September 23, 2020

Hydrogen – Fuel of the Future or Just Hot Air?

Hydrogen Series – Part 1

SUMMARY

Hydrogen – not for the first time – is currently a hot topic in the energy sector, with advocates promoting it as the fuel of the future, capable of addressing critical sustainable energy challenges. Governmental policies aimed at supporting a hydrogen economy are gaining momentum, and companies are starting to greenlight innovative projects that could dramatically change the energy landscape.

In this two-part series, we will look at (1) the basics of the hydrogen market, recently announced high-level government hydrogen policies and barriers to adoption; and (2) key market players and the industries where investment opportunities are likely to arise, along with what government support might be necessary to facilitate the investment needed to achieve the targets embedded in the high-level government policies.

A. INTRODUCTION TO HYDROGEN

Hydrogen, the most abundant element in the universe, is not found naturally in its pure form on Earth in significant quantities. Instead, it is found bound to other elements such as oxygen (e.g. to make water, H2O) and carbon (e.g. to form organic compounds, including fossil fuels). When we refer to hydrogen for use as a fuel, we are referring to pure hydrogen (H2).

Hydrogen has the highest energy content of any common fuel by weight; however, it also has the lowest energy content by volume when in gaseous form. Critically, pure hydrogen emits no carbon dioxide or other harmful emissions during combustion.

B. USES OF HYDROGEN – PRESENT AND FUTURE

Hydrogen is currently predominantly used in industry as feedstock: it plays a fundamental part in the production of ammonia for fertilisers and the production of methanol for polymers. It is also used in oil refineries to produce gasoline and diesel from crude oil.

Hydrogen is also increasingly used for power generation through fuel cells, which combine hydrogen and oxygen to produce electricity, releasing only water and heat as by-products. Stationary fuel cells are used to provide power in off-grid areas or, most commonly, as back-up power in lieu of diesel generators. In addition, the by-product heat can be used to heat nearby spaces.

The key driver of enthusiasm for hydrogen is its potential to decarbonise heavy-emitting sectors which have previously been difficult to electrify and have limited low or zero-carbon fuel alternatives. For example, the use of hydrogen in all forms of transportation is particularly promising. Passenger cars, buses and industrial vehicles (such as forklifts and trucks) can be fitted with hydrogen fuel cells, generating power to drive an electric motor. Fuel cell electric vehicles emit no CO2, particulates or other harmful emissions and can be more energy-efficient than vehicles powered by combustion engines or lithium batteries, allowing them to have longer ranges with shorter refueling or recharging time.

Hydrogen fuel cells and hydrogen products such as ammonia could be used in a range of different forms of transportation. In the case of shipping, hydrogen is currently being developed for on-board power supply, engine start-up and ship propulsion and is being considered as one means of achieving the International Maritime Organisation's strategy of cutting the shipping industry's total greenhouse gas emissions by 50% by 2050. Fuel cell-operated trains (an example of which is already running on a commuter line in Germany) offer a pollutant-free alternative to diesel or electric locomotives powered by expensive overhead lines or conductor rails.

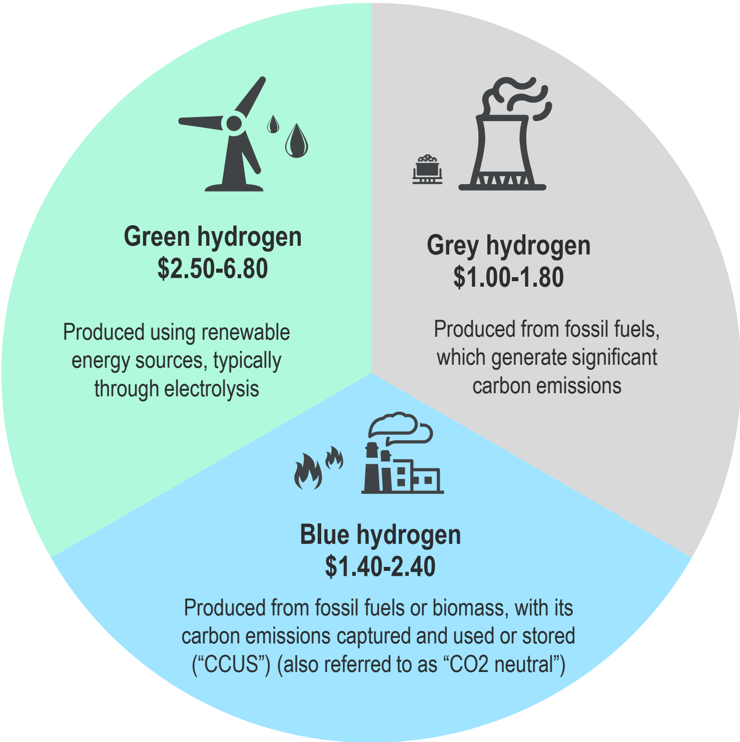
Hydrogen can also be used as a substitute for (or blended with) natural gas for home heating or power generation (including for peaking plants used to balance intermittent wind and solar generation). Additionally, hydrogen can fire industrial furnaces used in applications such as petrochemical, cement and steel production.

C. HYDROGEN PRODUCTION

Hydrogen is produced by extracting it from various compounds, including from fossil fuels using thermochemical conversion methods, from water using electrolysis and from biomass using biochemical conversion. Over 70% of the world's hydrogen is currently produced from natural gas, with significant production from coal as well (due to its still dominant use in China). Electrolysis currently accounts for approximately 4% of global hydrogen production.

As the combustion of hydrogen itself does not generate any CO2 emissions, its carbon footprint depends on the type of energy used in its production, as well as the infrastructure required for the relevant hydrogen use. Hydrogen is then classified as either green, blue or grey, according to how it is produced, as shown in Figure 1 below.

Figure 1: Hydrogen Production Methods and Costs (per Kg)



(Source: BloombergNEF, IEA March 2020)

Although green hydrogen's carbon footprint is near zero, only small amounts are being produced currently. The main reason for this is that green hydrogen is typically expensive to produce because of the large amounts of power required for electrolysis. Consequently, unless the local circumstances for green hydrogen are ideal, such as, potentially, solar-powered electrolysis in desert conditions, one of the main drivers of growth in the use of green hydrogen is likely to be governmental policy, which we discuss below.

The cost of production of blue hydrogen depends on both the price of natural gas and the cost of capturing and reusing or storing the carbon emissions. As carbon capture technologies develop and scale up, the cost of blue hydrogen should come down. As a result, the production of blue hydrogen is likely to become commercially viable before green hydrogen, and it is being promoted as a transition fuel.

Grey hydrogen has the cheapest production costs but its production generates significant greenhouse gases. It is therefore not a long-term solution to the clean energy challenge and is less likely to benefit from incentives.

D. TRANSPORTATION OF HYDROGEN

Today most hydrogen is transported by road in pressurised tankers or by pipelines, in gaseous or liquid form. Cryogenic cooling is required to liquefy pure hydrogen. Pipelines offer the possibility for large-scale transportation, and existing natural gas pipelines could in most cases be used to transport hydrogen blended with natural gas (with separation technologies at the point of use, where necessary) without the need to carry out expensive capital improvements to convert the underlying facilities.

However, the low-volumetric density of hydrogen makes it costly to transport in its pure form. The use of "carriers" such as liquid ammonia or methanol is being widely studied as a carbon-free and cost-effective means of transporting hydrogen. As we discuss in Part 2, pilot projects involving ammonia production using renewable energy are currently being tested and developed. Similar to LNG, Hydrogen could be transported in liquid form (whether pure or via "carriers") in tankers around the world, potentially relying on shipping routes, terminals and tankers already in use for LNG.

E. STORAGE OF HYDROGEN

Currently, hydrogen is typically stored in gaseous or liquid form in pressurised or cryogenic tanks (respectively) for small-scale applications. However, other hydrogen storage options will need to be used to develop large, cross-border hydrogen value chains in the future.

The use of underground salt and rock caverns and depleted gas fields is being explored for long-term storage. The Utah Intermountain Power Agency recently launched a project which will ultimately use renewable sources to generate green hydrogen during low demand periods, which will then be stored in local caverns and burned as needed to generate "green" electricity during periods of peak demand or when renewable generation is not available.

F. MARKET OUTLOOK FOR HYDROGEN

Demand for hydrogen has increased more than threefold since 1975. Global dedicated hydrogen production was approximately 70 million tonnes in 2019. Currently, "captive" production (retaining hydrogen for use on-site) accounts for the majority of the global hydrogen market, with the "merchant" market comprising only approximately 10%. In 2018, the size of the market was estimated to be approximately US $135.5 billion.

HSBC estimates that sales of hydrogen could potentially increase sevenfold over the next thirty years, consistent with the International Energy Agency's (IEA) forecast that the global hydrogen market will exceed US $900 billion by 2050. Levels of implementation of fuel cells in power generation and transportation applications are likely to be key determinants of future growth rates, although changes to the industrial, building and chemical sectors will also be highly relevant. Trade body Hydrogen Europe recently estimated that the development of the EU's hydrogen infrastructure and storage capabilities alone will require approximately €120 billion of investment by 2030.

G. BARRIERS TO ADOPTION

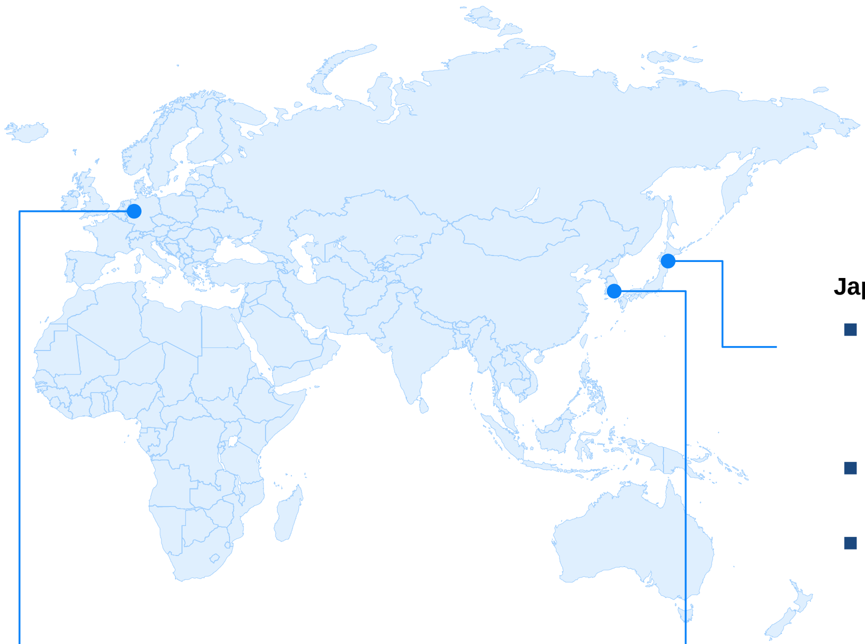
This is not the first time hydrogen has been at the top of the global political agenda. In 2003, President Bush and European Commission President Prodi made the development of a hydrogen economy a major priority. A White House press release at the time stated that by 2020 the hydrogen fuel initiative would make it practical and cost-effective for large numbers of Americans to choose to use clean, hydrogen-fueled vehicles. There is no clear answer to why these predictions were not fulfilled. What is clear is that barriers to adoption remain:

- Cost. Hydrogen is currently only cost-competitive for niche users in limited circumstances. For many uses, fossil fuels or alternative renewable energy sources remain a significantly cheaper fuel source. High energy loss in production means hydrogen cannot currently compete with these alternatives for many applications. This is unlikely to change in the near term, particularly for large-scale power generation. Similarly, the production of most commercial fuel cells currently requires the use of expensive platinum-based metals. Continued advances in fuel cell technology will facilitate the wider uptake of commercial-scale fuel cell use.
- Infrastructure. Appropriate infrastructure is needed to support the adoption of hydrogen technologies. This includes infrastructure for its manufacture, storage and distribution, although some natural gas infrastructure can be converted for hydrogen use with minimal investment. The EU hydrogen strategy contemplates €120-130 billion of investments in new gas grid infrastructure for the transportation of hydrogen around Europe. Similarly, hydrogen refueling stations need to be available to support the widespread adoption of fuel cell vehicles. This is straightforward only where use is localised, e.g. at airports for towing vehicles or for use in forklifts at warehouses.
- Perceptions of safety. The common perception, dating back to the Hindenberg airship disaster, that hydrogen is a dangerous gas also needs to be addressed. While hydrogen is extremely flammable, it is not necessarily more dangerous than other flammable fuels such as gasoline if it is stored and used properly.

H. A CHANGING POLICY ENVIRONMENT

Over the last three years, a number of governments have announced national hydrogen strategies, including Japan (2017), South Korea (2019), New Zealand (2019), Australia (2019) and, in 2020, the Netherlands, Norway, Portugal, Germany and France. Perhaps most notably, in July 2020 the EU published its Hydrogen Strategy (discussed further below). The figure below highlights some of the key policies.

Figure 2: Key national and supra-state hydrogen strategies



European Union

- Strategy includes an investment agenda, research and development, and the establishment of enabling market rules
- Focuses on green hydrogen, but recognises the role of blue hydrogen on a short-term basis
- Aims to establish 40GW of electrolyser capacity in Europe by 2030 and 6GW by 2024; envisages potential investments of €13-15 billion in elecrolysers across Europe by 2030 and €150 billion for wind and solar capacity of 50-75GW

Individual EU Member States

- **Germany**: Aims to be a major exporter of hydrogen; investment agenda commits €9 billion to build hydrogen production facilities with a target capacity of 5GW by 2030, and annual investment of €100 million into hydrogen research and development
- **France**: aims to invest over €7 billion to achieve hydrogen production capacity of 6.5GW by 2030
- **Norway**: focused on the application of hydrogen technologies to transportation and industry

Australia

- Announced a AU $300 million fund to support emerging hydrogen technologies and commits AU $70 million for electrolyser projects
- Stage 1 of the plan (through 2025) focuses on developing supply/demand through pilots, trials and demonstration projects, and reforming regulatory/legal frameworks
- Stage 2 of the plan (2025 onwards) focuses on scaling up projects to support both domestic and export needs and building hydrogen supply chain infrastructure

Japan

- First country to set out a clear political commitment to stimulate the creation of the necessary infrastructure to support a hydrogen economy
- Focused on achieving cost parity between hydrogen and LNG/gasoline
- Approved ~US $150 million to develop infrastructure and ~US $91 million to offer subsidies to developers of refueling stations for FCEVs

South Korea

- Focuses on FCEVs and fuel cell power generation: aims to reach production of 6.2 million FCEVS by 2040 and 15GW of fuel cell power generation
- National strategy focuses on development of blue hydrogen through 2030

In the case of Germany's national hydrogen strategy, a significant investment budget of €9 billion to build hydrogen production facilities with a target capacity of 5GW by 2030 has already been approved. However, to date most government policies have been largely aspirational, without detailed implementation plans, hard funding commitments or specific regulatory/legislative enactments.

Neither the U.S nor the U.K has created a national hydrogen policy, although a national strategy is currently a topic of discussion by U.K Members of Parliament and is expected to be published in early 2021. The U.S. Department of Energy indicated it would spend US $64 million on hydrogen research and development in 2020, and U.S. Democratic presidential candidate Joe Biden has indicated his support for green hydrogen. In China, a 2019 white paper called for hydrogen to account for 10% of its total energy consumption by 2050 and the construction of 10,000 refueling stations. However, this plan is based primarily on grey hydrogen which relies on natural gas and coal-based feedstocks.

I. THE EU HYDROGEN STRATEGY

The EU's Hydrogen Strategy sets out ambitious goals for 40GW of electrolyser capacity in Europe by 2030 (including 6GW by 2024) to produce green hydrogen. By 2030, the European Commission has estimated potential investments of €13-15 billion in electrolysers across Europe and €150 billion for dedicated wind and solar capacity of 50-75GW. This agenda prioritises the development of green or "renewable" hydrogen, stating that renewable hydrogen is "the most compatible option with the EU's climate neutrality goal in the long term and is the priority focus." However, the strategy recognises that use of blue hydrogen will be necessary as a transition fuel in the short term. The key elements of the strategy are:

1. *Investment agenda*: establishes the European Clean Hydrogen Alliance to coordinate hydrogen investment by public and private stakeholders across the value chain, with potential EU support.
2. *Increase hydrogen demand and scale-up production*: developing government support mechanisms to benefit private sector investors and developers. Measures could include quotas, introduction of a comprehensive terminology and criteria for certification of green and blue hydrogen, changes to the EU Emissions Trading Scheme and use of carbon contracts for difference (which would guarantee a carbon price to a project developer irrespective of the price of carbon in the EU's Emission Trading System) and competitive tenders for direct support of green hydrogen.
3. *Design and enable a supportive framework*: by accelerating the deployment of refueling infrastructure through enabling market rules (including, for example, through repurposing existing facilities) and ensuring the integrity of the EU hydrogen gas market through legislative reviews.
4. *Research and innovation*: providing EU funding and support for hydrogen research and pilot projects, recognising the need for international collaboration and cross-border trading of hydrogen.

Exact implementation details are currently unclear, and the agenda remains largely a statement of intent. In terms of feasibility, it is also uncertain whether there are currently enough projects in the pipeline to meet the stated goals. EU Member States will need to arrange tenders for electrolyser projects by early 2021 if the goal of 6GW of capacity is to be achieved by 2024. The EU Commission recently invited developers to submit proposals for electrolyser projects for estimated funding of €25-30 million per project.

In addition, there are currently limited economic incentives for investors and developers to prioritise the development of green hydrogen given its higher cost profile relative to blue and grey hydrogen. Both the EU and European national governments will likely need to provide direct support and incentives for investors and developers to achieve their planned green hydrogen capacity goals by 2024.

J. CONCLUSION

Hydrogen presents exciting opportunities to create a more sustainable energy infrastructure, but past experience and existing barriers to adoption counsel caution at this stage. In Part 2 of this series, we will explore in more detail some of the key players in the market, existing and proposed projects and what is likely needed to facilitate a successful hydrogen economy.

*   *   *

ABOUT SULLIVAN & CROMWELL LLP

Sullivan & Cromwell LLP is a global law firm that advises on major domestic and cross-border M&A, finance, corporate and real estate transactions, significant litigation and corporate investigations, and complex restructuring, regulatory, tax and estate planning matters. Founded in 1879, Sullivan & Cromwell LLP has more than 875 lawyers on four continents, with four offices in the United States, including its headquarters in New York, four offices in Europe, two in Australia and three in Asia.

CONTACTING SULLIVAN & CROMWELL LLP

This publication is provided by Sullivan & Cromwell LLP as a service to clients and colleagues. The information contained in this publication should not be construed as legal advice. Questions regarding the matters discussed in this publication may be directed to any of our lawyers listed below, or to any other Sullivan & Cromwell LLP lawyer with whom you have consulted in the past on similar matters. If you have not received this publication directly from us, you may obtain a copy of any past or future publications by sending an e-mail to SCPublications@sullcrom.com.

CONTACTS

New York			
	Werner F. Ahlers	+1-212-558-1623	ahlersw@sullcrom.com
	Tia S. Barancik	+1-212-558-4415	barancikt@sullcrom.com
	John E. Estes	+1-212-558-4349	estesj@sullcrom.com
	Sergio J. Galvis	+1-212-558-4740	galviss@sullcrom.com
	Christopher L. Mann	+1-212-558-4625	mannc@sullcrom.com
	Inosi M. Nyatta	+1-212-558-7822	nyattai@sullcrom.com
	Melissa Sawyer	+1-212-558-4243	sawyerm@sullcrom.com
London			
	Silvia Brünjes	+44-207-959-8457	brunjess@sullcrom.com
	Craig Jones	+44-207-959-8488	jonescra@sullcrom.com
	Stewart M. Robertson	+44-207-959-8555	robertsons@sullcrom.com
	Samuel E. Saunders	+44-207-959-8509	saunderss@sullcrom.com
Paris			
	Olivier de Vilmorin	+33-173-045-895	devilmorino@sullcrom.com
Frankfurt			
	Carsten Berrar	+49-694-272-5506	berrarc@sullcrom.com
	Max Birke	+49-694-272-5504	birkem@sullcrom.com
	Krystian Czerniecki	+49-694-272-5525	czernieckik@sullcrom.com
Sydney			
	Waldo D. Jones Jr.	+61-282-276-702	jonesw@sullcrom.com
Hong Kong			
	Jonathon G. Hannah	+852-2826-8646	hannahj@sullcrom.com
	Jamieson J. Logie	+852-2826-8616	logiej@sullcrom.com