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NON-ELECTROLYTIC HYDROGEN PRODUCTION TECHNOLOGY TYPES

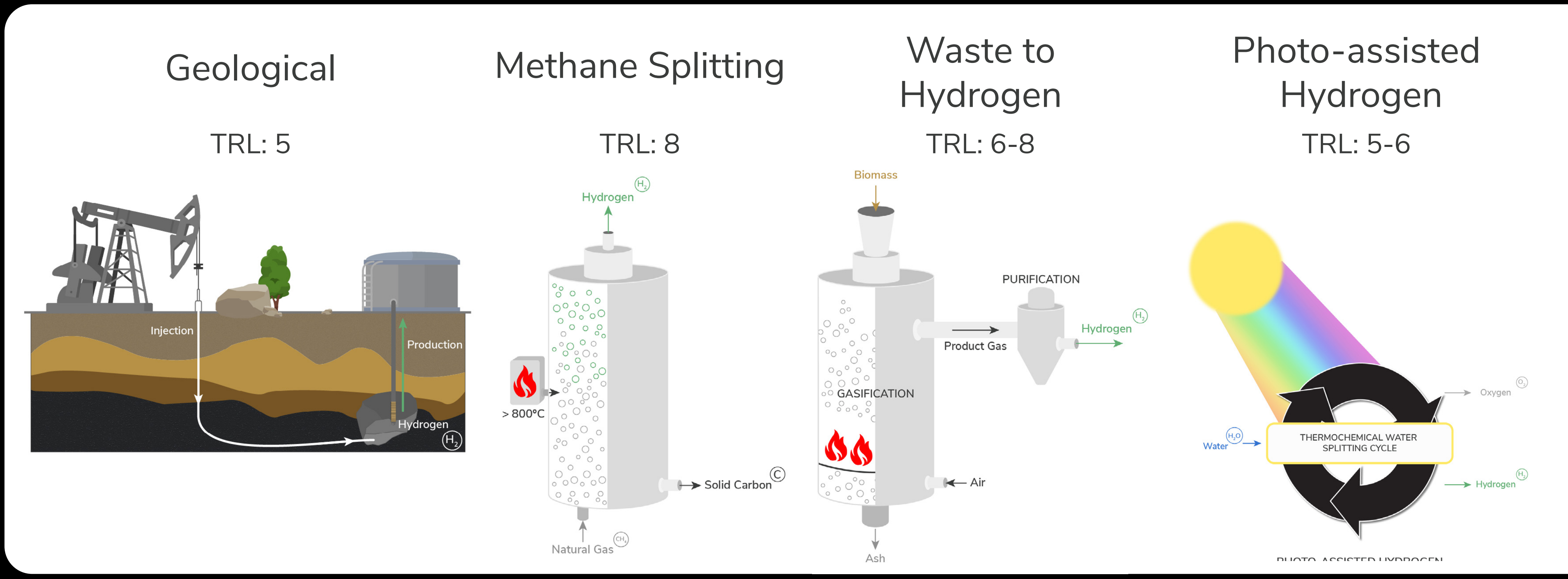
NON-ELECTROLYTIC TECHNIQUES FOR PRODUCING HYDROGEN

The attention on low-carbon hydrogen production has primarily been focused on electrolytic systems, where water is split into hydrogen and oxygen by passing an electric current derived from renewable sources. Various electrolyser designs at different stages of technology maturity exist to perform this process, each with its *own benefits and challenges*.

While industry supports electrolytic hydrogen production as a technically and economically viable method for producing low carbon-hydrogen, it still faces drawbacks, including high energy consumption due to the thermodynamically uphill process, efficiency losses, high capital costs and reliance on scarce, expensive materials. Given these challenges, non-electrolytic methods for producing low carbon hydrogen may hold potential to address these limitations and could offer a commercially viable alternative.

Widespread non-electrolytic options for hydrogen production encompass a range of distinct operational mechanisms, making direct comparisons challenging. With each technology possessing its own parameters and developmental pathways, caution should be placed on ensuring a fair evaluation. Among the non-electrolytic methods that have gained some commercial traction, though relatively limited, are geological hydrogen, methane splitting, waste-to-hydrogen systems, and photocatalytic techniques. Geological hydrogen involves naturally occurring hydrogen deposits formed through chemical reactions between subsurface rocks and water[1].

Alternatively, in methane pyrolysis, methane is heated at elevated temperatures to decompose it into hydrogen and solid carbon. The conversion is aided thermally, catalytically or via plasma action. Waste-to-hydrogen systems convert biological or non-biological waste materials into hydrogen through thermal or biological processes. In photocatalytic hydrogen production, light driven mechanisms often assisted by catalysts, split water into hydrogen and oxygen without requiring external electricity[2].

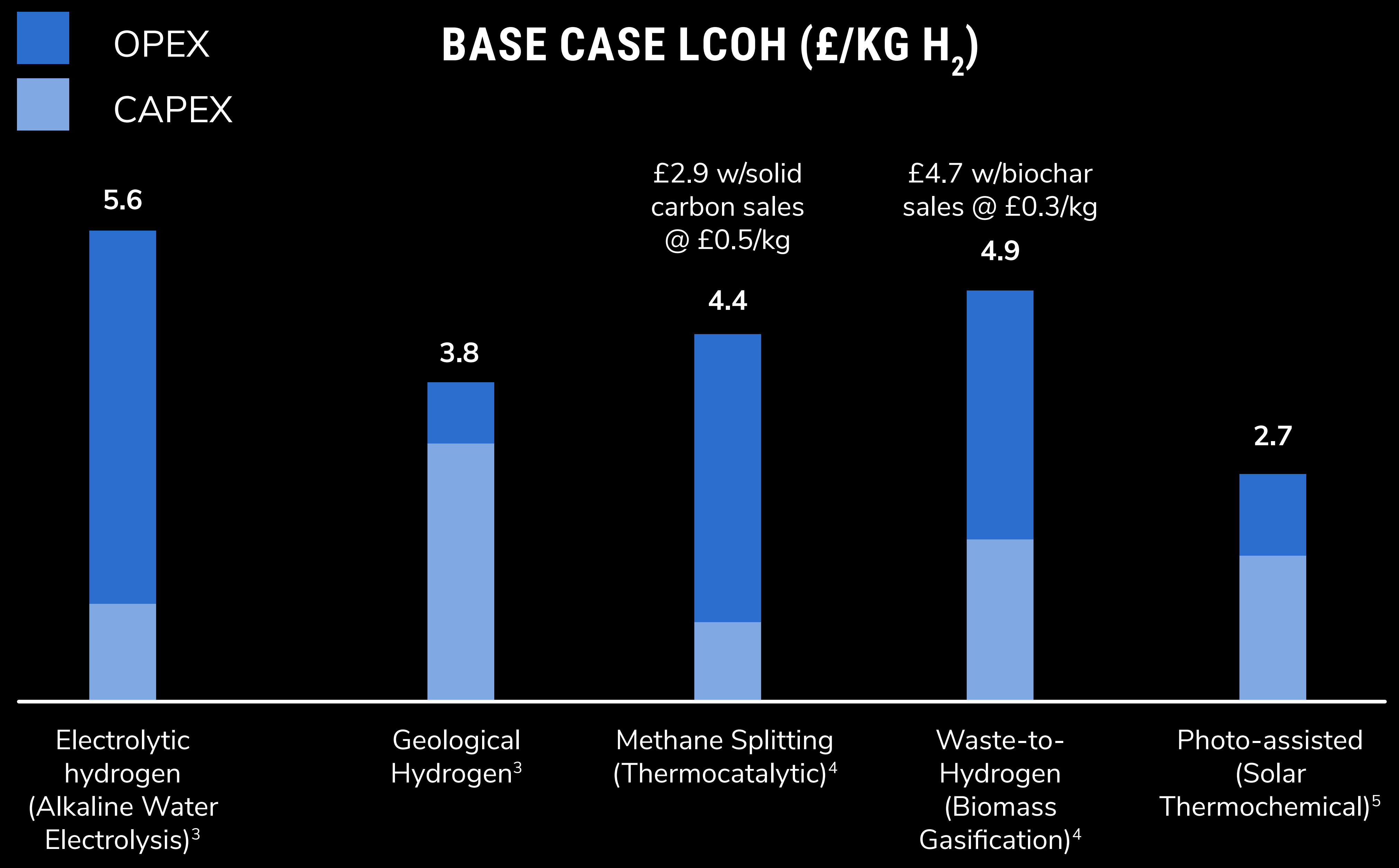


[1] Patonia et al., 2024 Natural (geologic) hydrogen and its potential role in a net-zero carbon future: Is all that glitters gold?
[2] The Royal Society., 2018 Options for producing low-carbon hydrogen at scale (TRL based on IEA analysis).

THE COSTS OF EACH PRODUCTION METHOD:

The levelised cost of hydrogen across the different production methods depends heavily on CAPEX, OPEX, system efficiencies, geographic locations and potential revenue streams. Geologic hydrogen is a potentially low cost option due to its direct hydrogen source, eliminating pre-production processes. However, costs can vary significantly based on the specific characteristics of the extraction field, with factors such as gas flow rate and hydrogen purity having a substantial impact. Other key cost drivers include land and mineral rights, as well as the proximity to hydrogen consumption areas. As a result, providing an accurate cost is challenging without considering the unique geological context of the extraction site. Other challenges associated with geologic hydrogen are its uncertain renewability, and production being geographically restricted to regions with specific mineral resources.

The LCOH of methane splitting is significantly influenced by the production pathway and potential revenue streams from solid carbon by-products. For instance, the thermal and catalytic methods each have distinct feedstock and energy requirements, which influence the OPEX. The price of solid carbon has a direct impact on the cost of hydrogen, potentially reducing the LCOH by 40-70%, depending on the demand for carbon and its corresponding price. Hence, the economics of hydrogen production are highly sensitive to fluctuations in the market value of the by product, making it risky to rely too heavily on this revenue stream. Overall, though a promising cost competitive alternative to electrolysis, key methane splitting challenges include its cost volatility, high energy demand and the need for high purity methane which increase operational costs.



Source: Gemserv Analysis [3, 4, 5]

*Solid carbon and biochar sales are illustrative of potential value of by-product and not reflective of actual production costs.

[3] Electrolytic and geologic LCOH based on Gemserv data source and analysis. Electrolytic hydrogen: Dedicated offshore wind power in the UK using 2024 costs. Geologic hydrogen: Oil and gas extraction methods tailored to geologic hydrogen in US using 2024 costs

[4] Hydrogen Europe (2024) Clean Hydrogen Production Pathways (Methane Splitting and Waste-to-Hydrogen LCOH Data Source; other assumptions based on Gemserv analysis)

[5] Falter and Sizmann (2021) Solar Thermochemical Hydrogen in the USA (Photo-assisted Production LCOH Data Source; other assumptions based on Gemserv analysis with costs adjusted for inflation as of 2024)

THE COSTS OF EACH PRODUCTION METHOD:

While waste-to-hydrogen systems bring environmental benefits and renewability, they face high upfront and operational costs. Feedstock variability and fluctuating feedstock prices impact production costs making it difficult to achieve consistent and competitive hydrogen pricing. The low process efficiency of waste-to-hydrogen systems further challenge their LCOH competitiveness. Much like solid carbon sales in methane splitting, potential sales of biochar as a by-product in the process also influence the LCOH though less significant. Photo-assisted hydrogen production could become a long term cost competitive alternative by reducing electricity demands and infrastructure needs compared to electrolysis.

However, expenses such as high labour costs increase the OPEX hence operations in lower cost regions can help drive the LCOH further. Overall, its low Technology Readiness Level (TRL), operational inefficiencies hence low H2 output limit its immediate commercial impact.

STATUS QUO AND OUTLOOK:

Geologic hydrogen is witnessing growing interest but remains nascent in commercial application. The only proven continuous production site is in Bourakébougou, Mali yielding at least 50 tonnes annually. Emerging prospects in Brazil and Australia are under early appraisal, while global exploratory findings in countries such as France, the US, Canada and South Africa estimate vast reserves exceeding 1 trillion tonnes[1]. However, commercial potential is dependent on identifying high purity reserves and active generation zones and therefore remains speculative. Methane splitting has seen some projects reach commercialisation though most remain at the demonstration phase.

Current production capacities for demonstration to commercialisation projects are estimated at 5,000 tonnes annually with projections suggesting over twentyfold increase by 2030 as announced projects come online[4]. Waste-to-hydrogen production is a commercially mature alternative, with thermal methods like gasification driving this growth and accounting for numerous operational plants globally. Due to the highly scalable technologies and increasing adoption, capacity is expected to grow 100x by 2030[4,6,7,8].

In contrast, photo assisted hydrogen production remains at the research and development stage, with no at scale demonstration or commercial systems yet. However, technology breakthroughs and a surge in patented technologies and startups across the globe indicate future potential.

Most non-electrolytic hydrogen production methods are currently in pilot or demonstration stages, with commercial viability expected post-2025. However, advancements in efficiency and economies of scale could make these methods cost competitive in the long term. Critical to growth are supportive legislation, policy and funding. For instance, legal barriers around geological hydrogen exploration remain a challenge. Only 3 out of 60 countries with hydrogen strategies provide legal frameworks recognising natural hydrogen fields[8]. Addressing permitting issues and public perception will be key to unlocking these reserves. In the EU, a regulatory barrier for both methane splitting and waste-to-hydrogen production is the ineligibility of solid carbon or biochar under the ETS free allowances[4]. This exclusion can deter companies from pursuing these methods as it restricts their ability to build a financially viable business case.

[6] International Energy Agency Bioenergy (2024) Hydrogen produced from gasification and implemented in gasification
[7] Based on multiple announced projects
[8] International Energy Agency (2024), Global Hydrogen Review

STATUS QUO AND OUTLOOK:

Low TRL technologies also require end to end commercialisation support. Funding initiatives like the EU's €40 billion Innovation Fund, Innovate UK's £90 million hydrogen investment, and the U.S. DOE and ARPA-E recently allocating US$20 million for geologic hydrogen exploration and USD$8.7 million for biomass to hydrogen research[8] are promising steps. To drive significant progress towards meeting hydrogen demand with cleaner production methods efforts must be more targeted to bridge the gap to large scale deployment. Several of these methods have the potential to scale, with various methane splitting[9,10] and waste to hydrogen plants[8] already announced each with annual production capacity well over 5 MW. A key challenge is the consistent availability of sufficient feedstock to sustain these capacities. The scalability potential of geologic hydrogen is significant. If only a small fraction (<<1%) of the estimated geologic hydrogen reserves are proven to be both high purity and capable of continuous generation they could support annual production capacities of at least 1 GW.

While electrolysis leads the way in project pipelines for low carbon hydrogen production today, alternative pathways are rapidly advancing, offering scalable and sustainable solutions for hydrogen's critical role in achieving net zero targets. 'In our view, non-electrolytic hydrogen production is expected to develop alongside electrolysis, though on a smaller scale by 2030, targeting niche markets with established cost enablers. Solar thermochemical methods are likely to thrive in coastal solar abundant regions, while waste-to-hydrogen systems can leverage waste management regulations and existing infrastructure. Methane splitting may gain momentum driven by strict carbon emission policies and new demand for solid carbon, while favourable geologies and market proximity could make geologic hydrogen viable.'

[9] Monolith Hydrogen (2024), The Monolith Process.
[10] Hycamite (2024) Projects: Scalable plants decarbonize industries.

If you have any questions about this article or are curious to find out more about the competition between the electrolyser types, please contact harry.morton@gemserv.com.

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Sandile Mtetwa
Research Analyst

Scan to find out more about our Hydrogen capabilities