THE FUTURE OF HYDROGEN

Part 1: An introduction to hydrogen

ADDLESHAW GODDARD

WHAT IS HYDROGEN?

HYDROGEN IS THE MOST COMMON ELEMENT IN EXISTENCE, ALTHOUGH PURE HYDROGEN (H_2) IS NOT NATURALLY ACCESSIBLE AS IT IS AN ODOURLESS, TASTELESS AND COLOURLESS GAS WHICH IS FAR LIGHTER THAN AIR AT NORMAL TEMPERATURES. IT DOES, HOWEVER, HAVE SEVERAL CRUCIAL TRAITS WHICH GIVE IT VALUABLE APPLICATIONS.

This article is Part 1 of a series 'The Future of Hydrogen'. In Part 1 we provide an introduction to hydrogen, provide a summary of its key uses and discuss some of the burgeoning opportunities. Later on in this series we shall discuss the future of hydrogen in the Middle East and regional opportunities, as well as what the regulatory landscape might look like, and how hydrogen may impact the energy transition.

Chiefly, as an energy carrier, hydrogen is extremely potent, at three times the energy per mass of traditional liquid hydrocarbons[1] and when burnt to release this energy it reacts with oxygen from the air, leaving water as the sole waste product. It is also exceedingly light, highly reactive and can be stored and transported as a compressed gas, liquid H_2 (at very low temperatures) or following reversible conversion to ammonia.

Hydrogen is most commonly extracted from hydrocarbons and water. The method in which hydrogen is extracted however varies considerably between the two, and results in varied amounts of waste CO_2. Therefore hydrogen tends to be categorised as green, blue or grey/black based on the production process and output of CO_2.

Green hydrogen is produced in a carbon free manner through electrolysis, meaning splitting water molecules into hydrogen and oxygen using an electrical current. However, to be labelled as 'green', renewably generated electricity must be used. Due to high costs in comparison with traditional energy sources and grey hydrogen, only a tiny proportion of current hydrogen production is green.

[1] Qamar Energy, 2020, Hydrogen in the GCC (a report for the regional business development team gulf region), page 5

[2] United Arab Emirates Ministry of Energy & Infrastructure, January 2021, The Role of Hydrogen for the Energy Transition in the UAE and Germany, page 15

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Blue and grey hydrogen are produced through the gasification of coal or, most commonly, the reforming of natural gas (or sometimes biogas) using very high-temperature steam in the presence of a catalyst (this is known as steam methane reforming or SMR). However, blue hydrogen is distinguished by the additional step of capturing or absorbing the released CO_2 and storing it in a site where it will not leak into the atmosphere (carbon capture and storage or CCS). Blue hydrogen is low carbon with maximum capture estimated at approximately 90% of emissions.[2]

HYDROGEN
IN INDUSTRY

Hydrogen has traditionally served a number of commercial and industrial purposes, predominantly as a feedstock. These roles are valuable and necessary but presently incur massive carbon costs with as much as 95% of hydrogen production being grey[3].

As a redactor agent hydrogen plays an important role in producing iron ores and metal alloys. It is also used heavily in the production of methanol, which is then used in a wide range of chemical, pharmaceutical and even clothing products.

Through combining hydrogen with nitrogen from the air in the Haber Process it can be converted into ammonia, which is crucial to global agriculture as a fertiliser and could assist with a global green transition as an inexpensive and environmentally friendly refrigerant.[4]

Alongside ammonia production the largest global use of hydrogen is the refining of crude oil into fuels like petrol and diesel. Whilst the use of hydrogen to refine fuels will inevitably continue, momentum is building behind the potential of hydrogen as a fuel in its own right.

HYDROGEN
AS FUEL

Hydrogen fuel cells are an established battery technology which can be used for electric cars, heavy vehicles and power generation. While there are a variety available with different requirements and advantages, they fundamentally rely on converting hydrogen into water through a reaction with oxygen (often from the air and sometimes in the presence of a catalyst). This reaction generates an electrical current while releasing zero CO_2 or air pollution. Furthermore, while they are currently far more expensive, these fuel cells outperform internal combustion engines in efficiency and electric vehicle batteries for range and speed of refuelling.[5]

In public transport there have been a raft of exploratory initiatives to incorporate hydrogen. Germany has operated a hydrogen-powered passenger train since 2018 and other countries like the UK and US are close to bringing hydrogen trains to commercial operation. Hydrogen trains have advantages over electrification, which can cost up to £1 million per kilometre of track. For instance, the capacity to retrofit existing trains, use existing track and avoid vulnerability to network-wide disruptions in electrified areas. Projects trialling hydrogen buses are likewise in motion, such as the Clean Air Hydrogen Bus Pilot in the UK. The marine applications of hydrogen as a fuel are potentially extensive as well, in an industry that relies heavily upon diesel engines and has committed to cut emissions by at least 50% by 2050.[6]

In aviation hydrogen fuel cells can be used to power in-flight electrical systems or as an ancillary power supply. Various uses of hydrogen in sustainable aviation fuels are also being explored, including combinations of biogas, hydrogen, and CO_2 and a form of synthetic kerosene made of captured CO_2 and hydrogen.

Natural gas is used extensively to power turbines for electricity generation and other industrial purposes. As with many other forms of gas infrastructure, electricity generation plants can function with a blended fuel source, and therefore can operate partially on hydrogen or even be adapted to use pure hydrogen. If the fuel source for these power stations is 'green' hydrogen, this could significantly reduce our reliance on fossil fuels. This is equally true with regard to the decarbonisation of heating with a number of countries trialling blending hydrogen into their existing natural gas networks. For instance, in the UK the energy regulator Ofgem have recently approved a £12.7 million facility which will test the performance of blends all the way up to 100% hydrogen.[7] Currently 80% of UK domestic properties are heated using gas[8], and heating accounts for a third of national greenhouse gas emissions.[9]

[3] CMS Law, 2020,The Promise of Hydrogen: An International Guide, page 5

[4] Hydrogen Industry Applications: Past, Present, and Future, WHA, accessed April 2021, https://wha-international.com/hydrogen-in-industry/

[5] CMS Law, 2020,The Promise of Hydrogen: An International Guide, page 181

[6] Maritime Hydrogen: The Next Big Wave, Fuel Cells and Hydrogen Joint Undertakings, accessed January 2021, https://www.fch.europa.eu/sites/default/files/Maritime%20hydrogen.%20The%20next%20big%20wave.pdf

[7] Tim McManan-Smith, 2020, Ofgem gives green light to £12.7m hydrogen trial project, the energyst, accessed January 2021, https://theenergyst.com/ofgem-gives-green-light-to-12-7m-hydrogen-trial-project/

[8] CMS Law, 2020,The Promise of Hydrogen: An International Guide, page 182

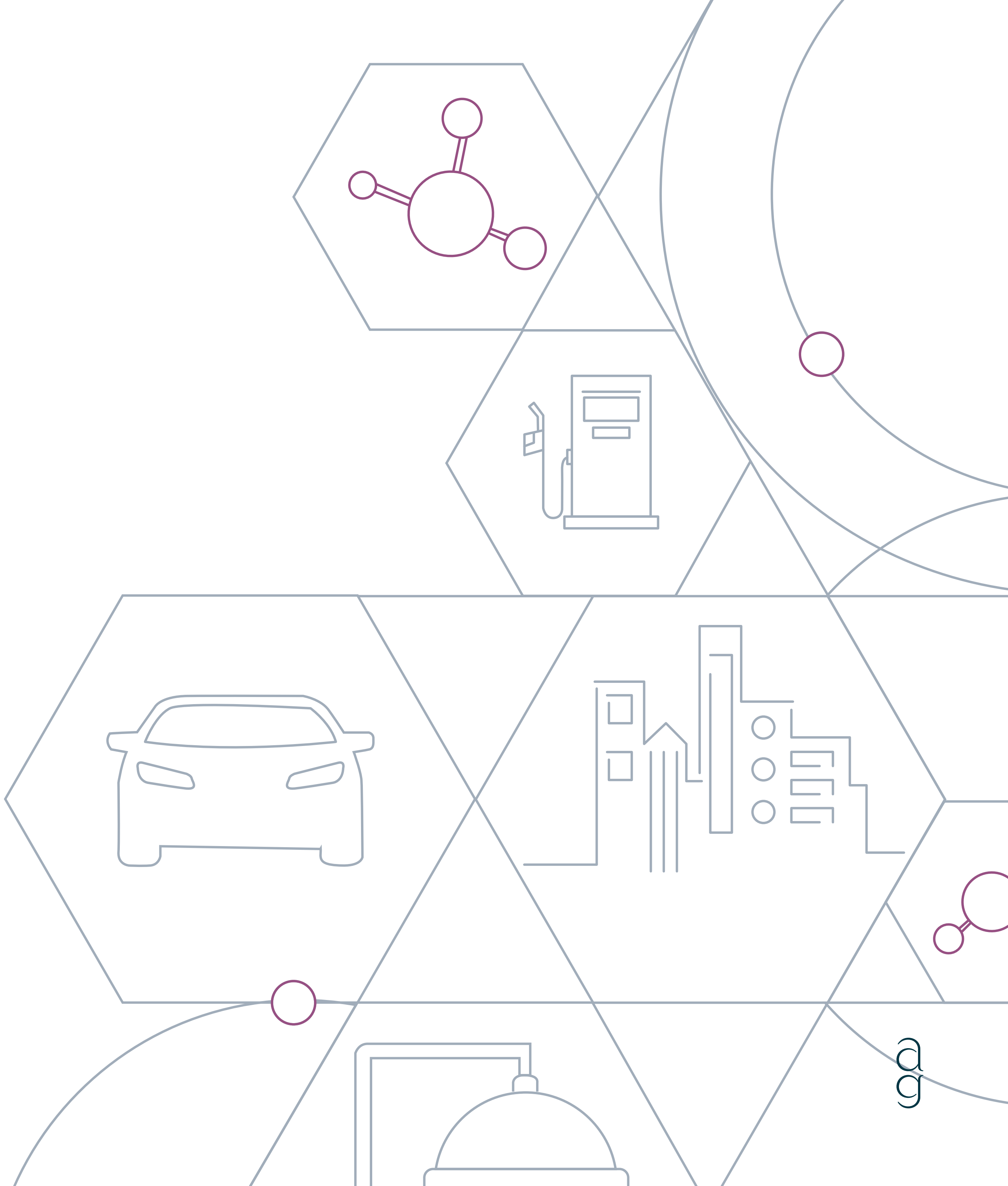
[9] Addleshaw Goddard, Imagine Zero Carbon Hydrogen Powered Homes. A World-First, page 2

THE OPPORTUNITY

Many nations, including the United Kingdom, have made substantial strides in recent years in increasing their proportion of renewable energy usage. However, renewable sources like wind and solar only produce electricity, which is estimated to account for merely 20% of total global energy consumption.[10] For non-electricity energy needs, in particular transport and heating, hydrogen, and in particular green hydrogen, could provide a crucial zero to low carbon alternative to fossil fuels, which could potentially be rolled out on a massive scale. If the international community is to meet their emission reduction commitments under the Paris Agreement, then a dramatic shift of this nature will be required.

Green hydrogen production may be limited but with technological advances the associated prohibitive costs of sourcing renewable energy from wind and solar have diminished. As technology continues to improve and markets adopt policies like carbon pricing and incentives structures, green hydrogen should become increasingly competitive.

The demand for hydrogen is still small compared with that for natural gas, being 9% of the market size in 2018.[11] However, for nations who have traditionally relied upon natural gas reserves blue hydrogen could offer an ideal point of transition to a sustainable energy portfolio. Nations like Saudi Arabia will have extensive gas pipelines, facilities and storage infrastructure which can be adapted for hydrogen, as well as deep and transferable corporate and governmental expertise. Moreover, such nations can store the captured CO_2 from blue hydrogen in voided oil locations and vacant land from which resources have previously been extracted.



[10] Schalk Cloete, 2020, Green or Blue Hydrogen: cost analysis uncovers which is best for the Hydrogen Economy, energypost.eu, accessed January 2021, https://energypost.eu/green-or-blue-hydrogen-cost-analysis-uncovers-which-is-best-for-the-hydrogen-economy/

[11] Qamar Energy, 2020, Hydrogen in the GCC (a report for the regional business development team gulf region), page 4

THE CHALLENGE

The targets being set for hydrogen as an energy source are ambitious, with the 2020 EU Hydrogen Strategy giving estimates that clean hydrogen could account for 24% of world energy demand by 2050. This would not come cheap. The EU envisages that investments in renewable hydrogen production capacity during this period would amount to €180-470 billion in Europe alone.

Shifting the means of current hydrogen production to renewable energy would require huge investment, even with technological improvements, while those countries who opt to focus on blue hydrogen will face enormous capital costs to install CCS facilities. Even where hydrogen can rely on the adaptation of a pre-existing gas network there will still be massive adjustments, retrofitting and investment required as well as establishing refuelling networks for vehicles. Beyond this, broad private investment is needed before such expensive technologies can become truly viable at scale. Global investment, and the global hydrogen market itself, have yet to truly manifest.

At present, globally, hydrogen-specific initiatives and regulations (such as rules governing fuel certifications, tariffs, and market access for pipelines) and are in the very early stages. However, the EU and many countries are preparing to implement hydrogen legislation, and once the regulatory framework is in place coupled with more aggressive emissions schemes, we are likely to see huge investment in this space.

IN PART TWO of this series we will expand upon the potential of the hydrogen market with particular reference to the Middle East, which is seen as a pioneer in the sector.

FURTHER INFORMATION

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ALEXANDER SARAC
Partner, Dubai
+971 4350 6442
+971 5015 42084
A.Sarac@aglaw.com

JOHN PODGORE
Partner, Dubai
Infrastructure Projects and Energy
+971 4 350 6461
+971 5 0640 3544
J.Podgore@aglaw.com

AUTHORS

- JOHN PODGORE
- ALEXANDER SARAC
- ELEANOR MORRIS
- SAMUEL WALLEY

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