Hydrogen from biomass

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Hydrogen is set to play a crucial part in the plans to decarbonise future global energy production and distribution across many sectors; for example, hydrogen could support the integration of variable renewables in the electricity system and reduced the emissions from hard-to-abate sectors such as iron and steel. Although hydrogen is abundant in the universe, free hydrogen is not readily found on Earth. The most abundant forms of hydrogen on the planet are water and hydrocarbons, especially methane. To obtain free hydrogen these molecules must be split, which requires energy. Conventional technologies for the production of hydrogen include steam methane reforming (SMR), a process by which methane is heated at high temperature and pressure with steam in the presence of a catalyst to produce a mixture of carbon monoxide and hydrogen. Conventional production leads to what is known as grey hydrogen, due to a very carbon intensive that can result in emissions of up to 27kg CO_2-eq/kg H_2.[1] Therefore, alternative lower emitting options are being explored.

Despite the current limited production around the world (less than 1% of current global production), low carbon hydrogen is seen as a silver bullet for the decarbonisation of future energy production and distribution. Some forms of low carbon-hydrogen are: green hydrogen, produced using renewable energy (i.e., solar and wind) and renewable feedstock (i.e., water); or blue hydrogen, produced through the above-mentioned SMR of natural gas but fitted with carbon capture and storage (CCS).

Hydrogen policy overview

Both in the UK and Europe, governments are moving quickly to set up policy frameworks that allow the deployment of significant low-carbon hydrogen production by the end of the decade (see Figure 1).

In the UK, low-carbon hydrogen was first included in the UK Government's Ten Point Plan for a Green Industrial Revolution, released in the last quarter of 2020.[2] The UK Hydrogen Strategy was published in August 2021 and set out the approach to developing a thriving low-carbon hydrogen sector in the UK to meet the ambition of producing 5GW of low carbon hydrogen production capacity by 2030.[3] However, this initial target was soon replaced by more ambitious ones (10GW, with at least half being green hydrogen), set within the British Energy Security Strategy, published in April 2022, in response to the Russian invasion of Ukraine.[4] That month, the UK Government also published the UK Low Carbon Hydrogen Standard (LCHS) that defined what 'low-carbon' hydrogen means. The standard states that emissions of H_2 production should be limited to 20g CO_2/MJLHV for the hydrogen to be considered low carbon. An update to the LCHS was published in April 2023.[5]

More recently, the Biomass Strategy, published in August 2023, states that most of the hydrogen produced this decade will come from water electrolysis powered by low carbon electricity and blue hydrogen. However, the document also declares the UK Government's commitment to support multiple

[1] IEA (2023), "Towards hydrogen definitions based on their emissions intensity". Available at: https://www.iea.org/reports/towards-hydrogen-definitions-based-on-their-emissions-intensity (last accessed August 2023).
[2] UK Government (2020), "The Ten Point Plan for a Green Industrial Revolution". Available at: https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution (last accessed August 2023).
[3] UK Government (2021), "The UK Hydrogen Strategy". Available at: https://www.gov.uk/government/publications/uk-hydrogen-strategy (last accessed August 2023).
[4] UK Government (2022), "British Energy Security Strategy". Available at: https://www.gov.uk/government/publications/uk-hydrogen-strategy (last accessed August 2023).
[5] UK Government (2023) "Low Carbon Hydrogen Standard (Version 2). Available at: https://www.gov.uk/government/publications/uk-low-carbon-hydrogen-standard-emissions-reporting-and-sustainability-criteria (last accessed August 2023).

production routes, including those that use biomass as feedstock, which fall within the framework of the bioeconomy, and therefore their developments are being watched closely by NNFCC. Lastly, the Biomass Strategy states its commitment to release a Hydrogen Production Delivery Roadmap by the end of 2023 that will include the government's position on hydrogen from biomass.[6]

At a European level, the EU Hydrogen Strategy, published in 2020, includes a list of 20 suggested key policy actions in different areas such as investment support and the support of production and demand, among others. The document also states that the "priority for the EU is to develop renewable hydrogen, produced using mainly wind and solar energy".[7] The Fit-for-55 package, published in July 2021, put forward a series of proposals to align European legislation to the aims set in the Hydrogen Strategy, and set a target of 5.6Mt of hydrogen production by 2030. Later, in April 2022, the European commission published RePowerEU, where they raised their ambitions to in regard to hydrogen to production to 10Mt, as a mean to reduce energy dependence on Russia.[7]

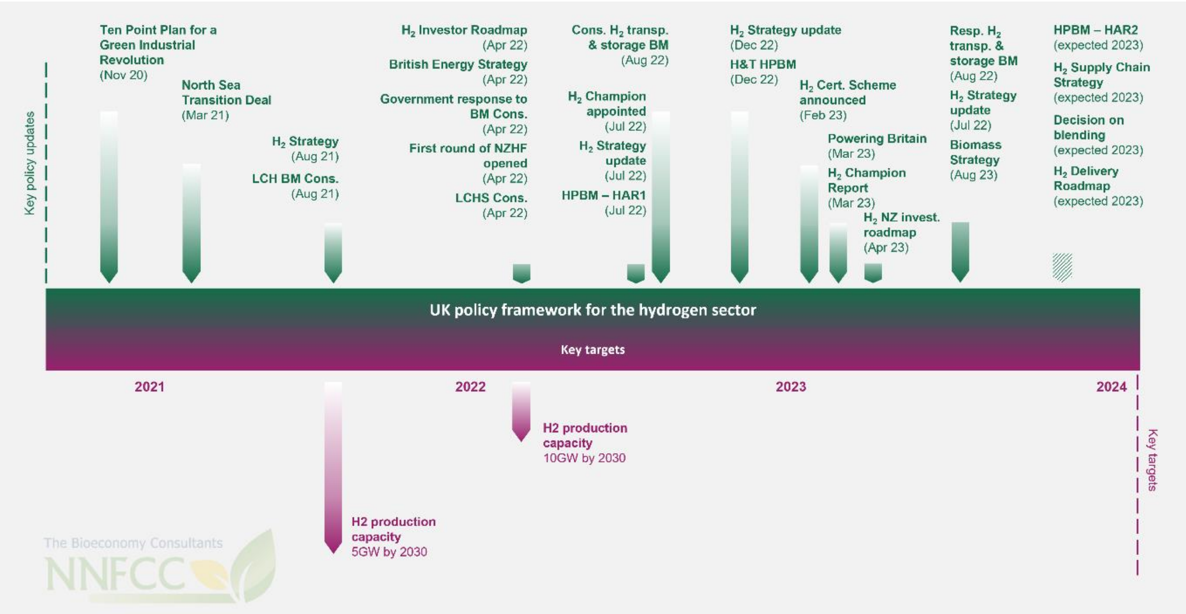

Figure 1 Overview of hydrogen related policy documents released by the UK Government over the last three years.

Production technologies

Electrolysis involves the use of electricity to separate water (H_2O) into H_2 and O_2. If the electricity used has been produced from renewable sources (e.g., wind, solar), the hydrogen produced is categorised as green hydrogen, and is sometimes referred to as electrolytic hydrogen. Electrolysis is a commercially available technology, and one of the two main routes being considered for the development and deployment of hydrogen production at large scale, along with SMR of natural gas with CCS. As an example, at least half of the UK target for hydrogen production needs to be met by electrolytic hydrogen, with the specific sub target of achieving a production capacity (in operation or construction) of 1GW of electrolytic hydrogen by 2025. In order to meet this sub target, the UK Government launched the first electrolytic hydrogen allocation round (HAR1) in 2022 and is expected to launch round 2 (HAR2) later this year. These offer joint Hydrogen Production Business Model (HPBM) revenue and Net Zero Hydrogen Fund (NZHF) capex support.

[6]UK Government (2023) "Biomass Strategy". Available at: https://www.gov.uk/government/publications/biomass-strategy (last accessed August 2023).

[7] European Commission, "Hydrogen". Available at: https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en (last accessed August 2023).

Despite the many advantages of electrolytic hydrogen (e.g., virtually zero GHG emissions, adding flexibility to the renewable grid), it also presents some challenges such as concerns around water supply and the requirement of elements that may face supply limitations in the future (e.g., nickel and platinum).

Hydrogen can also be produced from biomass from a battery of technologies that can be classified into thermal, biological, and electrochemical. Thermal processes include gasification, methane pyrolysis and SMR using biomethane as feedstock. Gasification consists of heating the substrate at high temperatures with a controlled amount of oxygen or steam, to produce hydrogen, carbon monoxide and carbon dioxide. Gasification of coal has been commercialised for many years, and some technologies for the gasification of biomass have already reached TRLs of 8-9. According to the Biomass Strategy, this is expected to be the most prominent production pathway of hydrogen from biomass.[6] SMR is a widely commercialised technology (using natural gas as a feedstock), however, variations to reduce the energy required for the process, such as autothermal reformer (ATR) are still in development (TRL 6). If biomethane is used as feedstock (derived, for example, from AD) instead of natural gas, green hydrogen results from the process. If CCS is added to any of those technologies, the process has the potential to provide negative emissions. Pyrolysis of methane leads to the production of hydrogen and solid carbon, instead of CO_2. This technology involves heating methane in the absence of oxygen at very high temperatures. However, this technology is still at relatively low TRLs.

Biological means of production include dark and photo fermentation processes. Both rely on microorganisms with a natural capacity for the production of hydrogen. The most significant difference between the two processes being their source of energy. Whereas for photo fermentation the energy is obtained from sunlight, for dark fermentation the energy is obtained from the biomass. Both processes are at early stages of developments (TRL 3-5).[8]

The electrochemical pathway, also known a biological electrolysis or microbial electrolysis cell (MEC), involves the conversion of organic compounds into hydrogen or methane through the work of electroactive anaerobic bacteria. The efficiency of this process seems to be higher than the conventional water electrolysis described above, however, it is still at very early stages of development (TRL 3).[8]

Hydrogen production technologies - fit within the existing policy framework

Support for commercial-scale low-carbon hydrogen production is available through the NZHF (development and capital support), the HPBM (revenue support) and the Renewable Transport Fuel Obligation. The applicants selected so far for Round 1 of the NZHF include electrolytic and CCS-enabled projects. As mentioned above, the UK Government launched the first electrolytic hydrogen allocation round (HAR1) in 2022 and is expected to launch round 2 (HAR2) later this year.

As part of the Hydrogen Strategy the UK Government confirmed its twin-track approach for the production of hydrogen through two main pathways (electrolysis and CCS-enabled reforming from natural gas). As such, a significant fraction of the government support to date has been focused on those two technologies.[9] Nevertheless, the document also stated that other production pathways (e.g., hydrogen from biomass) would be investigated for the longer term, and in consequence, in January 2022, the UK Government launched a new scheme – the Hydrogen BECCS Innovation Programme – to support the development of innovative technologies that will generate hydrogen from biomass and waste. The scheme included two phases, counting with £5 million and £25 million of support

[8] ETIP Bioenergy. Renewable hydrogen production of biomass. Available at: https://www.etipbioenergy.eu/images/Renewable_Hydrogen_Production_from_Biomass.pdf (last accessed August 2023).

[9] En:former (2021). "UK unveils twin-track hydrogen strategy". Available at: https://www.en-former.com/en/uk-unveils-twin-track-hydrogen-strategy/ (last accessed August 2023).

respectively[10]. The Scheme followed the publication of the Net Zero Strategy in October 2021, which stated that up to 20% of the hydrogen supply by 2050 could come from biomass gasification with CCS.[11]

According to the newly published Biomass Strategy, the production of hydrogen from biomass must meet requirements for the use of biogenic inputs, where relevant and as appropriate for the feedstock source and classification such as demonstrating compliance with the land, soil carbon and forest criteria, satisfying the minimum waste and residue requirement, and reporting on estimated indirect land-use change (ILUC) GHG emissions, in addition to be under the emissions stated by the above mentioned LCHS.[6]

Many of the technologies described above are at early stages of development and they will likely present specific opportunities when the technologies have developed further. However, it is important to consider whether the production of H_2 is the best possible use of a "limited" resource such as biomass. As an example, the Biomass Strategy suggest that the production of hydrogen involving biomethane could help developing local hydrogen use; however, the document also acknowledge that direct injection of biomethane into the grid is likely to be more energy efficient, and result in higher carbon reduction benefits. The Strategy also states that in the short-term the Government will continue to facilitate biomass deployment through a range of incentives and requirements covering power, heat and transport; and in the medium-term there will be a transition away from unabated used of biomass (e.g., BECCS, which will likely allow to deliver negative emissions as well as valuable co-products).[6]

Challenges and limitations to hydrogen deployment

Key stakeholders have stated some concerns about the production and utilisation of hydrogen. Firstly, hydrogen is an energy vector, as opposed to an energy source, and therefore its sustainability is not guaranteed, and it is dependent on the sustainability of the energy source from which it is derived. As an example, electrolytic carbon produced from electricity from the grid will be more carbon emitting than that produced from wind or solar energy.

Regarding production, in a recent position paper, the European Technology and Innovation Platform (ETIP) flags that very high levels of investment towards hydrogen in certain sectors could be detrimental, as there may be other commercially available renewable technologies that can meet the same needs in a shorter term and with higher profitability.[12] Similarly, within the biomass to hydrogen framework, it is important to understand whether the production of H_2 is the best possible use of a resource like biomass.

In terms of transportation, the infrastructure required to move pure hydrogen (and the captured CO_2 during production) long distances is not in place, and therefore only local utilisation is feasible in the short term.

Despite having significant potential of being used in a wide range of applications, the ETIP, for example, states that hydrogen will only play an important role in value chains where the specific properties of hydrogen are of high value. This could be in applications where hydrogen is used as a feedstock for industrial process, or hard-to-abate sectors such as specific means of transportation.[12] Lastly, hydrogen

[10] UK government (2022). "Government launches new schemes for technologies producing hydrogen from biomass". Available at: https://www.gov.uk/government/news/government-launches-new-scheme-for-technologies-producing-hydrogen-from-biomass (last accessed August 2023).

[11] UK Government (2021). "Net Zero Strategy: Build Back Greener". Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf (last accessed August 2023).

[12] ETIP Bioenergy & ETIP RHC (2023). "Renewable hydrogen: opportunities, limitations and threats of hydrogen for the energy transition in Europe". Available at: https://www.etipbioenergy.eu/images/RHC_ETIP-B_Renewable_Hydrogen_position_paper.pdf (last accessed August 2023).

is extremely volatile and flammable which leads to losses during transportation, and safety concerns during utilisation.

Concluding remarks

Due to the absence of carbon atoms in its structure, hydrogen is seen as a key element for the decarbonisation of many sectors. In particular, the utilisation of biomass brings the opportunity to produce low-carbon emitting hydrogen. Additionally, if integrated with CCS, negative emissions, vital to reach the carbon neutrality target of 2050, can be achieved. However, hydrogen is not, and cannot be, the solution for decarbonising every sector. Firstly, the necessary infrastructure for hydrogen production and transport is not widely deployed yet, and it will not be at the sufficient scale for many years; and the same happen with the required infrastructure for CCS. And secondly, hydrogen applications should focus on sectors where the specific properties of hydrogen are of high value (e.g., as feedstock for industrial processes), and in hard-to-abate sectors (e.g., certain modes of transportation) for which few other decarbonisation alternatives are available. In several sectors, many other technologies, including some making use of biomass, are currently deployed at scale (e.g., biomethane from AD), and should not be overlooked as they can be pivotal to meet the emissions targets, and not only in the short-term. In those sectors where other alternatives are available, too much attention to hydrogen could distract and delay the deployment of such alternatives.

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