogen production using electrolysers;*
- *Set up a traceability system for decarbonated hydrogen in 2020;*
- *Extend the measure of additional depreciation on the purchase of hydrogen vehicles at least under the same conditions as for CNG (heavy goods vehicles > 3.5 t);*
- *Mobilise financial institutions (private and public funding including CDC, BPI[4]) and standardise co-financing models for ecosystem deployment projects that pool different uses (mobility, industry, etc.) at the local level in the territories;*
- *Discuss with all stakeholders concerned by the simplification and harmonisation of authorisation and approval procedures for boats and associated hydrogen refuelling solutions;*
- *Pursue support for innovation, in particular to accompany industrialisation and the transition to the French scale".*

Energy & Industry

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 1 MW 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"**)[5] in 2015[6].

GRTgaz has announced in May 2020 that it is 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 70 km hydrogen transport infrastructure accessible, by adopting existing gas infrastructures[7].

Hydrogène de France and Teréga will develop a HyGéo pilot project to define solutions for significant hydrogen energy storage[8]. 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.

[4] CDC and BPI are State-owned financial entities
[5] https://www.jupiter1000.eu/
[6] https://www.cre.fr/Documents/Deliberations/Approbation/programme-investissements-2015-grtgaz
[7] https://www.h2-mobile.fr/actus/mosahyc-grtgaz-creos-lancent-reseau-europeen-transport-hydrogene/
[8] https://www2.terega.fr/fileadmin/presse/CP_FR/2020/CP-Terega-Hygeo.pdf

Transportation

Hydrogen is a technology competing with electric batteries and other 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 investment, the French Environment and Energy Management Agency **("ADEME")** is responsible for encouraging *"the development of clean technologies and savings"*[9]. It thus encourages the development of hydrogen and fuel cells by issuing tenders for projects, which is successful would qualify for a State subsidy. The tenders to date have included[10]:

— 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.

Market prospects for hydrogen

The potential of hydrogen to boost the economy is recognised in France. Both the 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.

9 Article L. 131-3, 5° of the Environmental Code
10 smartgrids-cre.fr

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

There have also been a number of mergers and acquisitions in the sector. For example, EDF created last year a subsidiary 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 near Lyon is due to open in November.

Currently, the projects are mainly financed by public bodies. However, it is likely that investors and banks will participate in the near future[11].

Finally, several gas system operators among which GRTgaz, which operates in nine EU Member States, proposed a European "hydrogen backbone". GRTgaz and Téréga participated 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 6,800 km) of pipeline is considered possible. If achieved it will link the different European hydrogen valleys. For 2040, a 23,000 km 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[12].

Challenges facing hydrogen projects

Legal framework

To date, the regulations regarding use of hydrogen in the mobility sector are more developed than for the injection of hydrogen into gas networks.

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

Financial support and incentives

The Government intends to include support measures for hydrogen projects in the French economic recovery plan to be presented in Autumn 2020. The Minister for Economy has indicated a possible increase of investment up to several billion euros in hydrogen. France's previous hydrogen strategy, presented in 2018, limited investment to EUR 100m.

The Government has also introduced incentives to encourage the uptake of new modes of transportation such as hydrogen powered vehicles. For example, employers can now offer a refund for commuting to and from work using hydrogen-powered vehicles[13].

Research and education

Lhyfe has its 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[14].

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

11 French industrialists in the starting blocks, Les Echos, 9 July 2020
12 http://www.grtgaz.com/fileadmin/medias/communiques/2020/fr/20200715-European-Hydrogen-Backbone-Report.pdf
13 https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000041858450&dateTexte=&categorieLien=id
14 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

There is no specific law on hydrogen in France at present. Hydrogen is mentioned in general laws on energy and mobility. For example, the Mobility Orientation Law No 2019-1428 of 24 December 2019 allows cities to create hydrogen refuelling infrastructures for vehicles and boats. For the time being, these small pieces of legislation mainly concerns hydrogen mobility.

Policy and Governmental programmes

The Government presented its Hydrogen Plan, "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.

Primary legislation

There is no dedicated Law about hydrogen in the French legal framework. Thus, the stakeholders have to the follow general rules arising from the France set of energy laws and regulations.

However, the most recent laws on energy and mobility encourage the development of hydrogen, in particular by giving new competencies to municipalities in order to install hydrogen recharging stations on their territory.

Generation
There are no specific regulations applicable to hydrogen producers. Production and recharging facilities are subject to 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 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.

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

Financing
Subsidies are awarded by a 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.

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) 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.

Regulatory bodies

As there are no specific provisions on 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: first, 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; second, support research and development, inter alia to make green hydrogen profitable; and, third, 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 6.5 GW carbon-free hydrogen through electrolysis;
- Conversion of our 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").

Germany

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Current status for hydrogen in Germany

Hydrogen in the German Energy Market

In the wake of the Fukushima nuclear disaster, the German Government announced the importance of Germany's energy transition, and the importance of the role of hydrogen in this transition. 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.

Power to Gas

Gas transmission operators **("TSO")** 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 green energy 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 green energy 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 filling stations and to industrial consumers through storage caverns. At the time of writing the project is on hold by the Federal Network Agency **("BNetzA")** due to unbundling concerns regarding the operation of storage facilities (i.e. power-to-gas plants) by transmission network operators.

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

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 this project is on hold by BNetzA due to unbundling concerns regarding the operation of storage facilities by network transmission operators.

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 offshore wind and recovering the waste heat generated. 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 filling 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 m³ 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").** The first converted pipelines will, 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 will connect demand centres in North Rhine-Westphalia and Lower Saxony with green hydrogen production projects in Northern Germany. By 2030, the starter network will 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 290m are expected by the end of 2025 to build the starter network with a total of EUR 660m by the end of 2030. However, besides the approval of the NDP the implementation of the starter network requires adjustments to be made to the legal framework, as discussed in more detail 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

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

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 needed. 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.

Power Generation

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 by early 2021. 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

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 National Hydrogen Strategy is 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, there is no consistent and complete framework covering the hydrogen value chain in Germany. Regulations and definitions are lacking or unclear. A framework for carbon capture and storage necessary for the market launch of "blue" hydrogen is lacking completely. Even the fundamental question of whether and, if so, how the established regulatory system for gas should apply to hydrogen is still waiting for a reply. All of this will have to be tackled within the context of the implementation of the National Hydrogen Strategy.

Incentives

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 by far more expensive than grey hydrogen, the market launch of green hydrogen is largely dependant 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 not clear 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.

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

Regulation of hydrogen

Construction of Hydrogen Production Facilities

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.

Transportation

The definition of "gas" in the Energy Act encompasses hydrogen as long as it is produced by electrolysis (power-to-gas).

Hydrogen produced by electrolysis also falls within the definition of "biogas" in the Energy Act, thereby profiting from the privileges for biogas concerning preferential network connection, network access and balancing.

Since hydrogen produced from electrolysis is defined as gas, pipelines transporting such hydrogen would qualify as gas supply networks under the Energy Act. To make things difficult, this applies to distribution networks only, since the definition of gas transmission in the Energy Act refers to the transmission of natural gas, thereby excluding hydrogen of any type.

Other types of hydrogen like blue hydrogen are not covered by these definitions at all. Consequently, they fall outside the scope of the Energy Act and its related regulations.

Pure hydrogen transmission networks are not covered by the existing regulatory framework.

As of today, a maximum of 10% hydrogen can be blended into the natural gas grid. According to the reports from the Technical Gas Association this share may be increased up to 20%. As part of the NDP the TSOs have announced their intention to completely convert existing pipeline sections to hydrogen and to build new hydrogen trunklines.

Network Tariffs

Under the Network Access Regulation, the injection of biogas (and hence hydrogen produced from electrolysis) into the gas transmission grid is free of charge.

Under the Network Access Regulation, the injection of gas (and hence hydrogen produced from electrolysis) into the local gas distribution network is free of charge.

Generally, facilities producing hydrogen from electrolysis are exempted from network access charges under the Energy Act.

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.
— 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.

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

— 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 is due to appoint a National Hydrogen Council. The Council will be 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.

Consultation on Regulation of Hydrogen Networks

As one of the first measures implementing the National Hydrogen Strategy **("BNetzA")** has opened a consultation proceeding in July regarding the regulation of hydrogen networks[4]. As stated in the accompanying consultation document, BNetzA basically assumes that existing regulations cover hydrogen only to the extent that distribution grids are concerned and that pure hydrogen transmission networks are not regulated at all. Therefore, the consultation focusses on the question of whether hydrogen networks should be regulated at all and if so, how.

BNetzA distinguishes three different scenarios:

— In scenario I, hydrogen is consumed primarily by some industrial sites and is transported in isolated local networks. Hydrogen production is only local.
— Since decentral hydrogen production is not sufficient to cover demand from industry additional long-distance transmission lines are required in scenario II.
— Scenario III assumes greater demand of the mobility sector. Isolated local pipelines are converted into meshed local networks interconnected by long-distance transmission lines.

BNetzA draws the following provisional conclusions:

— In scenario I access regulation may be appropriate especially in case of increasing access demand. There should be, however, no need for tariff regulation.
— In scenario II, like in scenario I, access regulation may be appropriate especially in case of increasing access demand. Tariff regulation seems possible.
— In scenario III, like in scenario I and II, access regulation may be appropriate especially in case of increasing access demand. The need for tariff regulation is obvious.

The outcome of the consultation and the conclusions drawn by BNetzA from the market response remain to be seen.

[4] https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/NetzentwicklungundSmartGrid/Wasserstoff/wasserstoff_node.html

Italy

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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.

Currently, hydrogen is mostly used in chemical and metallurgical industries in Italy. It is commonly obtained through a thermochemical process called "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, and so 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.

Industry

In 2019, SNAM S.p.A **("SNAM"),** one of Italy's leading energy infrastructure operators, launched a project called "SNAMTEC" 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

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.

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

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

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, 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 recently 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.

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

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.

Connection

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

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 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 will drive Italian energy policy over the next few decades. The Ministry of Economic Development has announced that, in compliance with the plan, 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.

Japan

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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, aims to reduce 2013-levels of CO_2 emissions by 80%; 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 will be held online in October 2020 and will 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.

Now Japan is 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

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/Nm3 by around 2030, and in the future, to procure it at reduced cost of 20 JPY/Nm3.

In Japan, various pilots are being carried out in order 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 in order to transport it to Japan by sea. In December 2019, the world's first liquefied hydrogen carrier "*Suiso Frontier*" was launched and is scheduled to be completed in the autumn of 2020. In Kobe, where the hydrogen will be received, a 2,500 m^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 (10 MW) 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

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.

FCVs
In terms of passenger cars, Toyota Motor Corporation **("Toyota")** and Honda Motor Co. **("Honda")** 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 plans to launch its next FCV model at the end of 2020. The new model's performance has been drastically improved by completely renewing the fuel cell system and extending the cruising range by approximately 30%, compared to the conventional model. Honda maintains its strategy to continues lease sales in Japan and announced in June 2020 that it will begin lease sales to individuals.

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. At the end of the 2019 financial year, 3,757 FCVs were in use.

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. At the end of the 2019 financial year, 57 fuel-cell buses were in use. There still 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.

Fuel-cell trucks
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 toward 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.

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.

However, in order 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 17 JPY/kWh by the time hydrogen power generation has been commercialised, in 2030.

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; it is aimed that costs will further reduce and 5.3m units will be introduced by 2030.

As for industrial fuel cells, phosphoric acid fuel cells **("PAFC")** and SOFCs have been on the market since 1998 and 2013, respectively. 20 kW-class SOFCs are 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.

Market prospects for hydrogen

General

As described above, FCVs and fuel-cell trucks are already used in the transportation sector. As of July 2020, there were 131 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 utilisation of hydrogen 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 are still small and would need to grow in order to attract much more private sector investment. In the field of ENE-FARM, major electronics 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.

The power is certified using the following values which allows retailers to appeal to consumers that the electricity derived from renewable energy sources is environmentally friendly:

— the "non-fossil fuel energy value";
— the "zero emission value"; and
— the "environmental labelling value".

This certificate system applies to hydrogen derived from crude oil, petroleum gas, combustible natural gas or coal. However, it is not clear whether this system applies to some other types of hydrogen, such as hydrogen derived from renewable energy.

Challenges facing hydrogen projects

Supply chain issues

At present, the cost of hydrogen at stations in Japan is approximately 100 JPY/Nm3, 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 at December 2015, only a few cars could be produced per day, unlike the significantly greater volumes that can be manufactured as internal combustion engine **("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 JPY 7m range, which is JPY 3m more expensive than a hybrid vehicle **("HV").** The price of a fixed-route bus is JPY 150m.
— In order to achieve the target use, the 2018 Roadmap aims to reduce the price difference between passenger car-type FCVs and HVs to JPY 700 thousand and to lower the price of fuel-cell buses to 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.

Low carbon hydrogen

— 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. The government aims to commercialise CCS technologies in 2020.
— In addition, in order 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.

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

Use at the Tokyo Olympic and Paralympic Games

Japanese companies have conducted research and demonstrated technologies to showcase hydrogen-related technologies at the 2020 Tokyo Olympic and Paralympic Games **("Tokyo 2020 Games"),** now postponed to 2021.

For the first time in Olympic and Paralympic history, hydrogen will be used as fuel for the torch and part of the torch relay. The hydrogen produced in the FH2R, mentioned above, will also be used as fuel for the torch.

Also, at the Tokyo 2020 Games, it has been decided that Toyota will provide approximately 500 FCVs for use in the Games. As a worldwide partner of the Olympic and Paralympic Games, Toyota will support the Tokyo 2020 Games with its full suite of electric vehicles, including FCVs and fuel-cell buses. The operation of the Games will also be supported by fuel-cell forklifts manufactured by Toyota Industries.

Using hydrogen-related technologies, the Tokyo 2020 Games aims to achieve the highest level of positive environmental impact ever achieved, through the reduction of CO_2 emissions.

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 should have been used for the Tokyo 2020 Olympic and Paralympic Games, and will be used at the postponed 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 neighboring public facilities.

Initiatives in the Aichi Prefecture: Since 2019, ten private companies, including energy, petrochemical and automobile companies, have been studying the possibility of large-scale hydrogen utilisation in the Chubu region, in cooperation with the Aichi Prefecture.

Transportation Landscape

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

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Current status for hydrogen in Mexico

Introduction

There are few current hydrogen projects in Mexico. Up to this date, the largest percentage of hydrogen production in Mexico is mainly used by the state-owned crude oil, natural gas, and petroleum company, Petroleos Mexicanos **("PEMEX")** and it is obtained through catalytic reforming of hydrocarbons and methods in which hydrogen is generated as a secondary product of other chemical processes.

In 1999, Mexican professionals and academics founded an association dedicated to the promotion and development of hydrogen technologies, for use in the energy sector. The association, *Sociedad Mexicana del Hidrógeno* **("SMH"),** organises an annual Technical Congress during which members of several research and development institutions, such as the Mexican Council for Science and Technology (or *Consejo Nacional de Ciencia y Tecnología* **"CONACYT"**), from across the country present their work. International specialists are invited to the Technical Congress as keynote guests and offers technical courses to students and professionals interested in the use of hydrogen as an energy source. The limited experience of hydrogen produced through electrolysis in Mexico has been conducted by members of SMH, who are the main players in this field.

In 2016, the SMH published the National Hydrogen Plan (the **"Plan"**). The main aim of the Plan was to identify key technologies, products, and markets for the development of hydrogen as a fuel and sustainable energy source in Mexico, through research, resource training, specialised human resources, the transfer of technology and production of goods and services. However, the Plan focused on investigation of this area and, as yet, there is no evidence of any projects being developed as a result.

Also in 2016, the Mexican Energy Ministry *(Secretaría de Energía)* along with the CONACYT granted funds to develop a prototype for a zero-emission electric vehicle powered by hydrogen fuel cells. This project was developed by the National Institute of Electricity and Clean Energy (or *Instituto Nacional de Electricidad y Energías Limpias* **"INEEL",** formerly *Instituto de Investigaciones Eléctricas*) along with the Centre for Research in Automotive Mechatronics of the Tecnológico de Monterrey *(Centro de Investigación en Mecatrónica Automotriz);* the Centre for Research and Technological Development *(Centro de Investigación y Desarrollo Tecnológico);* the Potosi Institute for Scientific and Technological Research *(Instituto Potosino de Investigación Científica y Tecnológica),* and the Autonomous University of San Luis Potosí *(Universidad Autónoma de San Luis Potosí).* The project used an electrochemical device fed by hydrogen gas and an oxidant (i.e. pure oxygen or air) which, when reacting, produced electricity and water as waste. The tests confirmed that the energy supplied by the all-electric hybrid system was sufficient to move the vehicle over a range of approximately 60km, with acceleration that reached over 1m/s2 and speed of around 45km/h. This prototype vehicle was developed for the utility market; however, its developers consider that only minor changes are required to extend its use to personal urban transport. Since these results were announced, there have been no further developments on this project.

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., a subsidiary of PEMEX, for USD 59m (around EUR 50m). Under the terms of the agreement, Air Liquide will supply hydrogen to PEMEX's Miguel Hidalgo refinery, based in Tula de Allende, Hidalgo State, for 20 years.[1]

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. Linde will invest approximately USD 40m into the operation of the hydrogen plant and PEMEX will provide the entire operating structure. It is estimated that the plant will have a capacity to produce around 42m ft^3 per day.[2]

Market prospects for hydrogen

In Mexico, M&A activity among hydrogen projects is limited due to the absence of current projects. However, this could be a significant area of growth for Mexico due to the growing global interest in hydrogen, which may trigger future M&A deals.

There are no specific (private or public) financing options for hydrogen projects in Mexico. Clean energy certificates **("CELs")** are a public mechanism that can provide financial benefits to hydrogen projects, as long as 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. Aside from this, there is little incentive to encourage financing of hydrogen projects.

[1] https://www.airliquide.com/sites/airliquide.com/files/2017/09/06/air-liquide-signs-a-long-term-contract-with-pemex-for-the-supply-of-hydrogen-to-the-tula-refinery-in-mexico.pdf

[2] https://www.pemex.com/en/press_room/press_releases/Paginas/2018-034-national.aspx

Challenges facing hydrogen projects

Legal Framework

There are provisions in the Mexican legal framework that set general guidelines on hydrogen as an energy source, such as the LIE and the Energy Transition Law, which catalogues "clean" energy. Under this legislation, "clean" energy is classified as that generated by the use of hydrogen through its combustion or its use in fuel cells.

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 26 March 2020 Standard and Poor's **("S&P")** Global Ratings, lowered Mexico's sovereign bond rating from BBB+ to BBB, 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 Sectoral Program derived from the National Development Plan 2019-2024 was published. This programme acts as a principle to guide the "rescue and promotion" of the energy sector in the following way:

"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

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

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.

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. In this context, the SMH states that *"it is essential to create an Official Mexican Standard on hydrogen management, based on the existing legal needs and absences."*

Transportation

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 Energy Regulatory Commission, as is further detailed, below.

Permitting

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 Energy Regulatory Commission 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 therefore, obtain 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 Energy Regulatory Commission 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

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 with 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 "traditional", 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 Energy Regulatory Commission (*Comisión Reguladora de Energía* **"CRE"**). Renewable energy power plants which generate 100% "clean" energy, will be awarded with 1 CEL per MWh; and combined cycle generators or plants that use co-generation will be awarded 1 CEL for each 5MWh generated.

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.

Middle East

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Current status for hydrogen in Middle East

Introduction

Whilst this area of the world is typically known for more traditional energy sources, over the last few years there have been a number of projects in the Middle East that demonstrate how the region is researching and developing hydrogen technology and the deployment of a hydrogen economy, among other renewable energy sources. Several projects have been undertaken in the UAE, Egypt and Saudi Arabia, the most notable of which are outlined below.

UAE

The United Arab Emirates **("UAE")** is a pioneer in renewable energy (particularly solar) and is committed to developing a green energy economy.

Air Liquide, a world leader in gases, technologies and services, recently undertook a study in collaboration with Al Futtaim Toyota and Khalifa University of Science, Technology and Research **("Khalifa University"),** to distribute Toyota's hydrogen-powered fuel cell electric vehicle **("FCEV"),** Mirai, and consider strategies of how to develop the hydrogen industry in the UAE. The study demonstrated that there is substantial potential for hydrogen mobility to become a major economy for the UAE, in line with the UAE's Vision 2021, as well as its clean energy goals.

In 2017, Al Futtaim Motors in partnership with Air Liquide opened the first hydrogen station in the Middle East, at Al Badia, Dubai Festival City. Construction of a second station was set to begin in 2020 in Masdar City, between Abu Dhabi National Oil Company **("ADNOC"),** Masdar Clean Energy, and Al Futtaim Motors, though it is not known when this is due to become operational.

In February 2019, the Dubai Electricity and Water Authority **("DEWA")** inaugurated the first solar-driven hydrogen electrolysis facility, the Mohammed bin Rashid Al Maktoum Solar Park, in the Middle East and North Africa **("MENA")** region in Dubai. According to reports, the hydrogen produced at the facility is intended to be stored and deployed for re-electrification, transportation and other uses. It is likely that the facility will be operational in 2022.

Expo 2020 Dubai, which has been postponed to October 2021 due to Covid-19, intends to showcase hydrogen mobility by powering a number of FCEVs with the hydrogen generated at the facility. In addition, the Emirates National Oil Company **("ENOC")** is planning to unveil a "Service Station of the Future" for the Expo, which will use multiple sources of energy, including solar and hydrogen.

The Abu Dhabi Police has also announced plans to convert its vehicle fleet to FCEVs by 2050.

Saudi Arabia
Hydrogen projects are generally considered to be in line with Saudi Arabia's clean energy targets and vision for 2030, however, there have only been two large-scale hydrogen projects to date.

In July 2020, Air Products & Chemicals **("Air Products"),** whose principal business is selling gases and chemicals for industrial use, announced plans to build a green hydrogen plant in Saudi Arabia. The plant will be powered by 4 GW of wind and solar power, making it the world's largest such project. The USD5 bn plant will be jointly owned by Air Products, Saudi Arabia's ACWA Power, and Neom, a new mega-city planned near Saudi Arabia's borders with Egypt and Jordan. Due to be operational in 2025 and situated in the city of Neom, the completed facility will produce 650 tons of green hydrogen daily, enough to run around 20,000 hydrogen-fuelled buses.

Egypt
Egypt has huge potential in terms of land and resources to produce hydrogen powered by solar energy for export. Egypt is considered a "sun belt" country with 2,000 to 3,200kWh/m^2 of direct solar radiation. The sun shines between 9 and 11 hours a day with few cloudy days. There are also land areas with high and steady wind speeds suitable for producing wind energy, which can also be used to produce green hydrogen.

Egypt has adopted an ambitious energy diversification strategy. The strategy aims at ensuring the continuous security and stability of power supply, the diversification of energy resources and the optimum exploitation of the country's resources. The strategy has set a target to achieve 20% renewable energy of the total national generation capacities by 2022. This share will increase to 37% in 2030 and to 42% in 2035.

Research and education

UAE
Air Liquide, Khalifa University, and Toyota distributor Al-Futtaim Motors have, in 2020, released a joint study that outlines the contribution of hydrogen to the energy transition and demonstrates the favourable prospects for hydrogen mobility in the UAE. Since 2014, Khalifa University has been collaborating with Japan to explore the possibility of establishing a hydrogen supply chain in order to increase hydrogen utilisation in the sustainable economy.

In March 2020, the DEWA Research and Development Centre (the **"R&D Centre"**), part of the Mohammed bin Rashid Al Maktoum Solar Park, was opened. The R&D Centre is focussed on four major operational areas: *"electricity generation from solar and clean energy, integration of smart grids, energy efficiency, and water"*. A solar-powered green hydrogen project is being built at the outdoor testing facility of the R&D Centre, which is expected to be launched at the Dubai Expo 2020 (postponed until 2021).

Saudi Arabia
In 2019, Saudi Aramco and Air Products signed a cooperation agreement to jointly build Saudi Arabia's first hydrogen FCEV fuelling station. The agreement brought together Air Products' technical knowledge and experience in working with hydrogen and Saudi Aramco's industrial experience, facilities and research and development capabilities. The fuelling station became operational in late 2019. As part of the agreement, a pilot fleet of FCEVs will be built, for which high-purity compressed hydrogen will be dispensed at the new fuelling station.

Several research and development initiatives and activities are currently being carried out at the King Abdullah University of Science and Technology **("KAUST")** into hydrogen and fuel-cell technologies. The aim of these studies being to the realise the results within Saudi Arabia's transport sector.

Market prospects for hydrogen

Hydrogen technology is still at the early stages of development in the Middle East. However, there are clear signs that the some of the oil-rich countries in the Middle East could potentially endorse more industrial and commercial uses of hydrogen as part of their transition to a greener economy. The **UAE,** for instance, is well on the path to a more diverse, secure and sustainable electricity sector and therefore CO_2-free hydrogen is of particular interest to UAE policy-makers, from a climate policy point of view. Earlier this year, the UAE Environment Minister was quoted as saying *"hydrogen produced by renewables in the very best locations* [in the UAE] *could become cost competitive in the next five years"*. The UAE, like most other countries in the Middle East, has sufficiently attractive resources for solar installations required to produce enough hydrogen to cover local demand. However, the UAE has two additional advantages: the availability of investment capital and a cooperative business environment, which could help it engage with the production of hydrogen and its potential as an export.

In **Saudi Arabia,** there are few large-scale projects, other than the plant to be built in Neom, mentioned above, and a hydrogen distribution system in the industrial city of Yanbu, built by Air Liquide. If these projects succeed, it is likely to lead to a new era of hydrogen developments throughout the Middle East.

With its large natural gas portfolio, **Egypt** has the opportunity to start producing blue hydrogen by converting a portion of its natural gas resources into hydrogen, using carbon-capture technology. In addition, Egypt is bordered by 2,450km of coast, as well has having 1,530km of the Nile River, placing it in a prime location to produce green hydrogen at scale and for low costs using electrolysis. Although a shift to a hydrogen economy might be a risk for Egypt, as a major natural gas-exporting country, it is a strategic chance to benefit economically and serve future decarbonised energy demand. Given its ample renewable energy resources, as well as its proximity to key markets, such as the EU, Egypt has outstanding opportunities to tap into new energy export markets.

Given the early stage of development in these countries, there has been little private sector involvement in M&A activity or project financing, though both are expected in the coming years as the hydrogen sector grows.

Challenges facing hydrogen projects in the Middle East

Legal framework

The Middle East needs a clear strategy for hydrogen. At present, there is no specific regulatory framework for the licensing and implementation of hydrogen projects in the UAE, Saudi Arabia or Egypt. The limited regulation of hydrogen in this region is discussed below.

Financing Hydrogen Projects

Mobilising private finance in support of a low-carbon transition is a challenge and investment in hydrogen projects is no exception.

The planned USD 5bn clean hydrogen-based ammonia production facility in Neom, **Saudi Arabia,** could be a model for securing further project financing.

Similarly, in **Egypt,** one of the main challenges facing hydrogen energy is the cost of production. Producing, storing and transporting hydrogen, as well as building the necessary infrastructure, is expensive and likely to involve substantial capital expenditure compared to other renewable energy resources. However, some banks have expressed a willingness to provide debt funding. Representatives from the European Bank for Reconstruction and Development **("EBRD")** announced to the Minister of Electricity, during their visit in February 2020, that they were willing to invest in green hydrogen in Egypt. Also, in February 2020, a delegation from General Electric **("GE")** met with the Minister of Electricity offering to launch renewable energy projects in Egypt using hydrogen, in a bid to capitalise on demand for the latest innovative technological trend in renewables.

Managing the Energy Mix

In the **UAE,** Abu Dhabi is currently investing heavily in various sources of low-carbon energy. The key question is how the Emirate will be able to efficiently integrate multiple energy sources into its electricity grid in the future, including nuclear, waste-to-energy, solar and thermal generation. A longer-term vision for Abu Dhabi also needs to set out policies and frameworks that accommodate emerging technologies and business models, including battery storage, electric vehicles and hydrogen fuel.

Regulation of hydrogen

UAE

In July 2019, the Emirates Authority for Standardisation and Metrology **("ESMA")** announced that it had completed the draft technical regulations for hydrogen-powered vehicles. The UAE is the first country in the MENA region to establish legislation for the future of the environmentally friendly vehicles industry.

Currently, there is no enabling regulatory framework for hydrogen projects in the UAE. Hydrogen projects could be subject to a number of laws and regulations including the following:

- Federal Law No 14 of 2017 on Trading in Petroleum Products which regulates the trade of petroleum products;
- Abu Dhabi Law No 7 of 1971 which established ADNOC;
- Abu Dhabi Law No 4 of 1976 being a gas ownership law entitling ADNOC to exploit Abu Dhabi's gas resources through joint agreement and projects undertaken with third parties;
- Abu Dhabi Law No 1 of 1988 which established the Supreme Petroleum Council; and
- Dubai Law No 19 of 2009 which established the Dubai Supreme Council of Energy.

The UAE Energy Strategy 2050 targets an energy mix that combines renewable, nuclear and clean energy sources to meet the UAE's economic requirements and environmental goals. According to this strategy document, by 2050, 44% of the country's energy must come from clean energy sources which include low carbon hydrogen.

Saudi Arabia

Currently, there is no dedicated legislation for hydrogen projects in Saudi Arabia. The Basic Law of Saudi Arabia (Royal Decree No. A/90 dated 27/8/1412 H (1 March 1992)) vests all the Kingdom of Saudi Arabia's oil and gas wealth in the Government. The Ministry of Energy, Industry and Mineral Resources **("MEIM")** regulates, develops and implements policies relating to oil and gas and represents the Kingdom's oil production and pricing policies internationally. MEIM supervises the activities of Saudi Aramco, a 100% government-owned enterprise that has exclusive access to oil and gas exploration, drilling and production in Saudi Arabia.

Egypt

Currently there is no unifying law which applies specifically to hydrogen projects in Egypt. Instead, the existing laws for the gas, transport and water sectors apply to hydrogen, which is classified as a gas under the Gas Market Law No. 196 of 2017 (the **"Gas Market Law"**).

The gas market is mainly regulated in Egypt by virtue of the Gas Market Law. "Gas'" is defined broadly under this law to be *"a mixture of hydrocarbon and non-hydrocarbon components, which exists in a gaseous state under standard conditions, including gas associated with oil or shale gas or extracted from biomass (biogas), as well as any other unconventional types of gas, whether it is liquefied or pressed or in a gaseous state, after treatment and separating any commercial derivatives such as condensate, butane, commercial propane, ethane-propane mixture according to the national network standard specifications, and it is considered a product that can be sold and traded in the markets."*

The Law provides for the establishment of a public body to be the regulator; this is the Gas Market Regulatory Authority. The Authority is responsible for regulating, licensing and overseeing all gas-related activities. The Law divided gas-related activities into (1) services activities, and (2) market activities. "Service activities" includes the operation of gas grids and facilities through transmission, storage, distribution of gas as well as LNG and regasification activities; "market activities" covers gas shipping and supply.

Regulation and national strategies specific to hydrogen and hydrogen technology will need to be put in place over time in Egypt in order to regulate the production, storage and transportation of hydrogen. Regulatory reform will be a key area of focus if Egypt wants to deploy a hydrogen economy. Until this reform happens, any hydrogen project will be governed by the existing gas, energy, water and environmental regulations.

The main laws and regulations that currently apply to Hydrogen include the following:

— Gas Market Law No. 196 of 2017 and its executive regulations issued by virtue of the Ministerial Decree No. 239 for 2018;
— Electricity Law No. 87 of 2015 and its executive regulations issued by the Ministerial Decree No. 230 of 2016; and
— Renewable Energy Law No. 203/2014.

Laws and regulations in respect of potential environmental impacts and safety include:

— Environment Protection Law No. 4 for 1994 and its executive regulations issued by virtue of the ministerial decree No. 338 for 1994;
— Law No. 7 for 2010 regulating Nuclear and Radiological Activities and its Executive Regulations issued by the Ministerial Decree No. 1326 for 2011; and
— Ministerial Decree No. 566 for 2002 for the Requirement and Measures of Carrying out Activities at the Egyptian Ports.

In accordance with the Paris Agreement 2015, Egypt submitted its Nationally Determined Contributions **("NDCs")** in 2017 to be activated in 2020. Whilst Egypt's NDCs do not include quantified targets or set a specific goal for future emission reductions, they mention the possibility of creating a domestic emissions market to help drive a reduction in greenhouse gas emissions **("GHGs").**

Regulatory bodies

UAE

In Abu Dhabi, the Supreme Petroleum Council creates and oversees the implementation of general and fiscal policy in relation to domestic oil and gas resources. The council also functions as ADNOC's board of directors.

In Dubai, the Dubai Supreme Council of Energy is responsible for policy development with a view to developing new energy sources.

In Sharjah, the Petroleum Council of Sharjah is responsible for regulating the oil and gas industry and granting concessions.

The main entities responsible for the generation, transmission and distribution of electricity in the UAE are:

— Emirates Water and Electricity Company **("EWEC")** – the sole procurer of water and electricity in the Emirate of Abu Dhabi. The transmission and despatch of water and electricity is carried out by the Abu Dhabi Transmission and Despatch Company **("TRANSCO").** TRANSCO operates a load despatch centre in Abu Dhabi and is responsible for ensuring that producers have sufficient "real-time" generation and water capacity available to meet continuously varying customer demands. The following companies are currently responsible for the distribution and supply of power and water in Abu Dhabi:
— Abu Dhabi Distribution Company **("ADDC")**
— Al Ain Distribution Company **("AADC")**
— DEWA is the sole purchaser of electricity in Dubai and currently owns all the generation, transmission and distribution capacity of the Emirate of Dubai.
— The Federal Electricity and Water Authority **("FEWA")** is responsible for generation, transmission, and distribution of electricity in the northern Emirates of the UAE.

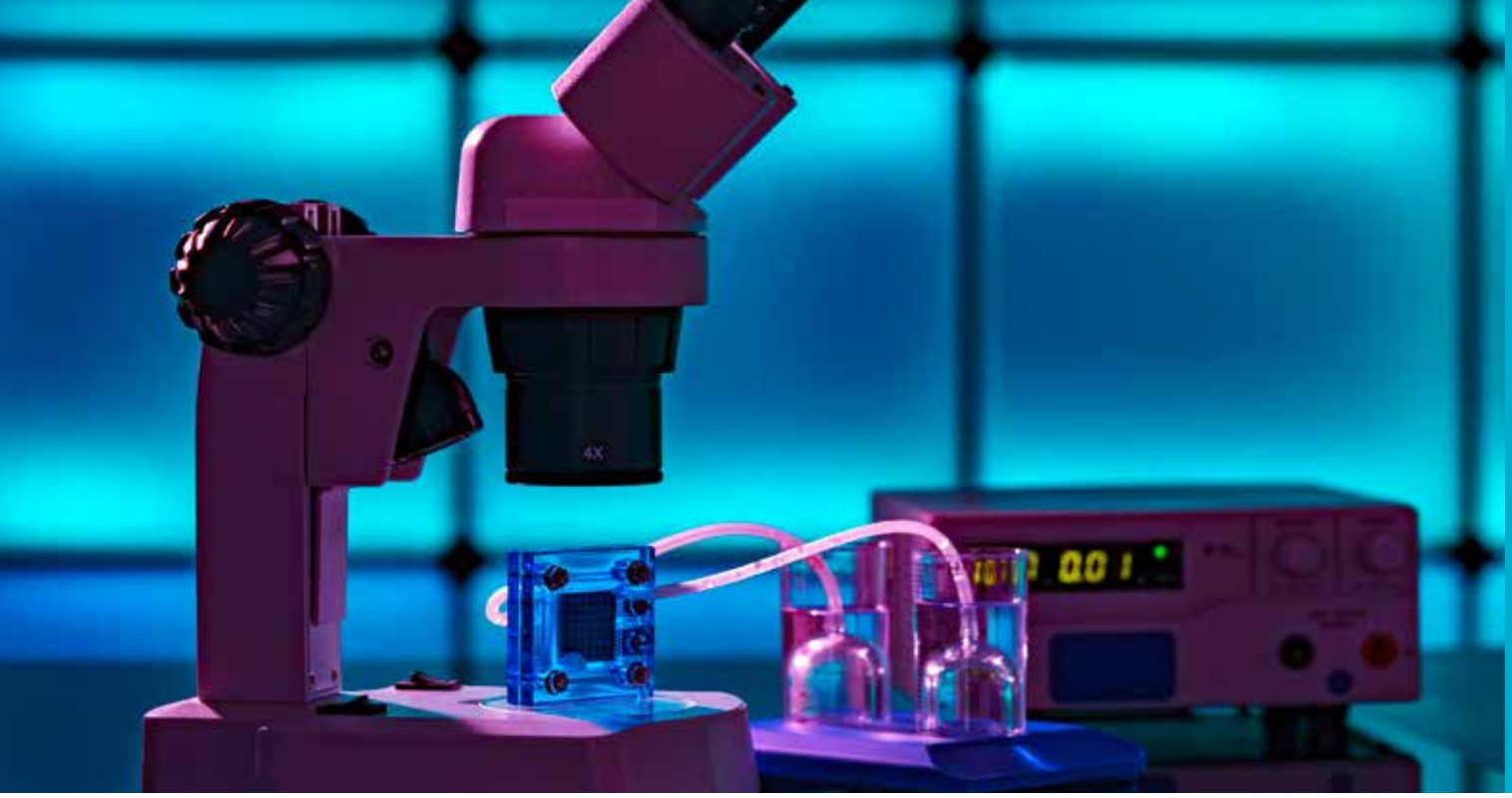
ADNOC is the UAE's state-owned oil and petrochemicals company. ENOC is the national oil company of the Emirate of Dubai. Both ENOC and ADNOC are involved in various hydrogen energy programmes.

The Roads and Transport Authority **("RTA")** is the authority responsible for public roads and transport in the Emirate of Dubai. In 2017, the RTA launched a trial run of the region's first hydrogen FCEVs using Toyota's Mirai in the Dubai Taxi Fleet. It plans to increase hydrogen-powered taxis in Dubai to 4,750 cabs by 2021.

Saudi Arabia

The major power-sector bodies relevant to hydrogen projects in Saudi Arabia are:

Regulatory Body	Role
The Ministry of Energy, Industry, and Mineral Resources ("MEIM")	— the government agency that handles policy and planning in the power sector.
The Saudi Electricity Company ("SEC")	— a government-owned Public Investment Fund **("PIF")** (holding over 80% of shares) that currently provides most of Saudi Arabia's electricity, with a generation capacity of 78GW in 2018. It also carries out all transmission and distribution activities.
Aramco	— the government-owned company that manages Saudi Arabia's oil and gas production. It is involved in power generation alongside SEC, as the primary supplier of feed stock.
The Electricity and Co-Generation Regulatory Authority ("ECRA")	— the Kingdom's independent regulatory body for Saudi Arabia's energy sector
The Power and Water Utility Company ("MARAFIQ")	— a government-owned entity that currently provides most of the power to the two industrial cities of Jubail and Yanbu, found in the Eastern and Al-Madinah Provinces, respectively.



Egypt

The National Council on Climate Change is required to, among other things:

— organise and implement national research efforts and projects to reduce emissions and adapt to climate change risks;
— vet projects submitted to the Green Climate Fund **("GCF");**
— remove obstacles that stand in the way of collecting, managing and processing climate change data;
— draw the national and sectorial policies in relation to climate change in light of the international conventions and the national interests;
— follow up the UNFCCC negotiations and the related protocols and agreements;
— support and increase research and development in climate change initiatives; and
— raise public awareness about climate change.

Upcoming developments

The second half of the 2020s is likely to see the emergence of a regional hydrogen economy in the Middle East, driven by heavyweight frontrunners such as the UAE, Saudi Arabia and Egypt. If initial investments in renewable energies continue to be made in the region, to a level sufficient enough to generate economies of scale, coupled with an appropriate transport infrastructure, the first player to make a move will generate a lock-in in terms of customer retention.

The Netherlands

Author: Martika Jonk

Current status for hydrogen in the Netherlands

Introduction

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 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 to cover approximately 50% by 2050, with gaseous energy carriers providing at least 30% of final energy consumption. In order to achieve this, scaling-up of 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.

The Netherlands has some unique selling points with regard 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, the Netherlands has large industries, such as Shell refinery, Yara and Tata Steel.

[1] Kabinetsvisie Waterstof 30 March 2020 MEZ DGKE/20087869
[2] Klimaatakkoord 28 June 2019

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 first hydrogen pipeline, which became operational in 2018. 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, with 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 busses already in operation;

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 will be the most appropriate locations for electrolysers across the country.[3]

Additionally, 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 EUR 27bn–EUR 64bn by 2040.

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

Transport

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], of which there is 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 of CO_2 within the port of Rotterdam, to ultimately produce blue hydrogen on a large-scale. Porthos is the first CO_2 storage project in The Netherlands. Similar projects are being investigated by the Port of Amsterdam (with Gasunie and also Tata Steel) and in the Province of Zeeland.

There is also opportunity for hydrogen to play a role in industry in the Netherlands, specifically in the development of hydrogen infrastructure and clusters to support industry. An Infrastructure Task Force has been formed and a report is expected towards the end of 2020.

[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)
[4] European Hydrogen Backbone Report July 2020
[5] See: www.porthosCO2.nl

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 by means of 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 done 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.

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 (2020–2021) 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 (2021–2022), 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

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

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

Market prospects for hydrogen

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

Challenges facing hydrogen projects

Reducing cost and securing demand

The biggest challenge facing hydrogen in the Netherlands is to create and implement a clean 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 and its storage capacity and sufficient demand in its industrial clusters.

Regulation of hydrogen

Legislative framework

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 will look at temporary roles for Gasunie with regard to transport, storage and conversion in order to kick-start the hydrogen market. Both private and public hydrogen networks are foreseen. The process to bring forward legislation to enable the transport and distribution of hydrogen by network companies has been initiated. This will be subject to a Ministerial Decree based on the current Gas Act. This Decree is expected to be published by the end of 2020 and should clarify the role of the network companies. 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

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.

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

Injection into the gas grid

One option to increase demand for green hydrogen is through blending hydrogen into the gas grid. Pursuant to the current Gas Quality Decree, a level of 0.5% hydrogen is permitted in the regional networks and a level of 0.2% in the national networks. The Gas Act will have to be amended in order to allow for a higher percentage of hydrogen blending. Physical blending of up to 2% is already achievable with minor adjustments and the government expects that this can be increased to approximately 10–20%. In its letter dated 2 November 2019,[7] the Minister of Economic Affairs and Climate Policy has announced that more detailed studies are required, as it may be possible that the gas grid could handle 100% hydrogen.

In addition, heating boilers have been developed for use with 100% hydrogen. As a result, the Ministry of Economic Affairs and Climate Policy has announced that it is investigating, with Gasunie, an obligation for the blending of hydrogen into the existing gas networks. A date is yet to be specified.

Health and Safety

The Netherlands has initiated a four-year Hydrogen Safety Innovation Programme that will be implemented as a public-private partnership, which 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 — Undertakes Environmental Impact Assessments
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 decommissioning
Autoriteit Consument & Markt ("ACM")	— Regulates the gas network

[7] Brief MEZ 7 november 2019 Beantwoording vragen over verplichte bijmenging waterstof in het gasnet DGKE /19253193.

Upcoming developments

Recent developments

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

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. During 2020 the parties have been occupied by the technical elaboration of the transport and storage infrastructure, obtaining all necessary permits and entering into agreements with companies for the supply of CO_2. Following this, the consortium will commence the construction of the infrastructure. The project is expected to be operational by 2024.

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 eight hydrogen refuelling stations in the Netherlands, but this amount is to be increased to a total of 20 by the end of 2021.

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 haoffshore 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.

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 below) and has received financial support from the European Union (EUR 11m) as well as the Netherlands Enterprise Agency (EUR 6m). In 2020, parties are finalising the technical details and economic models of the project. Construction is to commence towards the end of 2020. By 2022 the plant is expected to be operational.

Element 1: in 2018 Gasunie Deutschland announced its cooperation with Dutch TSO TenneT and gas transmission company Thyssengas on the build of a 100 MW power-to-gas pilot using offshore wind energy. The project is called 'Element 1' since hydrogen is the first element in the chemical system. The installation is built near the North of Germany where 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.

North Sea Wind Power Hub: Dutch TSO TenneT proposed in 2016 to make CO2 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.

Hydrogen Storage: in 2011 Gasunie discovered the possibility to store 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.

Magnum Project: The Nuon 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 facility is capable of generating enough power to serve the needs of approximately 2m 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, Nuon Magnum will be the world's first such facility to generate 100% carbon-free power using hydrogen as fuel.

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 400 kilograms of hydrogen per day.

Peru

Authors: Alejandro Diezcanseco, 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.

Currently in the Peruvian oil & 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, in 2016 started the operation of a hydrogen plant. 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.

Furthermore, 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.

[1] http://www.minam.gob.pe/cambioclimatico/wp-content/uploads/sites/127/2019/01/10.-Mitigaci%C3%B3n.pdf
[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

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.

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, transport and storage of hydrogen would be specifically regulated.

Regulation of hydrogen

Legislation

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 taxis

Transport of hydrogen by road

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.[5]

[4] Bill Project N° 3753/2018.
[5] 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 first quarter of 2021.

Poland

Authors: Piotr Ciolkowski, Michal Padamczyk

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. It 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. **("Azoty")** – the largest chemical consortium in Poland – is currently the biggest producer of hydrogen in Poland. Azoty uses hydrogen in various chemical processes. 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.

As at mid-2020, the development of dedicated hydrogen projects in Poland is limited, though there are hydrogen generation, transportation and storage projects in planning stages as described 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).

Energy & Industry

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 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 Transmission System Operator, to produce green hydrogen for use in its refining processes. Whereas GAZ-SYSTEM S.A. **("Gaz-System")** – the Polish Gas Transmission System Operator and a member of Hydrogen Europe since 2019 – 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.

Transportation

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 impacts 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.

Energy System Management

The outcome of the joint project of LOTOS and PSE will serve to ensure the stability of the National Power Grid since there are plans to increase the share of the renewable energy sources in the Polish energy mix.

Market prospects for hydrogen

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. 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. However, 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 many 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, below), 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. One of possible solutions being considered is the use of green bonds as financial instruments targeted for low carbon projects, such as those involving 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.

Challenges facing hydrogen projects in Poland

Legal framework

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.

Financial support and incentives

The Polish government has established a well-financed Low Emission Transportation Fund, which supports matters connected with the generation and use of alternative fuels in general, which would include hydrogen. However, plans concerning its replacement are currently advancing; its crucial role in this respect would be transferred to the National Fund for Environmental Protection and Water Management. 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

The National Centre for Research and Development supports the research and development into hydrogen storage projects. The Low Emission Transportation Fund also provides financial support for research and education in respect of alternative fuels. However, awareness of hydrogen and understanding 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 is currently 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 capture hydrogen in transportation, although this area is also not well covered. According to the draft Poland's Energy Policy for 2040, the legal framework for hydrogen will be enacted in 2021 and, pursuant to the latest announcements of representatives of the Ministry of the Climate, a dedicated Act on hydrogen is scheduled to be published in 2021. Poland's Hydrogen Strategy shall be presented still in 2020.

Policy and government programmes

As previously mentioned, there are a number of government initiatives such as the National Centre for Research and Development, the Low Emission Transportation Fund, 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.

Recently, 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.

Generation

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

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

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

The Act on Bio-components and Liquid Bio-fuels sets out the operating principles for the Low Emission Transportation Fund, which provides support for hydrogen transportation projects, amongst other alternative fuel projects.

Permitting process

The Building Law and the Act on Spatial Planning and Land Development are fundamental in determining where and how hydrogen installations can be constructed. They are also crucial in the permitting process of planned projects as they determine aspects connected with occupancy and security, since hydrogen is considered as a flammable and explosive gas.

Secondary legislation and other legal documents

Relevant secondary legislation includes the Minister of Energy's Regulation on the granting of support by the Low Emission Transportation Fund for the acquisition of new, hydrogen fuelled vehicles by natural persons for non-business purposes. However, stakeholders claim that there are still issues related to the lack of support for vehicles which are leased or rented long-term.

The Regulation of the Minister of Energy has detailed rules for shaping and calculating tariffs and settlements in gas trading and is vital for matters associated with tariffs.

Another regulation worth mentioning here is the Regulation of the Minister of the Economy on the detailed conditions for the functioning of the gas system. This Regulation governs, inter alia, the detailed conditions related to the transport, distribution and storage of gaseous fuels and the quality parameters of such gaseous fuels.

The draft of Poland's Energy Policy for 2040 and the National Energy and Climate Plan 2021–2030 each recognise the key role that hydrogen will play in the Polish energy mix and the need to develop hydrogen technology.

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, in particular 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 in particular 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 Ministers on projects that may significantly affect the environment, the installations required for hydrogen storage would qualify as such installations under this Act.

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 1 MJ/s is not subject to the licensing requirement. Specific rules related to transport of dangerous goods apply to the 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 governs spatial planning and the building process, which are vital areas for the installation of electricity generators and refuelling stations, among other things.

Upcoming developments

By the end of 2020, the Ministry of the Climate intends to publish the Polish Hydrogen Strategy for 2030, with perspective until 2040. It will be a key strategic document for the development of hydrogen in Poland. The aim of this strategy is to build hydrogen installations with a total capacity of 2–4 GW.

An LOI was signed by the Ministry of the Climate and 17 other entities, in 2020, 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 Gaz-System, PGNiG, Azoty, Tauron, JSW, PKN ORLEN, and LOTOS. The signatories of this LOI declared to cooperate in the research and development of hydrogen.

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 been recently been established by the Polish government.

The Act on Electromobility and Alternative Fuels obliges local governments to invest in hydrogen fuelled public transport. Effective from 2028, a certain percentage of the public transport must be made up of zero-emission buses. 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.

Portugal

Authors: Monica Pacheco, Manuel Branco

Current status for hydrogen in Portugal

Introduction

Hydrogen is a key element in Portugal's near term energy transition. There are already a number of ongoing projects concerning hydrogen production and transportation. Portugal has also a number of projects for decarbonising of industry as well as the decarbonisation of electricity and heat generation.

Whist, at present, the usage of low-carbon hydrogen in Portugal is low, Portugal is endeavouring to grow the domestic use of clean hydrogen. Green hydrogen, in particular, is expected to be a major contributor to helping Portugal comply with its ambitious 2030 targets 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 July 6th, 2020 and publication of the final document was recently approved and published on August 14th by Resolution of Council of Ministers.

We have set out below some key hydrogen related projects currently in development in Portugal.

[1] "A hydrogen strategy for a climate-neutral Europe" https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

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.

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

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. The bus would have the same fuel cell as the Toyota Mirai and is expected to have a driving range of up to 400 km. This bus is particularly innovative as the tank is located on the roof of the providing a larger capacity for passengers.

Industry

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.

[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.

Heating

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 1 MW and 12 MWh 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

As mentioned above, the hydrogen market in Portugal is nascent and 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

Hydrogen legislation in Portugal is not specific as it is spread out through several laws depending on which sector is involved. There are several laws relating to gas transportation, fuelling systems, storage and installation of gaseous fuels in buildings but these are not applicable to hydrogen.

It is expected that the government will amend Decree law 30/2006 of February 15th (amended by Law 42/2016 of December 28th) and Decree Law 140/2006 of July 26th (amended by Decree Law 38/2017 of March 31st) which regulate the transportation, storage and reception of gas. Through these amends it is expected that the Government will introduce a separate section dedicated to regulating the use of hydrogen and will incorporate regulation on the distribution, generation and transportation of hydrogen.

[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. There is also a law (Law no. 19/2014 of April 14th) that has a baseline of environment policies. This means that there is need for environmental impact assessments in relation to all aspects of a hydrogen project.

Regulatory bodies

The hydrogen sector is currently regulated within the remit of energy regulation: there is no specific regulatory body for the regulation of hydrogen projects.

DGEG (from the State's direct administration) and ERSE (the energy regulator) are the regulatory bodies which are 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, two further domestic projects are worth noting:

"Green Flamingo"
The project which is due to begin construction in 2021 is to create a EUR 7bn hydrogen solar power plant in Sines. Sines was chosen as the location for hydrogen production infrastructure owing to the deep waters that surround the port as well as the existing electric connections. It also has the weather suited to producing solar energy. The project involves 15 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.

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 tons a year. The forecasted investment for this project is around EUR 90m. The project is being developed but, as yet, there is no estimated date to become operational.

Romania

Authors: Varinia Radu, Raluca Diaconeasa

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 andin 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.

Energy & Industry

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.

Research and education

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 **("MEEMA")** 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"*.

Challenges facing hydrogen projects in Romania

Legal framework

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.

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.

Generation

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

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.

Transport, import and export of hydrogen

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 as demonstration projects.

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.

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 recent public speeches from various stakeholders advocating for a transition to a hydrogen economy from a carbon-dependent one.

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 in the near future. At a national and local level, decision-makers should find appropriate ways to promote new technologies, such as hydrogen, in order to attract international as well as domestic investment.

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, any 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 **("State Programme")** of hydrogen energy would be developed in Russia along with a road map for the future. With this in mind a working group was created in the Russian Ministry of Energy.

The Russian Ministry of Energy has drafted the above road map (the **"Road Map"**) of development of hydrogen energy in Russia for 2020 to 2024 and submitted this document to the Russian Government for review.

The draft Road Map provides for the following initial stages:

— by the end of 2020, the Government should prepare the concept of hydrogen energy development and establish the incentive measures for the pilot projects on hydrogen production; and
— by the beginning of 2021, first incentives for exporters and purchasers on the domestic market should emerge.

Industry

At present hydrogen is produced in Russia primarily for use in oil refinery, steel and chemical industries. There are several producers of hydrogen, most of them being 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.

Transport

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 November 2019, the first hydrogen fuelled tramway was tested in Saint-Petersburg. However, this is still far from implementation of a full-scale use of hydrogen-powered transport.

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"**),[1] 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.

Following the European and German hydrogen initiative, in June 2020, the Russian-German natural resources forum created an expert group to explore possibilities for Russian-German and Russian-European projects in the hydrogen sector.

[1] https://energynet.ru/upload/Перспективы_России_на_глобальном_.pdf

It is likely that in relation to hydrogen projects, investors will apply the same financing approaches as used in energy sectors such as oil and gas. As such 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.

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 25 MW) hydro power industries, where the applied beneficial tariffs fixed for 15 years allow investors to receive a guaranteed 12% profit margin.

At present investors may potentially apply only for general state support mechanisms such as investment tax credits, tax reliefs and other benefits subject to specifics of the project. To boost development in the hydrogen area, dedicated tax and export customs exemption may be envisaged.

According to the draft Road Map recently submitted to the Russian Government (see above), Gazprom and Rosatom will be the first producers of hydrogen who are due to launch pilot hydrogen plants by 2024.

It is also envisaged that Rosatom will construct the test field for trains with hydrogen fuel cells by 2024.

Challenges facing hydrogen projects in Russia

State support and incentives

As mentioned above, there are no dedicated state support measures or incentives relating to the hydrogen industry in Russia. It is expected that the Russian Government will focus on this issue more when the State Programme and Road Map have been adopted. Lack of state support prevents the implementation of major projects in this emerging industry, particularly since such projects require significant capital investments at 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 Russian Government to secure export opportunities for hydrogen (for example, there have been discussions with Japan during 2019), it is still not completely clear how and where Russian hydrogen will be sold. Ideally such sales should be secured by long-term contracts. However, it is also possible that when exporting hydrogen Russia will face similar obstacles (which are mainly of political nature) as it is currently facing when selling gas to the EU and China.

Infrastructure

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

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 no significant progress has been made yet. As a result of the sanctions imposed on Russia by the EU and USA at present it is 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.

Legal framework

As explored in more detail below, 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.

Applicable laws and regulations, particularly relating to safety and licensing issues, need to be reviewed and harmonised in order to encourage the effective development of hydrogen.

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).

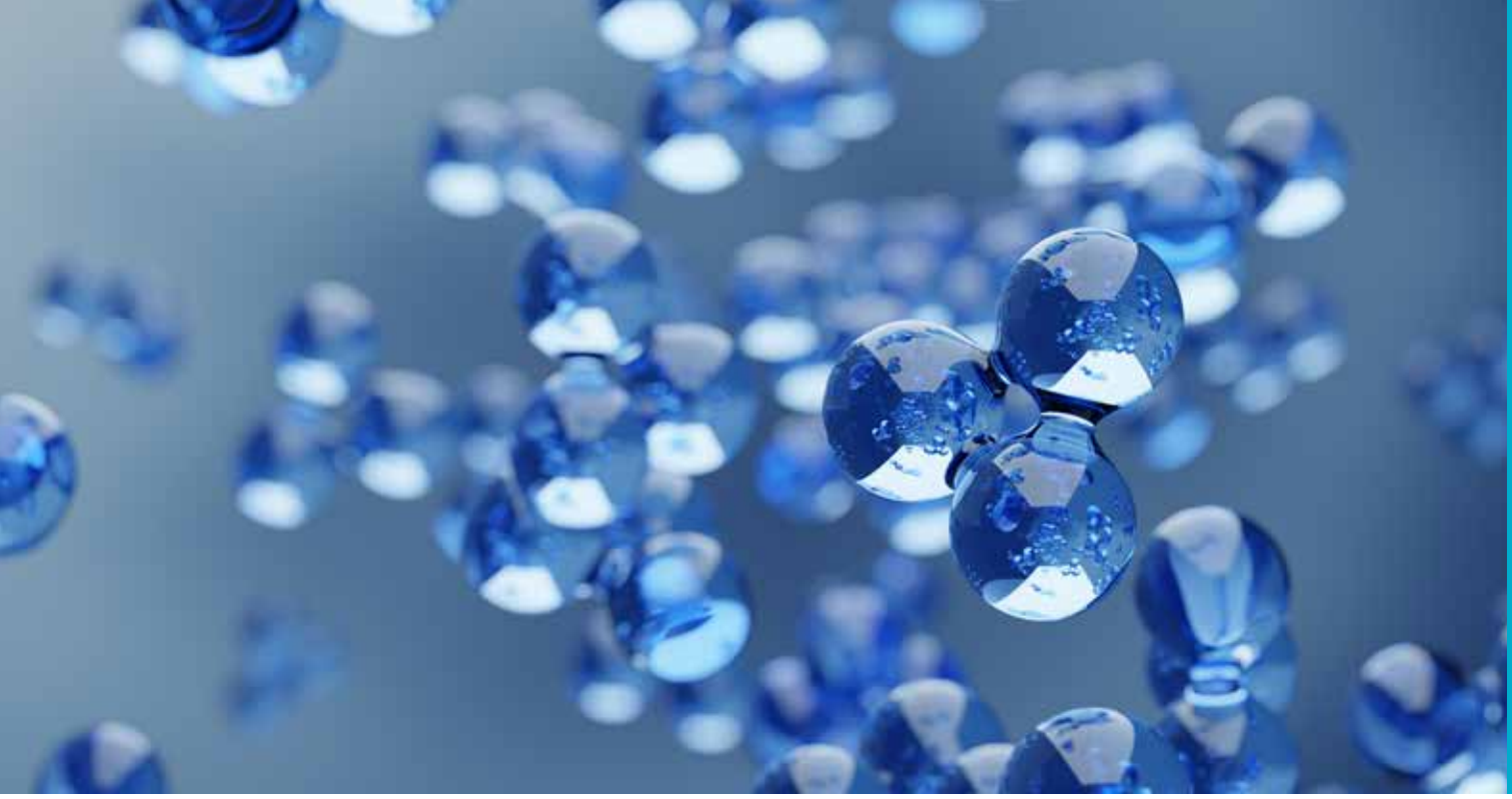
The abovementioned Federal Law on Gas Supply in the Russian Federation No. 69-FZ of 31 March 1999 applies only to natural and oil-well gas.

It may be assumed that the State Programme and Road Map, if adopted in the near future, will provide the timelines for development of the legal framework for hydrogen.

Since no dedicated act for hydrogen is adopted in Russia, 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

As mentioned above, the State Programme is yet to be developed and implemented.



Targets

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

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

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

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 no specific regulatory body which is responsible for regulation of hydrogen projects. Since major hydrogen projects are currently envisaged in the energy sector, the Russian Ministry of Energy is driving the process of the development of the State Programme and Road Map as mentioned above. The Deputy Minister of Energy is presiding over the dedicated working group.

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 over 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 which has a monopoly to export 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 State Programme and Road Map will be adopted by the end of the year 2020. This should boost development of hydrogen projects and introduce state support measures as well as hydrogen-specific legislation. This should attract investment in this area.

It is likely that first major hydrogen projects in Russia will be focused on hydrogen exports. However, there is also a potential to use of hydrogen in both the domestic energy and transportation sectors.

It is important to note that such development is fully in line with the ultimate goals of energy transition and shift to decarbonised economy as recently declared in Russia. In particular, following the base case scenario, it is envisaged to reduce, by 2030, greenhouse gas emissions by 67% 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.

Singapore

Authors: Marc Rathbone, Adrian Wong, Jacob Quek

Current status for hydrogen in Singapore

Introduction

While the hydrogen market is nascent in Singapore, there is growing expectation that the use of low-carbon hydrogen will play a substantial role in enabling Singapore to reduce its carbon footprint in the future. In 2016, Singapore ratified the Paris Agreement, committing to tackle climate change through reducing its emissions intensity by 36% below 2005 levels by 2030.[1] To achieve this, the Singapore Energy Market Authority (**"EMA")** has identified hydrogen as one of the emerging low-carbon alternative energy solutions which it is looking into.[2]

Hydrogen as an Alternative Energy Solution

To further develop and assess the viability of hydrogen as a potential alternative energy solution, the Singapore government, in partnership with several multinationals and research institutions, recently embarked on a host of hydrogen projects, some of which are listed further below.

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. Instead, in its 2018 Budget, Singapore placed its emphasis on electric vehicles as an alternative to internal combustion engine **("ICE")** vehicles.[3] However, this decision has been queried in February 2020 in parliament given that several other countries appear to be favouring hydrogen fuel cell vehicles as one of the preferred alternatives to ICE vehicles.[4]

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.

1 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)
2 https://www.ema.gov.sg/ourenergystory; https://govinsider.asia/inclusive-gov/singapore-hydrogen-energy-market-authority-ema-ntu/
3 https://www.todayonline.com/singapore/mps-concerned-govts-plan-put-all-eggs-electric-vehicle-basket
4 Ibid.

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.

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.[5] It is expected that the development of such infrastructure and facilities will be the next phase of development as the technology develops and matures and hydrogen becomes established as a feasible alternative energy solution. This would likely be a key driver of growth and opportunities in this space 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.[6] 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.[7]

It is hoped that with the increased efforts into research and investment into infrastructure (both in Singapore and globally), the production and use of green hydrogen as an energy solution will become viable in the near future.

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 should eventually lead to reductions in costs.

[5] https://www.todayonline.com/commentary/hydrogen-more-sustainable-bet-spores-energy-future
[6] Ibid.
[7] https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/042020-asia-may-draw-lessons-from-singapores-swift-move-on-hydrogen

Health and Safety

The issue of health and safety has always been a key consideration in the use of hydrogen. This is because hydrogen is a colourless, odourless and highly flammable gas, and its large-scale use has commonly been perceived as risky because of how easy it may leak and ignite in relatively low temperatures.[8] 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.

Notwithstanding, various technological advancements in recent years have rendered handling hydrogen to be as safe, or even safer, than other flammable fuels such as gasoline or natural gas. In this regard, Singapore has a strong safety track record as one of the top oil refining countries in the Asia-Pacific, and its experience in this field places Singapore in good stead in the future.

The Singapore government further seeks to mitigate such safety risk by adopting an incremental approach through the use of pilot projects (such as the self-contained power grid on Semakau Island), so that the safety and sustainability of hydrogen as an energy solution can be assessed over a period of time before it is implemented in Singapore on a larger scale.

Legislative framework

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 may create some degree of legal uncertainty or gaps in legislation 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

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.

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 gasses in Singapore more generally, as different legislations will apply at the various stages of importation, transport, production and storage of hydrogen.

[8] https://www.todayonline.com/commentary/hydrogen-more-sustainable-bet-spores-energy-future

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.

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 legislations mentioned in Section 4 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.[9]

In October 2019, the SP Group set up the first zero emission building powered by green hydrogen in Southeast Asia. The system which was implemented was developed in conjunction with Marubeni Corp and Tohuku University in Japan.[10]

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.[11]

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, trigeneration 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.

[9] https://www.businesstimes.com.sg/energy-commodities/a-tiny-island-off-singapore-may-hold-keys-to-energys-future
[10] https://www.spgroup.com.sg/wcm/connect/spgrp/c9d8ef18-9a18-4b91-a98b-0e0c0f611b68/%5B20191030%5D+Media+Release+-+SP+Group+Sets+Up+First+Zero-Emission+Building+Powered+By+Green+Hydrogen+In+Southeast+Asia.pdf?MOD=AJPERES&CVID=
[11] https://www.citygas.com.sg/press-release/companies-collaborate-to-explore-hydrogen-as-a-low-carbon-alternative-for-singapore/

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. This Ministry is responsible for the development of an implementation strategy for renewable energy and the overall decarbonisation of the Slovak industry and transport.

Transport

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. In an effort to decarbonise, car manufacturers, for example Kia Motors Slovakia, are considering producing hydrogen powered vehicles in the future.

Accordingly, there are no hydrogen powered vehicles registered in Slovakia at present and a hydrogen fuelling infrastructure for fuel cell electric vehicles **("FCEV")** does not yet exist.

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 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

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

The Slovak government is considering potential for hydrogen injection into the natural gas grid to displace methane gas consumption and reduce emissions.

The domestic natural gas grid is well-developed (94% of the population has access to natural gas grid in Slovakia) and interconnected with a number of neighbouring countries. The natural gas distribution network provides natural 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 natural gas will remain dominant so blending may be attractive for decarbonising heating.

Market prospects for hydrogen

The hydrogen market in the 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. There is however 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 low carbon hydrogen is necessary. The Minister of Economy has suggested that low carbon 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 the other European cities, including the Czech Republic, so would serve as models for the country.

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.

With regard to 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

As in many other jurisdictions, there is no specific 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 (j) biohydrogen, which is hydrogen produced from biomass").* The regulation of hydrogen in Slovakia is discussed in more detail, below.

Regulation of hydrogen

Legislation

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%.

Real Estate and Consenting

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

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)
— 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

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 5.

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.

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, 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 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 **4–8 hydrogen filling stations before the end of 2020**. 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.

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, though a timeframe has not yet been established, the project has a good prospect of being established. The intended centre would facilitate both basic and applied research in the production, storage and combustion of hydrogen for the automotive industry.

South Korea

Author: Zachary Song

Current status for hydrogen in South Korea

Introduction

South Korea is seen as one of the leading Asian countries in the development of hydrogen projects, with many of the 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.

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.

Additionally, in August 2020, Hanwha Energy Corporation **("Hanwha Energy")** begun operating a 50MW fuel cell plant in the Daesan industrial complex, in Seosan City. 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.[1]

Globally, South Korea's Hanwha Energy has primary rights to develop and operate the hydrogen charging facilities for Nikola Motor Company's hydrogen fuelled trucks in the United States.

[1] 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

Energy & Industry

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. It has been a global leader since 2007 for the development of fuel cells and holds approximately 50% of the market share in South Korea. 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

Globally, South Korea recorded the largest number of sales in hydrogen fuelled automobiles in 2019. South Korea currently has the greatest number of hydrogen powered vehicles on its roads: it has 4,194 vehicles, compared to 2,089 in the US and 644 in Japan. To meet demand, South Korea saw an increase from 14 to 34 hydrogen refuelling stations in 2019. However, the number of stations in South Korea is still less than the 112 hydrogen refuelling stations in Japan and 70 in the US. As of September 2020, there are 20 additional refuelling stations undergoing development across South Korea. At the forefront of the hydrogen transportation sector is the vehicle production at Hyundai Motors **("Hyundai")** in South Korea. Hyundai has been developing core technologies for fuel cell electric vehicles **("FCEV")** since it produced its first prototype in 2001.[2] Its goals are to produce 500,000 FCEV by 2030 and invest approximately 7.6trn Korean Won (approximately USD 6.4bn) in research and development. According to the company, it aims to produce approximately 1,100 FCEVs in 2020.

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, in 2020, produces about 8,200kg of hydrogen per day. The plant is capable of fully charging around 1,300 FCEVs per day and 473,000 FCEVs per a year.

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 several has 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.

[2] https://www.autocar.co.uk/car-review/hyundai/ix35-fuel-cell-2013-2018

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.

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. 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, 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 has set a target to sell 1,600 FCEV trucks in Switzerland by 2025. Switzerland is expected to be a growing market for FCEV and a forward base to infiltrate the entire European market.

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 are currently involved in the project financing of a USD 200m fuel cell facility in Incheon, South Korea. The project in Incheon will have a capacity of 39.6MW.

In addition, the South Korean government has set out its goals to subsidise hydrogen projects, so investors may also seek government support where this is available. More on this below.

Challenges facing hydrogen projects in South Korea

Legal framework

While the Hydrogen Economy Development and Safe Management of Hydrogen Act **("Hydrogen Act")** was promulgated in 2020, it will not come into force until 2021. Furthermore, the subsidiary legislation has yet to be promogulated. Overall, however, South Korea's legislation is moving relatively swiftly to catch up with the hydrogen industry practicalities and South Korea is ahead of many of its peers in developing a legal framework for hydrogen projects.

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.

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 Act and this is due to come into force on 5 February 2021. Until the implementation of the Hydrogen Act, 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, governs hydrogen energy related issues.

It is expected that the Hydrogen Act will become the central legislation regulating the hydrogen industry, while the Renewable Energy Act will be used where an issue is not covered.

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".

Primary legislation

As mentioned above, the cornerstone of hydrogen legislation in South Korea will be the Hydrogen Act. However, until its implementation in 2021, the Renewable Energy Act will govern hydrogen-related issues.

Hydrogen production

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

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 of hydrogen

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.

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.

Secondary legislation and other legal documents

Relevant secondary legislation to the Hydrogen Act has yet to be drafted, however the Ministry of Energy is drafting an enforcement ordinance and an enforcement regulation that will be subsidiary to the Hydrogen Act. The Ministry held a public hearing on the drafts of the ordinance and regulation in July 2020, to hear the opinions of industry experts and academics. The ordinance and regulation will specify the criteria for hydrogen specialised companies, products that will be subject to safety measures, and the training of hydrogen experts.

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 will also be regulated by the Hydrogen Act, which states that the imported hydrogen related components can be inspected by the Ministry of Energy or the local authority of the relevant city or district. The government will establish the Foreign Marketing Support Centre to assist with the export of hydrogen specialised companies.

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.

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.

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.

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 South Korean government has, in 2020, approved the development of what will be **South Korea's largest hydrogen fuel cell production facility to be built in Moonkyung City**. This USD 227m project will establish a facility on 500,000m^2 of land in order to provide electricity to regions of the Gyeongbuk Province.

Also in 2020, **a 200MW facility has been approved for construction in Sejong City**, the nation's newest political capital city. The project aims to construct a fuel cell electricity generation facility capable of generating 15–20MW by 2022, and then expand the capacity gradually to 200MW by 2030.

Hyundai continues to develop and invest in FCEVs in South Korea and it aims to produce approximately 1,100 FCEVs in 2020. Hyundai has a target to produce 500,000 FCEVs by 2030 and invest 7.6 trillion Korean Won (approximately USD 6.4bn) into the research and development of hydrogen powered vehicles.

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.

There are large-scale pilot projects in their early stages in Spain. For example, the Power to Green Hydrogen project being launched in Mallorca by Enagás, the Technical Manager of Spain's gas system, that will generate over 300 tonnes of hydrogen per year using solar PV electricity. The project aims to demonstrate hydrogen's role in sustainable urban transport (trialled in 5–10 buses and 10 passenger vehicles), the feasibility of its injection into the gas grid, and its commercial application in hotels and municipal buildings. The project will be served by a dedicated pipeline transporting pure hydrogen.

The ambitious renewable electricity targets set by NECP, for 2030 and beyond, mean that Spain can position itself as an exporter of green energy. As an example, the NECP has already identified a minimum of approximately 14TWh of curtailed green electricity that could be utilised to power electrolysers by 2030. The hydrogen generated could then be stored and exported or otherwise commercialised.

Energy & Industry

At present, the overwhelming majority of hydrogen in Spain is used for industrial purposes, mainly in refineries and chemical industries – all of which is "grey" hydrogen. With increasing pressure on these energy intensive industries to decarbonise their production processes in the short and medium term, many are turning to low-carbon hydrogen-based options.

In June 2020, Spanish energy company, Repsol, announced plans to construct a plant for the production of e-fuels in the port of Bilbao.[1] Located next to the Petronor refinery, the project will be one of the world's largest plants to manufacture net zero emissions synthetic fuel, using CO_2 captured from the refinery, as well as green hydrogen generated from renewable energy. The plant will be a partnership between Repsol and other companies, such as Enagás and Petronor.

Transport

In Madrid, a fleet of 12 cars (Toyota's fuel cell electric vehicle (**"FCEV"**) Mirai) are expected to be rolled out, along with a newly built refuelling station. Similar plans are in development at the Green Hysland project in Mallorca, where a fleet of 10 cars, 5–10 buses and new fuelling stations are expected. Both projects are due to be operational in early 2021. Additionally, Barcelona is in the process of acquiring a further 10 urban buses, while Madrid is considering similar plans for the near future.

The H2Ports project in Valencia aims to deploy the first fuel cell-powered reach stacker and terminal tractor by 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 **("BEV").** In addition, in June 2020,[2] the Spanish Prime Minister announced support for the development of green hydrogen as part of a comprehensive plan for modernising the automotive industry in Spain, a sector responsible for 10% of national GDP.

In line with the EU Directive on the deployment of alternative fuels infrastructure (2014/94/EU), Spain has called for the country-wide deployment of 20 publicly available hydrogen refuelling stations to support the deployment of fuel cell electric vehicles in the short term.

[1] https://elperiodicodelaenergia.com/repsol-construira-una-de-las-mayores-planta-de-combustibles-sinteticos-cero-emisiones-del-mundo-a-partir-de-hidrogeno-verde-en-petronor/

[2] https://www.eleconomista.es/ecomotor/motor/noticias/10576693/05/20/El-Gobierno-aprobara-en-breve-un-plan-de-apoyo-al-sector-de-la-automocion.html

Market prospects for hydrogen

The development of a hydrogen market in Spain is at an early stage but has significant room for growth. The Spanish government is in the process of launching a national hydrogen strategy; having sought input from stakeholders, the strategy was approved in early October 2020 and aims to boost clean hydrogen production in the country.

Using the Hydrogen Council estimates and extrapolating these to Spain, the National Hydrogen Association estimates an annual turnover of EUR 1.3bn by 2030 in the sector, with an accumulated investment of EUR 3.56bn from both public and private sectors.

A Spanish hydrogen roadmap has yet to be designed but is likely to focus on identifying which local and regional hubs will be suitable for green hydrogen production, taking into account the necessary demand, location of end users and investment risks. This roadmap may also help to identify the necessary elements along the value chain in order to help foster the growth of a national hydrogen industry.

Due to the current, premium cost of green hydrogen, public grant-type funding will be necessary to help bridge the gap with respect to conventional or competing technologies. Early stage demonstration projects are seeking funding mainly at an EU 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 research and development, 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

While the NECP advocates for hydrogen to have a key role in the Spain´s decarbonisation strategy, the country still lacks a dedicated hydrogen plan. Without this, investors are unsure about the long-term prospects of this technology and are less likely to invest in early stage projects. As of October 2020, a draft national roadmap has been approved following a public consultation process and shows the government's willingness to support Spain's energy transition in order to meet international carbon emission targets. All the same, a more comprehensive national strategy should go beyond recognising the complementary role of hydrogen as a necessary energy vector; rather, it should include specific objectives related to hydrogen uptake, particularly for application in the industrial and transport sectors, as well as necessary modifications to the current regulatory framework, financial incentives to bridge the cost gap, and a system for accounting for renewable gases (e.g. guarantees of origin).

Legal framework

Spain does not have a comprehensive legal framework specific for hydrogen technologies. Furthermore, hydrogen production from renewable sources is hindered due to the classification of electrolysis as an "energy use", rather than an "energy conversion device". This situation subjects electrolysers to connection charges, as well as much longer development times and environmental constraints, making green hydrogen a less competitive energy source. This uncertainty of regulation has deterred investment from the private sector, with any pilot projects being carried out in a purely experimental capacity.

Similarly, clearer rules around hydrogen injection into the gas grid need to be developed.

Securing end users and reducing costs

The current cost premium for hydrogen technologies compared to conventional technologies remains an obstacle for market uptake in Spain. While developing hydrogen at scale remains a key lever for reducing costs, research and product development activities also need further support to enable this cost reduction. In order to make large demonstration projects on a commercial scale (i.e. multi-MW), end users must be identified and engaged with.

Financial support for deployment

Due to the current cost premium, action is required by public agencies to help remove this barrier and enable hydrogen projects to be implemented in Spain. A funding programme should 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.

It has been estimated that, over the next decade, the cost of Spain's hydrogen strategy will be approximately EUR 8.9bn, however it is expected that the majority of this funding will come from private investors. Nevertheless, the Spanish government has stated it will support such hydrogen projects that create jobs.

Lack of awareness

Despite the recent surge of interest in hydrogen technologies, potential end users and the Spanish public in general are still largely unaware of their ability. More targeted communication on the benefits of hydrogen will be needed as, otherwise, time will need to be spent informing potential project partners about the technology, its status and prospects.

Regulation of hydrogen

Specific legislation/regulation

There is currently no specific legislation for hydrogen in Spain, though this may change following the announcement of a national hydrogen strategy. In terms of hydrogen production, it is considered the same as any other inorganic gas production facility and is subject to the same conditions regardless of size, which could hinder the development of small projects.

In relation to the injection of hydrogen into the gas grid, the PD-01 protocol applies. This document provides the technical specifications for gas circulating inside the grid and makes reference to European 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.

At national level, Ley del Suelo (the **"Land Law"**) establishes a basic regulation of land use. However, the 17 autonomous administrative regions in Spain, Comunidades Autónomas, have each developed different regimes of land use. As hydrogen production plants are considered to be facilities for the manufacture of chemical products and inorganic gases, such as hydrogen, the land use in each administrative region must permit this industrial activity.

Other regulations

There are no prohibitions against the use of land for hydrogen production, but there are for the storage of large quantities of hydrogen. If hydrogen stored is greater than 200,000 tonnes an Environmental Impact Assessment **("EIA")** is needed.

As a general rule, local authorities are in charge of permitting projects. As such, whilst there may be few variations between installations from one part of the country to another as a practical matter, local 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 and will require an Environmental Impact Assessment. Furthermore, installations for the storage of pressurised hydrogen containers 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 (of up to 1000MPa) are required.

With regard to the transportation of hydrogen by road, the European Agreement concerning the International Carriage of Dangerous Goods by Road **("ADR")** will apply.

Regulatory bodies

There is no specific regulatory body which is responsible for the regulation of hydrogen projects in Spain. Instead, a number of regulators exist who may have responsibilities depending on the activity in question.[3]

Grant Authority	Permit Requirement
Regional Government	— Administrative authorisation; — Environmental Impact Assessment; — Integrated Environmental Authorisation
Council	— Construction Permit
National Government	— Grid Connection

Upcoming developments

In August 2020, the Ministry of Ecological Transition and Demographic Challenge begun a public consultation for a draft roadmap of hydrogen in Spain. The Minister for Energy and Environment announced, in October 2020, that the government had approved a hydrogen strategy under which Spain aims to have installed 4 GW-worth of electrolysers by 2030, reaching 300-600 MW by 2024. Publication of this roadmap will indicate the country's comprehensive plans for hydrogen over the coming decades.

Key projects that being implemented in Spain in the next 12–24 months include:

— **Green Crane –** a joint Spanish-Italian proposal for large-scale hydrogen production, led by transmission system operators **("TSO")** Enagás and Snam SpA. The hydrogen production hubs are located in areas that will be majorly affected by the energy transition, for example locations experiencing closures of coal mines and coal power plants.
— The **Power to Green Hydrogen** project in Mallorca will install a production capacity of around 300 tonnes per year for a variety of uses, including transport (car fleet and urban buses), commercial heat and power. The project also aims to demonstrate the feasibility of injecting hydrogen into the gas grid.
— **Hydrogen fuel cell urban buses** in Barcelona and Madrid are expected to be rolled-out in the next few years.
— **A fleet of 12 Toyota Mirais** will be deployed in Madrid, together with the first hydrogen refuelling station. This will be the first publicly available hydrogen refuelling station in Spain for refuelling at 700bar.
— The deployment of hydrogen technologies in handling equipment (a reach stacker and a terminal tractor) as part of the **H2Ports project**, in Valencia, will also advance the development of fuel cell solutions for port-related activities.

[3] For a more comprehensive list, see hylaw.eu

Turkey

Authors: Döne Yalçın, Levent Bilgi

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 playing an important role alongside renewables and key to decarbonise the heating sector through the blending of hydrogen with methane on 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 document") 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 submission of stakeholder contributions was 22 June 2020 and the contributions are due to be published in an opinion document, a "blue document". Following this the government would introduce a further opinion document, also known as the "red document", currently planned to be released in January 2021. It is expected that the "red document" will set out the decisions made by MENR following the consultations. The final phase is an application document, known as the "green document", which will show the government's method for the application of decisions. It is likely this will include an approach towards a new legislation for promoting hydrogen developments in Turkey.

Though no specific timeline has been stated, the short-term goal of the MENR approach is to prepare test projects to strengthen the organisational structure and research and development of hydrogen potential in Turkey.

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 as one of the most important parts of the planned roadmap.

In addition, there are a number of ongoing projects in Turkey that are being carried out to develop the use of hydrogen by research centres of universities, institutions (for example, the International Centre for Hydrogen Energy Technology **("ICHET")**) and certain private sector companies.

Transportation

The Regulation on Rules and Procedures Regarding Increasing the Energy Efficiency in Transportation aims to ensure energy efficiency in transportation by 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, which is 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 400 km.

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. The MENR is considering producing hydrogen from local coal and using the it for transportation purposes. According to the MENR, the production of hydrogen is still not cost-effective in Turkey. However, hydrogen in transportation might be able to be used efficiently considering that an ordinary bus in Turkey could travel 1,030 km on hydrogen produced from one tonne of local coal.

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 with the aim of testing and analysing 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 to be developed.

[1] https://fuelcellsworks.com/news/turkey-tubitak-mam-energy-institute-premiers-hydrogen-vehicle/

Industry

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, the MENR stated that the development of a local hydrogen industry is one of the 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.

The MENR is determined to increase the use of hydrogen and, as mentioned above, a document outlining the MENR's approach has been prepared to obtain opinions, proposals and recommendations from hydrogen stakeholders in Turkey, regarding the future strategy of hydrogen energy. The main purpose of this document is to develop a local hydrogen strategy in two phases: short-term and long-term.

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 with 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 does have 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, the MENR have stated that the creation of efficient legislation is considered as one of the long-term goals of the government.

[2] https://www.kallanishenergy.com/2020/07/30/turkey-tests-20-hydrogen-gas-blend-for-heating/

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, in order 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 industry, transport and heat sectors.

Regulatory 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

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

In 2011, a hydrogen energy production plant was commissioned in Bozcaada, as part of the **Bozcaada Hydrogen Energy Project.** This pilot plant was built in 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, in 2012, 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 in 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 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 sixteen 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 is 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 water fronts however there have been no official statements about when the plants may be operational.

In February 2020, two hydrogen-powered vehicles were developed 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 250 to 400 km.

[3] https://fuelcellsworks.com/news/turkey-tubitak-mam-energy-institute-premiers-hydrogen-vehicle/

Ukraine

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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]

Despite the above, the practical application of hydrogen in Ukraine is still quite limited. As of September 2020, 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[6].

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.ntseu.net.ua/stories/549-hydrogen-energy

In addition, naturally occurring hydrogen accumulations were discovered in one of the regions of Ukraine in 2019[7] which can, in theory, be extracted. Ukraine does not yet have the technologies required for extraction and so these must first be implemented to capitalise on this discovery.

Nevertheless, there is significant opportunity 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"),** or the use of hydrogen as an alternative fuel for transportation, are likely to be the most promising methods of hydrogen use in Ukraine.[8]

This 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.[9] Promotion of this method is likely to increase as the Operator of the Ukrainian GTS became a member of the European Clean Hydrogen Alliance.[10] Furthermore, in July 2020, Regional Gas Company, the Ukrainian gas distributor, and the National Academy of Science of Ukraine began testing the effects of using of hydrogen in gas networks on five test sites in Ukraine.[11]

The storage of hydrogen has also been considered in Ukraine as a means to balance the Ukrainian energy system, which is necessary due to the rapid development of renewable energy.[12]

Other market players in energy sector are also starting to show their interest in hydrogen technologies. Ukraine's largest energy group, DTEK, has become the first Ukrainian company to join the industry and research association, Hydrogen Europe.[13]

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.

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 cubic meters of green hydrogen could be produced in Ukraine, annually[14] – 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.[15]

7 https://elektrovesti.net/69285_ukrainskie-uchenye-nashli-prirodnyy-vodorod-v-nedrakh-rovenskoy-oblasti
8 https://hydrogen.ua/ua/events-ua/1073-narada-pro-stvorennya-naukovo-tekhnichnoji-radi-vodneva-energetika-v-minekoenergo-visnovki-dlya-galuzi
9 https://delo.ua/business/kak-ukraine-razvivat-vodorodnuju-ekonomiku-ek-364696/) (https://www.epravda.com.ua/projects/greendeal/2020/06/24/662145/
10 https://kosatka.media/en/category/gaz/news/operator-gts-ukrainy-stal-chlenom-evropeyskogo-alyansa-s-chistogo-vodoroda
11 https://kosatka.media/category/gaz/news/rgk-sertificirovala-specialistov-dlya-vodorodnyh-ispytaniy
12 https://www.epravda.com.ua/projects/greendeal/2020/05/18/660480/
13 https://www.h2-view.com/story/dtek-joins-hydrogen-europe/
14 https://mind.ua/publications/20205250-mozhlivosti-alternativnoyi-energetiki-dozvolyayut-skorotiti-spozhivannya-tradicijnih-energonosiyiv-udvichi
15 https://hydrogeneurope.eu/sites/default/files/Hydrogen%20Europe_2x40%20GW%20Green%20H2%20Initative%20Paper.pdf

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.[16]

Nevertheless, hydrogen technology is still 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.

As of September 2020, there have been few instances where financial institutions have supported the development of hydrogen projects in Ukraine.[17] 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 attentions will instead turn to providing debt financing to stakeholders wanting to invest in new, low carbon technologies in Ukraine, including hydrogen projects. The promotion of hydrogen technologies will be important given that the infrastructure needed for the development of low carbon hydrogen projects is likely to involve significant capital expenditures.

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 the 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.[18]

[16] https://www.ntseu.net.ua/stories/549-hydrogen-energy

[17] http://www.ukrgasbank.com/press_center/news/12141-ekobank_otkryvaet_put_k_avtomobilyam_na_vodorode_v_ukraine

[18] In his speech Ivan Haidutskyi suggested extending the practice of green auctions with RES producers to hydrogen storage projects. These pilot projects can rationally be expected of such companies as Naftogaz of Ukraine or Ukrenergo. The representative of SE VUHLESYNTEZGAZ UKRAINY emphasized the importance of spreading awareness with the aim calling the attention of our citizens to the introduction of hydrogen technology.

Research and education

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.[19] 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".[20]

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".[21]

Regulation of hydrogen

Policy and government programmes

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.[22]

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 presented on 21 January 2020 – envisages an increase in the industrial production and use of hydrogen as an energy resource and the replacement of combustion engines vehicles with electric and hydrogen vehicles[23].

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.[24] Please note that 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.

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.

19 https://ecolog-ua.com/news/ponad-try-milyony-gryven-na-vodnevi-proekty-vydilyly-v-nan-ukrayiny
20 https://ecolog-ua.com/news/ponad-try-milyony-gryven-na-vodnevi-proekty-vydilyly-v-nan-ukrayiny
21 http://www.naftogaz.com/www/3/nakweb.nsf/0/11772E471EB0FC90C22581690026DFB6?OpenDocument&Expand=9.2& Prof. I.M. Karp, Academician of the NAS of Ukraine, DEng, spoke during the discussion of the reports made on hydrogen related topics.
22 https://hydrogen.ua/ua/events-ua/1053-vodneva-energetika-krajini-es-pidtrimali-ukrajinu-ta-jiji-dorozhnyu-kartu-v-gannoveri
23 https://mineco.gov.ua/news/34731.html?fbclid=IwAR0icQXBd8pBVJvMNP1Bj6g3zP4kFSDMx3BChUCC4tFFR2wgdRqRzEoM13o and 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
24 https://zakon.rada.gov.ua/laws/file/text/58/f469391n10.pdf

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[25] 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.[26]

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.[27]

[25] https://zakon.rada.gov.ua/laws/show/222-19#Text, 14
[26] https://zakon.rada.gov.ua/laws/show/2059-19#Text
[27] 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

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.

In order 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

Hydrogen produced from biomass is defined as an "alternative type of gaseous fuel" in the Law of Ukraine On Alternative Types of Fuel.[28] 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.[29]

Regulation of hazardous activities

Hydrogen is considered as a hazardous (flammable)[30] and explosive[31] 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, 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)[32] and the operation of hazardous equipment (including of equipment for usage, production, storage and transportation of hydrogen)[33] 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 on the basis of declaration of compliance with labour safety requirements.

In addition, hydrogen projects are likely to be considered as "hazardous projects" (in particular, facilities for hydrogen production and hydrogen pipelines).[34] 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).

28 https://ips.ligazakon.net/document/T001391?an=30&is_no_morph=true&hide=true
29 https://ibuhgalter.net/ru/articles/333) (https://zakon.rada.gov.ua/laws/show/481/95-%D0%B2%D1%80#Text
30 https://zakon.rada.gov.ua/laws/show/956-2002-%D0%BF#Text
31 https://ips.ligazakon.net/document/RE23603?an=221&is_no_morph=true&hide=true
32 https://zakon.rada.gov.ua/laws/show/1107-2011-%D0%BF#Text
33 https://zakon.rada.gov.ua/laws/show/1107-2011-%D0%BF#Text
34 https://ips.ligazakon.net/document/RE12160?an=1&is_no_morph=true&hide=true

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.[35]

Transportation of hydrogen across Ukrainian customs border is also subject to additional ecological control.[36]

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).

35 https://ips.ligazakon.net/document/re16196a?an=13813) (https://ips.ligazakon.net/document/reg7879?an=13225
36 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

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:

— an amendment of the GTS Code for usage of hydrogen in the GTS[37];
— the adoption of the bill regulating production of the hydrogen from waste and biomass[38]; and
— various technical regulations in relation hydrogen and production processes[39].

Industry associations are already researching and developing hydrogen deployment across Ukraine, looking towards 2035 for deployment.[40] It is also worth noting, that various hydrogen related projects are starting to be unveiled in Ukraine. For example, during 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 800 MW and electrolysis-based hydrogen production facilities with a capacity of 200 MW in Zaporizhzhia** region of Ukraine. Furthermore, 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**.[41]

[37] https://mind.ua/ru/openmind/20204093-zelenyj-vodorod-dlya-ukrainy-kak-spasti-prirodu-i-gts
[38] https://www.ntseu.net.ua/stories/549-hydrogen-energy
[39] https://mind.ua/ru/openmind/20204093-zelenyj-vodorod-dlya-ukrainy-kak-spasti-prirodu-i-gts
[40] https://blog.liga.net/user/arepkin/article/33656
[41] https://en.interfax.com.ua/news/investments/682339.html

United Kingdom

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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 0.7 m tonnes (Mt) in 2020 to between 3–19 Mt by 2050[1]. 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

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. For example, over the course of 2020[2], Network Rail's cross-industry Traction Decarbonisation Network Strategy is considering areas for deployment of overhead electrification, battery or hydrogen trains. 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)[3] and has committed to introduce 3,000 buses in the UK by 2024[4]. This has 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.

[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/878642/decarbonising-transport-setting-the-challenge.pdf
[3] https://airqualitynews.com/2020/05/01/wrightbus-announce-plans-for-3000-hydrogen-buses/
[4] https://www.route-one.net/news/wrightbus-owner-plans-3000-hydrogen-buses-by-2024/

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 process 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 ten large industrial sites would be converted to use 100% hydrogen.

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.

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 early 2020 the UK government announced a GBP 90m fund to tackle emissions from homes and heavy industry. GBP 70m of this includes funding for two of Europe's first-ever large scale, low carbon, hydrogen production plants: on the river Mersey and in Aberdeen. The funding will also be used for developing technology to harness offshore wind to power electrolysis and produce hydrogen off the coast of Grimsby[5].

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.

[5] https://www.edie.net/news/6/Government-focuses-on-hydrogen-in--90m-industrial-decarbonisation-funding/

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.[6]

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. This creates a number of gaps and uncertainties which need to be addressed before the hydrogen economy can flourish.

Regulation of hydrogen

Legislation

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.

[6] http://www.h2fcsupergen.com/wp-content/uploads/2020/04/2020_04_H2FC_Supergen_Hydrogen_Fuel_Cells_P_Dodds_DIGITAL_W_COVER_v05.pdf

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

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

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

There has been a number of hydrogen projects developing over the course of 2020. 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[7]:

— **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 Progressive Energy Limited, in collaboration with Johnson Matthey, SNC Lavalin and Essar Oil, 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.

[7] https://www.gov.uk/government/news/90-m-uk-drive-to-reduce-carbon-emissions

United States of America

Current status for hydrogen in the US

Introduction

The US is one of the world's largest producers of natural gas and oil. Hydrogen is an emerging key technology in the US and has the potential to be a multi-bn dollar industry.[1] However, given the changeable political attitudes compared to long-term policy thinking required for development of nascent technologies such as low-carbon hydrogen, it remains to be seen whether the US will look to transition away from fossil fuels in favour of low carbon energy sources.

Notwithstanding the above, there is the potential for hydrogen to become a major part of the US energy mix, earning an potential estimated revenue of USD 130–170bn per year by 2050.[2] To put this into context, in 2018 the total revenue of the United States' oil and gas industry came to around USD 181bn. To achieve this level of hydrogen deployment, however, increased support for research and development is crucial as well as the introduction of a supportive regulatory framework.

The US has the abundant low-cost primary energy sources needed to produce low-carbon hydrogen. For hydrogen produced by electrolysis for example, the country has ample resources such as wind, solar and hydropower. For hydrogen produced via natural gas reforming with carbon capture and storage the US has abundant low-cost natural gas and carbon storage capacity. With access to these resources the US is well positioned to produce low-cost, low-carbon hydrogen. That said, with access to these invaluable resources the US may choose to exploit them in other ways rather than produce hydrogen.

Due to variation among national and state policies, infrastructure needs, and community interest, each state and region of the US has its own specific policies and road maps for implementing hydrogen infrastructure. Owing to certain pioneering projects in hydrogen having been developed on the West Coast, we focus in this chapter on states such as California where there has been more progress in the development of low-carbon hydrogen as a new energy source.

[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://www.forbes.com/sites/energyinnovation/2019/10/07/how-hydrogen-could-become-a-130-billion-us-industry-and-cut-emissions-by-2050/#280a67b12849

In a report titled "Road Map to a US Hydrogen Economy", the US energy industry has identified that hydrogen can play a role in five major sectors of the US economy – as:

— fuel for buildings;
— transportation fuel;
— feedstock for industry and long-distance transport;
— industrial fuel; and
— for power generation and grid balancing.[3]

The majority of hydrogen projects in the US to date relate to the transportation sector.

Transport

Transport accounts for around a third of US carbon emissions. The US is already among the leading countries in moving towards broad commercialisation of fuel cells and hydrogen energy in transport: with over 7,600 fuel cell electric vehicles **("FCEV")** currently on the road – more than any other country – the US is home to more than half of the global FCEV stock. There are also 32 fuel cell electric buses in operation and more than 25,000 fuel cell forklifts. In addition, there are a number of prototype heavy-duty fuel cell electric trucks in operation in California and Arizona.

The state of California is leading the way in hydrogen mobility. The majority of FCEVs on the road in the US are located in the state. 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 currently has 31 strategically located commercial stations across the state.[4]

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.[5] 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.

Industrial Fuel

The industrial sector is one of the biggest consumers of energy in the US and is responsible for around 10% of overall domestic carbon emissions. At present, nearly all hydrogen used in the industrial sector is "grey" hydrogen so low-carbon hydrogen is an attractive method in order to decarbonise industrial processes which are difficult to electrify.

Power generation and grid balancing

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.

[3] https://static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/5e7ca9d6c8fb3629d399fe0c/1585228263363/Road+Map+to+a+US+Hydrogen+Economy+Full+Report.pdf
[4] https://www.californiahydrogen.org/resources/hydrogen-faq/
[5] https://cafcp.org/sites/default/files/Road%2BMap%2Bto%2Ba%2BUS%2BHydrogen%2BEconomy%2BFull%2BReport.pdf

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.

Projections

In 2019 an updated US Energy Policy Simulator was released, run by Energy Innovation: Policy and Technology LLC, who aim to research and analyse policies that reduce greenhouse gas emissions in the US by working closely with other experts, NGOs, the media and the private sector. The US Energy Policy Simulator is a computer model that estimates the impact of energy technologies and policies, and has highlighted a number of scenarios where hydrogen plays an important role in the country's future energy mix:

— A "business-as-usual" case shows modest growth in hydrogen vehicles. Hydrogen continues to be used as a feedstock in industry (at present, hydrogen is only used in industry in the US as a feedstock). US production remains dominated by fossil fuels, where 95% comes from natural gas and 5% from electrolysis.
— A "hydrogen-demand" case gradually increases the share of hydrogen vehicles to 5% (cars and small trucks) or 10% (buses, medium and heavy trucks) by 2050. Also, industry shifts 10% of its non-feedstock fossil energy use to hydrogen by 2050. Hydrogen production remains dominated by reforming natural gas.
— A "hydrogen-demand plus electrolysis" case includes growth in hydrogen demand in the transportation and industry sectors as in the hydrogen-demand case, and hydrogen production gradually transitions to 100% electrolysis by 2050.

Market prospects for hydrogen

The US Department of Energy's **("DOE")** funding for hydrogen and fuel cells has ranged from approximately USD 100m to USD 280m per year over the last decade, with approximately USD 150m per year since 2017. In June 2020, the DOE announced the intention to invest up to USD 100m over five years in two new DOE National Laboratory-led consortia to advance the research and development of hydrogen and fuel cell technologies.[6]

Due to the advanced petroleum refining and manufacturing industries, which are experienced in the financing and managing of capital-intensive megaprojects, the US could be well equipped to mobilise large private investments in hydrogen equipment development, hydrogen production, and distribution infrastructure.

Transport

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.[7] There is therefore a need for long distance capability – with such vehicles having a projected sale growth of 1 percent per year over the next decade.[8] Such long distances and preferences for large vehicles favour FCEVs.

[6] https://www.energy.gov/articles/doe-announces-new-lab-consortia-advance-hydrogen-and-fuel-cell-rd
[7] https://cafcp.org/sites/default/files/Road%2BMap%2Bto%2Ba%2BUS%2BHydrogen%2BEconomy%2BFull%2BReport.pdf
[8] https://static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/5e7ca9d6c8fb3629d399fe0c/1585228263363/Road+Map+to+a+US+Hydrogen+Economy+Full+Report.pdf

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 ten years into zero-emission infrastructure in California. The programme will include public education, brand-neutral marketing programmes and increased access to ZEVs for consumers.[9]

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.

Challenges facing hydrogen projects in the US

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 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.[10]

[9] https://afdc.energy.gov/fuels/laws/HY?state=CA
[10] https://www.pv-magazine.com/2020/08/25/solar-powered-hydrogen-under-2-kg-by-2030/

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.

Regulation of hydrogen

Each state in the US has its own specific policies in relation to hydrogen. As mentioned previously, states along the US west coast are generally more advanced in this respect. As such, California has again been selected as the key example in this section.

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.

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.[11]

The **California Energy Commission** is the state's primary energy policy and planning agency. The Warren-Alquist Act established the California Energy Commission 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.

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, CA. 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.

[11] 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.

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, most significantly;

— 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.

Upcoming developments

Bloom: California-based Bloom will begin offering electrolysers alongside hydrogen-powered fuel cells to tap the green hydrogen market. Bloom's core product is its Energy Server, which concerts natural gas into electricity through an electrochemical process without combustion, reducing carbon emissions. In 2019, Bloom announced that its Energy Servers could be upgraded to run on hydrogen, or a blend of hydrogen and natural gas. Now, Bloom says it will begin offering electrolysers to make renewable hydrogen.[12] The company plans to start selling electrolysers from 2021.

Ways2H and Ford, Bacon & Davis: plan to design and build modular waste-to-hydrogen facilities in California by the end of 2020. The approach converts waste into renewable hydrogen with a net zero-carbon footprint. The first California waste-to-hydrogen production unit will be transportable; it has been sized to fit in three 20-foot containers, processing 1 tonne of waste per day and producing 40 to 50 kilograms of hydrogen per day.[13] Further facilities in the US are planned in 2021.[14]

SGH2 Energy Global: part of the Solena Group, this company has planned the world's biggest green hydrogen plant for California. The plant will produce as much as 11,000 kilograms of green hydrogen per day, and 3.8m kilograms per year. That is nearly three times more than any existing or planned green hydrogen facility. Construction will begin in 2021 and is expected to be fully operational in the first quarter of 2023.[15]

12 https://www.greentechmedia.com/articles/read/bloom-energy-stock-price-soars-after-launch-into-green-hydrogen-market
13 http://biomassmagazine.com/articles/17177/ways2h-teams-with-ford-bacon-davis-on-waste-to-hydrogen-plants
14 https://renews.biz/61340/waste-to-deliver-green-hydrogen-in-california/
15 https://www.forbes.com/sites/kensilverstein/2020/05/26/the-worlds-biggest-green-hydrogen-plant-is-underway-in-california-its-prospects-for-electric-power-and-transportation/#72e426c2a96d

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