Hydrogen for bioenergy in the UK

Introduction

The global hydrogen market is expected to reach $124.5 billion by the end of 2021 and to rise further to $184 billion by 2028[i]. Currently, about 45 million tonnes of pure hydrogen are produced worldwide[ii]. Of this, less 1% of global pure hydrogen is made from renewable sources[iii]. The IEA's report on the Future of Hydrogen found that hydrogen is benefiting from unprecedented political and industrial support, which should now be accompanied by technological scale-up and a reduction in associated costs to allow hydrogen to be more widely available globally. It is therefore reasonable to think that the global market share of renewable hydrogen will significantly increase in the years and decades to come.

Hydrogen has a varied range of commercial uses, from electricity generation, to rocket fuel and the production of fertiliser. Hydrogen (H_2) can be produced via multiple pathways and technologies, and from different sources, each of which results in the production of hydrogen with varying degrees of environmental impacts.

Conventional hydrogen, which is currently the most widely used form of hydrogen, is produced from fossil resources, more specifically, it is obtained from natural gas. Natural gas is primarily composed of methane (CH_4) (along with small amounts of ethane, butane, pentane and propane), which can be converted to hydrogen via steam-methane reforming. This process relies on heat, as methane reacts with steam under specific pressure conditions to produce hydrogen, carbon monoxide and small amounts of carbon dioxide. Further hydrogen can then be produced via a subsequent process referred to as water-gas shift reaction. The gas obtained from both of these can then be purified via pressure-swing adsorption, which removes impurities, leaving pure hydrogen as a final product[iv].

Hydrogen is differentiated according to its production source via the use of colours. For instance, "white hydrogen" refers to naturally occurring H_2 (i.e. not produced via any man-made process). Conventional hydrogen produced from steam-methane reforming (the most common one) is referred to as "grey hydrogen". More specifically, grey hydrogen indicates that the CO_2 produced as a result of the hydrogen synthesis process was not captured in an attempt to reduce greenhouse gas emissions. Should the emissions be captured and locked underground via Carbon Capture and Storage technology (CCS), the resulting hydrogen is referred to as "blue hydrogen". A new experimental technology for the production of hydrogen from natural gas produces what is being dubbed as "turquoise hydrogen". In this case, methane pyrolysis is used to produce hydrogen and a solid carbon by-product – therefore significantly reducing greenhouse gas emissions[v].

Sustainable hydrogen (or "green hydrogen") refers to hydrogen which has been produced from renewable sources and via technologies that do not emit greenhouse gases. There are currently two main processes being used for the synthesis of green hydrogen: water electrolysis and biomass gasification. Simply put, water electrolysis is the process of breaking down water molecules to obtain separate oxygen and hydrogen atoms. The hydrogen atoms can then be transformed into a gaseous form[vi]. The process of water electrolysis itself does not produce any greenhouse gas emissions, however the source of the electrical power should be renewable for the whole process to become sustainable. Should the electricity used by derived from wind, solar or biomass, the hydrogen produced via electrolysis will be considered sustainable.

Finally, biomass gasification is not too dissimilar from natural gas steam-methane reforming (as seen above). Here, biomass is exposed to high temperatures (without combustion) which triggers the release of carbon monoxide, carbon dioxide and hydrogen. Just like with natural gasification, further hydrogen can be obtained through the process of water-gas shift reaction[vii]. Further CCS technology can be used to reduce CO_2 emissions.

Uses of hydrogen in the bioenergy

Within the scope of the bioeconomy, hydrogen could be a major source of bioenergy for power, heat and transportation. These services are likely to be mainly supplied through fuel cell technology, which produces sustainable electricity.

Hydrogen in combination with fuel cell technology is being strongly considered as a potential energy source. Fuel cells are electrochemical cells which transform the chemical energy of a substrate (in this case hydrogen) into electricity while releasing heat and water. This technology has the potential to power laptops, rockets, vehicles, buildings and entire power stations alike. Aside from electricity, the only by-products released as a result are water and heat[viii]. Compared to conventional combustion engines, fuel cells offer higher degrees of efficiency and release lower, or zero, greenhouse gas emissions.

Hydrogen boilers have also been identified as a viable alternative to natural gas boilers for heating. When combusted, hydrogen only releases steam, unlike fossil fuels which release carbon dioxide. However, it remains impossible to be fitted with a hydrogen boiler at the moment as there is no supply through the grid, or even through fuel suppliers[ix]. This is due to the relative novelty of hydrogen boilers and the fact that logistics difficulties and safety concerns remain prevalent.

Support for hydrogen in the UK

In its Energy White Paper published in December 2020, the UK Government announced its intentions to become a world leader in the production of low-carbon hydrogen for heat, power and transport. The country has set itself a target of 5GW of hydrogen production capacity by 2030. A more detailed UK Hydrogen Strategy was set to be published in Spring 2021, however the release was delayed and the final report was published on the 17th August 2021[x]. The 100-page long report sets out the UK's key steps and milestones for the next decade for the development of a sustainable hydrogen industry. These steps are laid out with a view of reaching the planned 5GW low carbon hydrogen production capacity by 2030. This target, and the strategy developed as a result, are underpinned by a government-led analysis which revealed that 20 to 35% of the country's energy consumption by 2050 could rely on low carbon hydrogen. The Strategy is aiming to support the development of hydrogen for several industrial sectors such as chemicals, transport, heating and power. In addition, the UK Government will be taking a "twin track" approach with the development of both green and blue hydrogen. The full report contains multiple support documents and consultations detailing the extent of the Strategy, with precisions on the amount of funding for different sectors of the industry.

Before the Government's Hydrogen Strategy was released, and despite the lack of a defined long-term strategy at the time, the UK had still begun to invest money and develop infrastructure for renewable hydrogen in view of the country's 2050 net zero target.

Hydrogen has been identified as an investment priority area and will therefore benefit from the newly established Net Zero Innovation Portfolio. This fund will make £1 billion available to 10 priority areas which have been identified as crucial for reaching the 2050 net zero target. In addition to the Net Zero Portfolio, the Net Zero Hydrogen Fund was set up to provide further funding opportunities (£240 million in total) to support the development and adoption of hydrogen. Furthermore, £81 million was also allocated to the development of hydrogen for heating specifically.

National Grid Gas UK is currently being sponsored by the Government to build an auxiliary smaller grid to test the viability of adding hydrogen into the national grid in the future. This would allow for the widespread delivery of hydrogen for power and heat generation (for industry, businesses and households alike).

The UK Government has also started to subsidise the use of hydrogen as power fuel for big companies. More recently, this was done at two major oil refineries, namely Essar Oil UK and Killingholme. The full investment totals £7.5 million and is destined to cover part of the cost of a new hydrogen-fuelled furnace for Essar Oil UK, and to promote research into hydrogen-fuelled fire-heaters for the Killingholme refinery[xi]. The hydrogen use here will be provided by the HyNet North West project, an industry-led endeavour which aims to produce, store and distribute hydrogen to industry in the North West of England and North Wales from 2025[xii]. HyNet will also develop and use carbon capture and storage (CCS) technologies to further lower the region's overall greenhouse gas emissions.

Although no longer active, the Hydrogen for Transport Programme (HTP) is worth mentioning as it was set up to promote the development of the hydrogen vehicle market in the UK. Through this scheme, £23 million in grants were allocated for three years, from 2017 to 2020[xiii], and was designed to support the establishment of refuelling infrastructures and the deployment of new hydrogen-powered vehicles.

Conclusion

A number of limitations remain for the widespread production and delivery of sustainable hydrogen. In particular, costs associated with the production of hydrogen and hydrogen-derived energy remain high. Lowering costs is expected to be achieved via the development of more efficient and more durable technologies. Due to its high energy content, hydrogen also poses risks as it is a very flammable gas. For hydrogen to become a staple of a net zero UK, which would include a nationwide rollout through the national grid, more research will need to be performed to ensure the safety of such an endeavour. Projects such as the one currently being carried out by National Grid Gas UK will be instrumental in overcoming this obstacle. Finally, storage and transportation remain difficult as, unlike natural gas which is heavier, hydrogen needs to be cooled down and converted into its liquid form to ensure its stability through storage and transport.

There is no doubt that the UK Hydrogen Strategy will provide much more details on the future of hydrogen in the country and will provide a lot of new attractive opportunities for stakeholders and perhaps customers.

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