VIEW POINT

HYDROGEN HORIZONS: APPLICATIONS AND BUSINESS INSIGHTS

Abstract

The POV delves into hydrogen's power to revolutionise the energy industry. Considerations such as electrolysis, a means of producing hydrogen, and its potential use as a storage medium for renewable energy sources are all part of the analysis. From fuelling cars to creating energy, we explore a wide range of potential uses. Opportunities for businesses in the hydrogen economy are highlighted, along with the part that innovative technologies and government initiatives play in propelling its widespread use. Problems like cutting costs and improving infrastructure have been addressed. Lastly, the article delves into what is to come, shedding light on emerging trends that will influence the future of hydrogen utilization.

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Understanding the Role of Hydrogen in the Energy Landscape

Global energy consumption has significantly changed since the Industrial Revolution, with access to fossil fuels, nuclear, hydropower, and renewable technologies, increasing production and consumption. In 2024, global energy consumption grew by 1–2 percent annually, with oil making up 40.4 percent of the world's final energy consumption. Hydrogen, the simplest and most abundant element, is becoming an energy carrier, storing, moving, and delivering energy from other sources like natural gas, coal, biomass, waste, or splitting water molecules. Hydrogen's adaptability and capacity to store energy during renewable production peaks highlight its significance in the energy transition, which aims to displace conventional energy sources in all sectors of the economy.

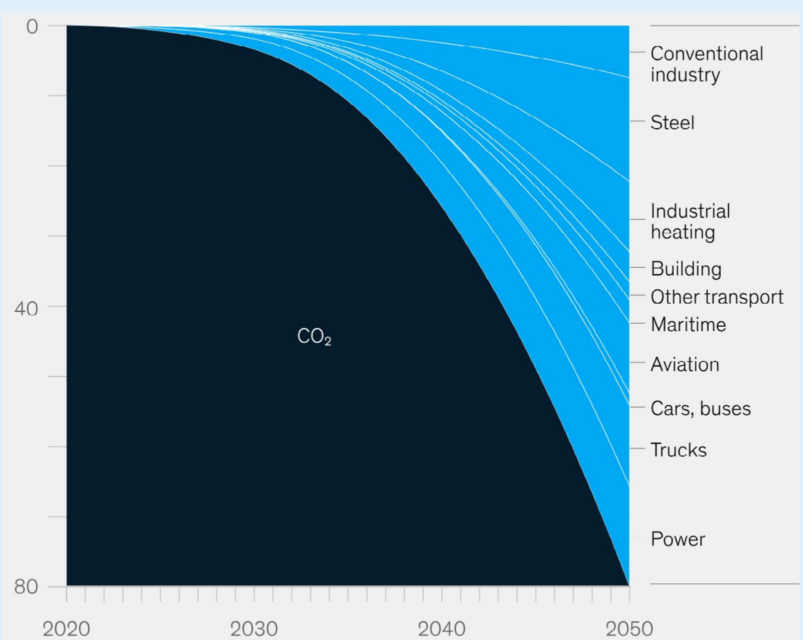
Hydrogen is a promising sustainable energy carrier, with its colourless, odourless, tasteless, non-toxic, and non-poisonous properties. However, it is prone to leaks and can become flammable in confined spaces. Prompt ventilation and detection sensors are needed to reduce risks, and a cryogenic storage vessel is needed to keep liquid hydrogen in that state. A cleaner and more sustainable alternative to fossil fuels, hydrogen can be manufactured from renewable energy sources like wind, solar, hydropower, and biomass. When considering the environmental impact, extracting hydrogen from renewable sources is better than using alternatives that rely on fossil fuels.

Importance of Hydrogen as a "Clean Energy Carrier"

Compared to conventional fuels, hydrogen fuel has several positive environmental effects, such as producing hydrogen from a variety of domestic resources and emitting almost no greenhouse gases. It can be made from natural gas, coal, solar, wind, and biomass, allowing for diversification of energies and improving national energy security. Hydrogen-powered fuel cell electric vehicles emit only water and warm air, whereas low- or zero-emission sources like solar, wind, and nuclear energy offer environmental and health benefits.

Hydrogen fuel is becoming a clean and reliable energy vector for decarbonization owing to its diverse supply and low pollution and GHG emissions. It has potential in the stationery and transportation energy sectors, as it reduces greenhouse gas emissions and air pollution. Hydrogen fuel cell vehicles emit only water vapor and warm air, making them a promising alternative for long-haul transport and heavy industries that are hard to electrify.

Clean hydrogen can contribute as much as 80 gigatons of C02 abatement by 2050, with most coming from industrial uses and transport.



The energy sector can also benefit from hydrogen by electrolyzing excess renewable energy, reducing fossil fuel use and greenhouse gas emissions. However, the environmental impact depends on how hydrogen is produced, with gas-to-hydrogen production emitting most hydrogen. To maximize its environmental benefits, hydrogen production must switch to electrolysis using renewable energy.

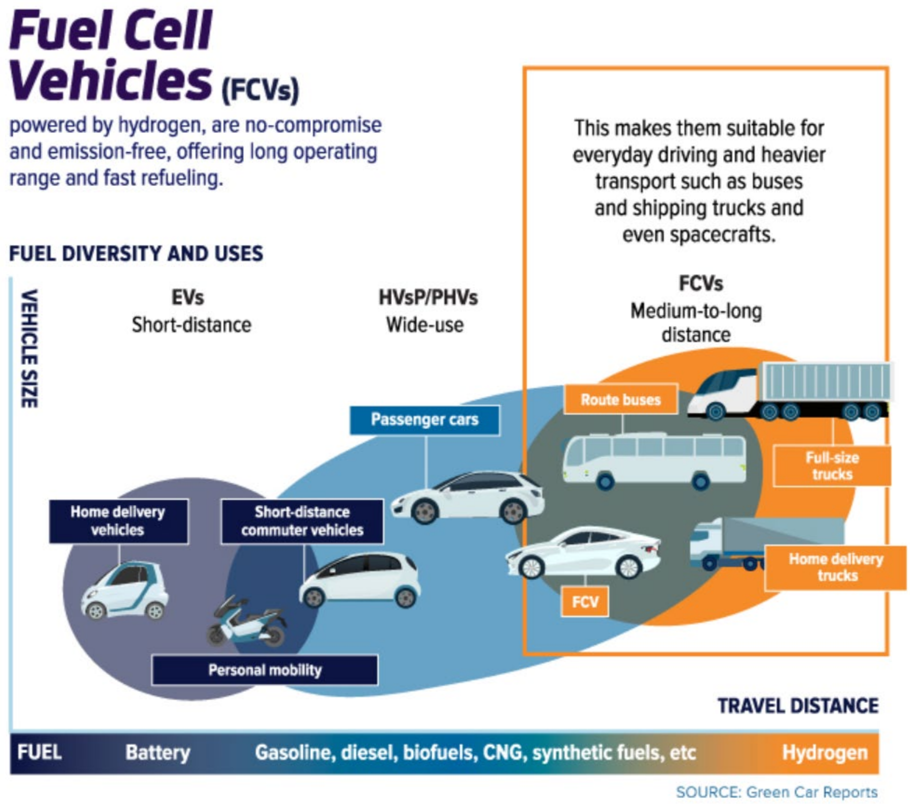
Figure 1: *CO2 Abated from Hydrogen End Use, Gigatons of CO2 (Cumulative Reduction)*

Source: *Hydrogen Council Decarbonization Pathways; McKinsey Hydrogen Insights*

Hydrogen is seen as a key enabler of the global transition to sustainable energy and net-zero emissions economies. It reduces industry and logistics CO2 emissions and stores and transports renewable energy. Hydrogen can replace fossil fuels in some applications without infrastructure change, especially in sectors like heavy industry, chemical production, long-haul transport, and residential heating that are difficult to electrify or costly to decarbonize.

Hydrogen Applications in Various Industries

Hydrogen Fuel Cell Vehicles (FCVs) are a promising alternative to gasoline and diesel vehicles because of their environmental and energy benefits. They emit heat and water from their tailpipes, reducing oil dependence and emitting no harmful air pollutants. However, FCVs face challenges such as low energy density, high manufacturing costs, safety concerns, fuel cell durability issues, insufficient hydrogen refuelling infrastructure, and hydrogen storage and transportation complexity.



Source link: [Visual Capitalist]

Developing hydrogen infrastructure and refuelling stations is a major challenge for FCVs. The U.S. Department of Energy launched H2USA, a public-private partnership, to improve hydrogen infrastructure. With 59 retail hydrogen stations in the US in 2023, there are at least 50 more under construction. Hydrogen fuel production and delivery to service stations are expensive at low volumes, and currently fossil fuels produce hydrogen, which is cheaper than renewable energy. Overcoming these obstacles will be crucial for the adoption of hydrogen fuel cell vehicles.

Automotive hydrogen adoption issues and opportunities include reducing greenhouse gas emissions, improving energy security, and diversifying the energy mix for the automotive industry. To tackle these problems, the hydrogen industry needs to collaborate with energy providers, governments, and automobile manufacturers to fund the development of hydrogen infrastructure and technology, as well as to draft laws and incentives that encourage the adoption of hydrogen.

Industrial applications of hydrogen include petrochemical production, oil refining, and metal processing industries. Hydrogen is used in petrochemicals to produce ammonia, methanol, and other chemicals, clean low-quality feedstocks, and fuel heating, power, and transportation. Hydrogen's versatility as a feedstock and reducing agent in industrial processes contributes to its advancement and sustainability.

Case studies highlight the successful integration of hydrogen in various industrial sectors.

Queensland Nitrates: Australian manufacturer of ammonium nitrate for mining, Queensland Nitrates, is investigating the feasibility of producing green ammonia. Their Moura location was the subject of a feasibility study in collaboration with Neoen and Worley and funded by ARENA (Australian Renewable Energy Agency) around 2021 to determine whether the nation's first green hydrogen-to-ammonia facility could be constructed there. Without releasing greenhouse gases, this facility would generate ammonia using renewable energy sources.

FH2R: The Fukushima Hydrogen Energy Research Field (FH2R), which was initiated in Japan around 2021, is a leading green hydrogen initiative that uses R&D to establish large-scale, cost-effective production. By employing a 20 MW solar plant and a 10 MW electrolyser, the project generates and investigates green hydrogen production to not only decarbonise energy sectors but also substantially reduce electrolyser costs by 80%.

Green H2F Puertollano I: Spanish Green H2F Puertollano I, which was initiated around 2021, is devising a process to generate hydrogen from renewable energy sources (solar or wind) for use in the production of green fertilizers, to fuse green technology with conventional industries. This emphasis on green hydrogen paves the way for a more sustainable agricultural sector while simultaneously reducing carbon emissions from fertilimissions from fertilizer production. The project has produced green hydrogen from renewable sources in a demonstrable manner and is currently conducting trials to incorporate this hydrogen into the fertilizer manufacturing process. Although, the implementation of green fertilizers on a large scale has not yet been accomplished, this endeavour is making a significant contribution to the progress made in this domain.

Power Generation: Hydrogen as a Renewable Energy Storage Medium

Hydrogen can be utilized in fuel cells for stationary power generation, providing a clean, efficient, and reliable energy supply for various applications. These cells convert hydrogen and oxygen into electricity and water without combustion or emissions, making them suitable for primary, backup, or combined heat and power systems. Combining fuel cells with solar and wind energy can create hybrid systems that balance intermittency and variability, resulting in high efficiency, fuel flexibility, minimal maintenance, low noise, and reduced greenhouse gas emissions.

Power systems can be more adaptable and dependable with hydrogen storage and conversion using wind and solar energy. Hydrogen can be stored in tanks, pipelines, or underground caverns, which can be converted into ammonia or synthetic fuels. During high electricity demand or low renewable generation, stored hydrogen can power transport, industry, and heating through fuel cells or turbines.

Hydrogen can stabilize grids and enable renewable energy transitions by utilizing renewable electricity or heat, water electrolysis, biomass gasification, or thermochemical cycles. It can be stored and transported as compressed gas, liquid, or metal hydrides for flexible energy management. Reduced emissions of greenhouse gases and air pollution can result from this integration's ability to regulate energy supply and demand using intermittent renewable sources, such as wind and solar.

Business Opportunities in the Hydrogen Economy

The European Union, China, Japan, and US policies to promote hydrogen development and deployment are affecting the global hydrogen market. The global hydrogen market is expected to grow from $177 billion in 2019 to $1.4 trillion by 2050, driven by clean hydrogen demand in industries like manufacturing, transport, power, and heating.

"More than 684-Megawatt scale projects are announced globally with a focus on production, industrial usage, transport, and infrastructure. 314 in Europe, 154 in Asia, 103 in North America, 54 in Oceania, 34 in Middle East and Africa and 25 in Latin America"

Transportation, power generation, industry, and household demand for low-carbon energy solutions are driving this expansion. Some of the most prominent companies in this industry, include INOX Air Products, Linde, Iwatani, Hydrogenics, Air Products and Chemicals, and Air Liquide. These businesses employ a wide range of techniques, including electrolysis, steam methane reforming, thermochemical water splitting, biomass gasification, and captive and merchant hydrogen transport, among others.

New business models, such as hydrogen hubs, clusters, and valleys, aim to integrate hydrogen production, distribution, and usage in a coordinated and collaborative manner to access its potential. Policies and incentives can be aligned across government levels and stakeholders, and standards and certification schemes for low-carbon hydrogen can be developed.

The hydrogen economy's viability and scalability depend on factors such as feedstock availability, production technology efficiency, distribution and storage infrastructure, end-use application demand, and policy and regulatory frameworks that support or hinder hydrogen market development. The hydrogen value chain must be considered from production to end-use to determine the hydrogen economy's economic viability and scalability.

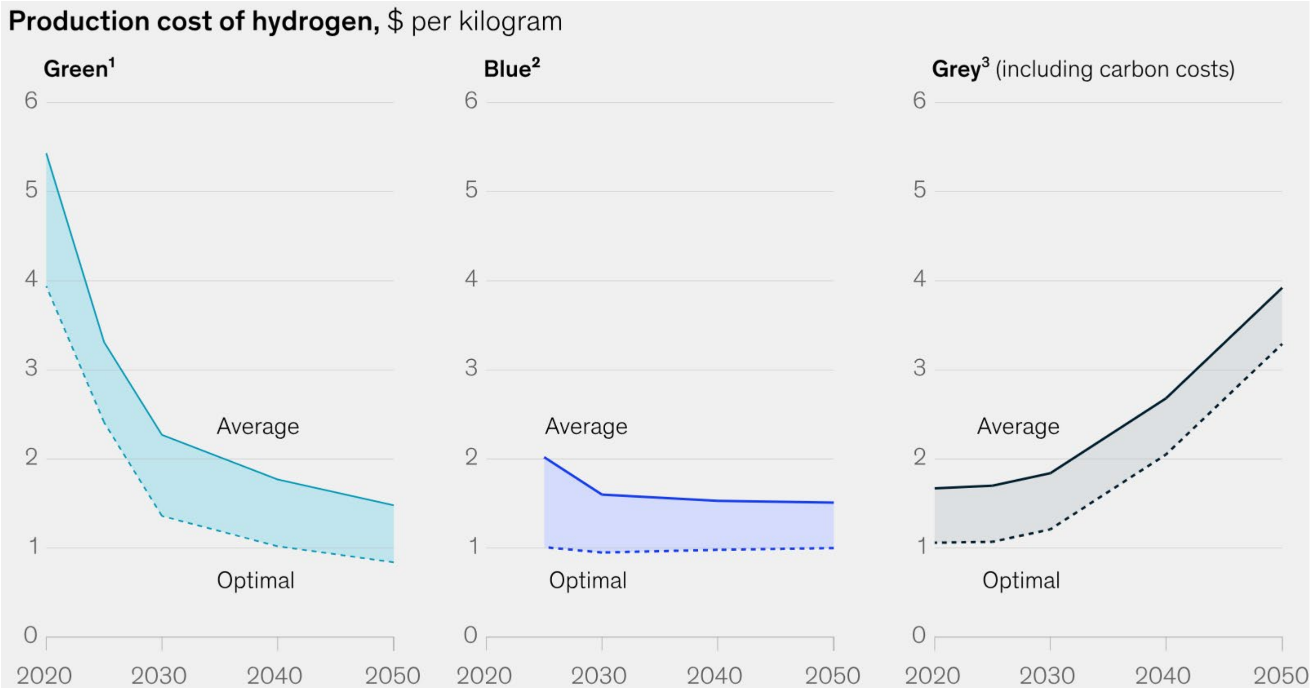


Figure 3: Clean Hydrogen Costs are Expected to Decline Over the Next Decade
Source: *Hydrogen Council Decarbonization Pathways; McKinsey Hydrogen Insights*

Technological Advancements and Government Support Driving Hydrogen Adoption

Recent technological advancements in hydrogen production, storage, and utilization have significantly improved, with only 0.1 percent of global hydrogen production being green. Green hydrogen may be a promising clean energy investment owing to the falling costs of renewable electricity and electrolysis technology. Research has examined low-cost, efficient hydrogen fuel generation, storage, and use methods. Innovations in R&D and support drive innovative technologies like bifacial modules, high-efficiency panels, and energy storage. Lower solar panel costs, technological advancements, and increased environmental awareness demonstrate cost optimization efforts.

India: India's National Green Hydrogen Mission aims to make the country a global leader in green hydrogen production, use, and export. The mission's coalition of Indian and international industry partners focuses on hydrogen production, storage, and industrial clusters. Government policies and incentives, such as India's New Green Hydrogen Policy, help the government meet its climate target and become a green hydrogen hub.

Europe: A concrete strategy propels Europe to the forefront of the hydrogen race. Strong investments are being made by the EU in infrastructure, research, and development. National strategies for hydrogen production that prioritise green hydrogen hubs are among the most ambitious of the member states, including France (€8.2 billion), Germany (€9 billion National Hydrogen Strategy), and Spain (€9 billion). In pursuit of a genuinely global hydrogen economy, their combined objective is to install an enormous 80 GW of electrolyser capacity throughout Europe and Africa, by 2030.

Japan: Prominent advocate of hydrogen for an extended period, Japan is currently engaged in diligent efforts to realize its "hydrogen society" objective. Fuel cell technology (e.g., Toyota's hydrogen-powered coaches for the 2024 Paris Olympics), refuelling stations (e.g., Nippon Kaiji Kyokai's approval of a hydrogen-powered multi-purpose vessel), and green hydrogen production (e.g., collaborating with Australia on lignite-to-hydrogen projects) are all gaining momentum due to substantial government investments. To further diversify their supply chain, they are also piloting the importation of green hydrogen from Brunei.

Korea: Hydrogen is a significant catalyst for economic expansion in South Korea. Massive hydrogen deployment is the focal point of their ambitious hydrogen road map. To ensure that hydrogen vehicles and fuel cells are widely adopted, the government invests significantly in research and development. The establishment of a robust supply chain for these environmentally friendly fuels is the objective of a recent joint hydrogen and ammonia supply network agreement with Japan.

Australia: Clean hydrogen production is a prime candidate for Australia due to its abundant renewable resources. To. Such an undertaking is "H2Perth," which intends to construct and export green hydrogen on a massive scale.

America: Although new, North America is gaining momentum rapidly. Many states, including California, are at the forefront of pursuing the United States' clean hydrogen objectives. "Green Hydrogen Hubs" is a noteworthy example of a California initiative. In contrast, Canada's objective is to establish a "clean hydrogen corridor" that would streamline interprovincial trade and transportation. By utilising Canada's current natural gas pipelines, this corridor would facilitate the transportation of hydrogen.

Challenges and Considerations

The cost competitiveness of hydrogen compared to conventional energy sources is a significant factor, with hydrogen solutions expected to drop by up to 50 percent by 2030. Factors, such as capital, operating, and infrastructure costs are driving hydrogen technology costs, which can be reduced by a third by increasing plant size from 1 MW to 20 MW and further by automating stack.

To reduce the costs of hydrogen technology and enhance profitability, there are various approaches that can be taken. These include utilising digital technology, adopting financial strategies such as diversifying revenue streams, implementing a hydrogen/carbon credit system, and expanding infrastructure development.

Technological and market risks of hydrogen deployment include fires and explosions owing to hydrogen's flammability, high production costs, complex supply chains, and new safety standards. To mitigate these risks, new safety standards, hydrogen-compatible materials, and dedicated leak detectors should be developed.

Future Outlook and Emerging Trends

The global hydrogen market is experiencing rapid growth which is driven by technological advancements, such as green hydrogen production using renewable energy and power-to-gas (P2G) technology. The hydrogen economy has both advantages and disadvantages, including high operational costs, optimal design, and a limited specialized workforce. However, strategic factors like integrating electricity, heat, cooling, and gas systems are crucial for flexibility.

Renewable energy synergies between hydrogen and renewable energy can increase the renewable electricity market's growth and reach. Technological disruptions in the hydrogen economy can affect market competitiveness, industry structure, and value chains. The cost advantages and spread of renewable energy have led to international and regional integration of power networks and markets.

The hydrogen economy's potential is driven by technology, renewable energy synergies, and strategic considerations. Addressing grid integration, system optimization, and market dynamics issues is crucial for its realization.

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Syman Biswas is a Senior Associate Consultant working at iCETS. His main objective revolves around researching various industries for trends and emerging technologies like AI, Blockchain, etc., and their impact on several industries. He is a technology enthusiast who enjoys exploring and learning about new & emerging technologies.

References

- https://ourworldindata.org/energy-production-consumption.
- https://www.energy.gov/eere/articles/hydrogen-clean-flexible-energy-carrier.
- https://h2tools.org/bestpractices/hydrogen-compared-other-fuels.
- https://afdc.energy.gov/fuels/hydrogen_benefits.html.
- https://www.lse.ac.uk/granthaminstitute/explainers/how-important-is-hydrogen-to-climate-action-and-what-are-countries-doing-about-it/.
- https://www.carbonbrief.org/in-depth-qa-does-the-world-need-hydrogen-to-solve-climate-change/.
- https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming.
- https://www.energy.gov/eere/fuelcells/hydrogen-production-biomass-gasification.
- https://www.energy.gov/eere/fuelcells/hydrogen-fuel-basics.
- https://www.fueleconomy.gov/feg/fcv_benefits.shtml.
- https://afdc.energy.gov/fuels/hydrogen_infrastructure.html.
- https://energy.economictimes.indiatimes.com/news/renewable/green-hydrogen-adoption-in-india-opportunities-challenges-and-the-way-ahead/100177937.
- https://expleo.com/global/en/insights/whitepapers/hydrogen-automotive-report-2021/.
- https://www.capgemini.com/in-en/insights/expert-perspectives/hydrogen-the-future-of-automotive-fuel/.
- https://www.forbes.com/sites/forbesbusinesscouncil/2022/09/08/hydrogen-in-oil-refineries-understanding-the-importance-of-hydrogen-monitoring-and-best-practices/.
- https://www.thechemicalengineer.com/features/uses-of-hydrogen-in-industry/.
- https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/May/IRENA_Coalition_Green_Hydrogen_2021.pdf?rev=ffd96aeed97c4d029b01aa3a93131e8b.
- https://www.aurogroup.ac/technology/thenewengineer/hydrogen-engines-mechanical-revolution.
- https://www.energy.gov/eere/fuelcells/articles/fuel-cells-stationary-power-applications.
- https://www.pv-magazine.com/2022/04/15/the-hydrogen-stream-fuel-cell-engines-for-stationary-power-uses/.
- https://smartgrid.ieee.org/bulletins/march-2023-1/grid-integration-of-hydrogen-electrolyzers-and-fuel-cells-opportunities-challenges-and-future-directions.
- https://www.scientificamerican.com/article/solar-and-wind-power-could-ignite-a-hydrogen-energy-comeback/
- https://www.iea.org/reports/global-hydrogen-review-2023

- https://www.globenewswire.com/en/news-release/2022/10/25/2541206/0/en/Global-Hydrogen-Generation-Market-Size-to-grow-USD-230-81-Billion-by-2030-CAGR-of-6-6.html.
- https://www.hydrogeninsight.com/analysis/review-of-2023-the-key-developments-and-trends-in-the-global-hydrogen-sector-part-1-production-/2-1-1574671.
- https://www.mckinsey.com/capabilities/sustainability/our-insights/five-charts-on-hydrogens-role-in-a-net-zero-future.
- https://web-assets.bcg.com/bc/82/a99c71144a60aa435736f574cffe/bcg-infrastructure-strategy-2023-building-the-green-hydrogen-economy-mar-2023-r.pdf
- https://www.deloitte.com/global/en/about/press-room/new-deloitte-report-emerging-green-hydrogen-market.html

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