HYDROGEN REVOLUTION

A comprehensive look at Hydrogen Energy

In the global pursuit of NET-ZERO EMISSIONS, *hydrogen is poised to assume a pivotal role of significant prominence. Net zero refers to an ideal state where the* NUMBER OF GREENHOUSE-GAS EMISSIONS *released into the atmosphere is equal to the amount removed. To prevent a permanent and catastrophic warming of the planet, all industries must achieve net zero.*

IN BRIEF:

- The anticipated need for hydrogen by the year 2050 might range between 150 and 500 million metric tonnes annually.
- The anticipated variability is contingent upon the extent of worldwide climate goals, the progress of industry-specific initiatives, the implementation of energy-efficient practices, the adoption of direct electrification, and the utilization of carbon capture technologies.
- Investors are becoming increasingly interested in the potential of hydrogen to play a significant role in the shift towards a low-carbon economy.
- While the exact role of hydrogen in the energy transition and the feasibility of scaling up production and usage remain uncertain, a spectrum of potential investment opportunities is emerging, particularly in the commodities, utilities, and capital goods sectors.

[1]Hydrogen serves as an environmentally friendly fuel, generating only water when used in a fuel cell. Its production can be sourced from diverse domestic resources like natural gas, nuclear power, biomass, and renewable sources such as solar and wind. These characteristics make it a compelling choice for fuel in applications related to transportation and electricity generation.

Hydrogen finds utility in various settings, including cars, homes, portable power, and numerous other applications. Furthermore, hydrogen operates as an energy carrier, facilitating the storage, transportation, and delivery of energy generated from alternative sources.

HISTORICAL CONTEXT

The 20th century saw a significant shift in the use of hydrogen with the development of the hydrogen-oxygen fuel cell by Sir William Grove in 1839. This laid the groundwork for the utilisation of hydrogen as a potential energy carrier. During World War II, hydrogen gained strategic importance as a lift gas for military airships.

In the latter half of the 20th century, there was a growing interest in hydrogen as a potential clean fuel. NASA's use of hydrogen as rocket fuel in the

[1] International Energy Agency, "Hydrogen", IEA (Paris, 2022). https://www.iea.org/reports/hydrogen

Apollo program and subsequent space missions demonstrated its high energy content and efficiency.

As concerns about environmental issues and sustainable energy grew in the late 20th century and early 21st century, hydrogen emerged as a key player in discussions about clean and renewable energy. The development of hydrogen fuel cells for powering vehicles gained momentum, and governments and industries started exploring hydrogen's potential in addressing energy challenges.

MARKET TREND

The market analysis reveals a significant upward trend in the demand and production of hydrogen across diverse sectors, as depicted in the accompanying figure.

Of particular significance is the observed rise in demand for low-carbon hydrogen, intended to replace conventional fossil fuel sources. Forecasts indicate that in the transportation sector alone, hydrogen is projected to satisfy more than 40% of global demand by 2050.

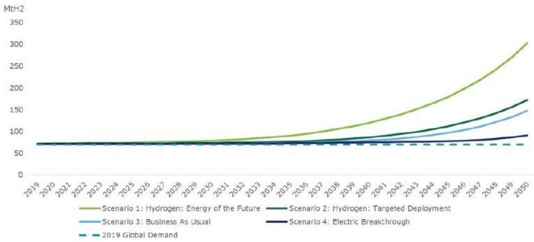


EXHIBIT 1: DELOITTE, GLOBAL HYDROGEN DEMAND

The utilisation of hydrogen has experienced significant growth in major consumption regions worldwide, with the exception of Europe. In Europe, the use of hydrogen faced substantial setbacks due to decreased activity, particularly within the chemical industry. This downturn resulted from a notable surge in natural gas prices triggered by the energy crisis stemming from Russia's invasion of Ukraine. Numerous fertiliser plants curtailed production or halted operations for extended periods during the year, leading to a nearly 6% reduction in hydrogen usage in the region.

In contrast, North America and the Middle East witnessed robust growth, approximately 7% in both cases, which more than offset the decline observed in Europe.

In 2022, industrial plants produced approximately 285 kilotons of low-emission hydrogen, an increase from the 240 kilotons recorded in 2021. Over 90% of this production capacity is dependent on fossil fuels with carbon capture, utilisation, and storage (CCUS) technologies. These installations are distributed across North America, the Middle East, and China. Since the release of the GHR 2022, there has been minimal advancement in hydrogen production through electrolysis.

Only three relatively modest projects became operational in 2023, including one in Spain (utilising 8 MW of electrolysis to replace natural gas with hydrogen), one in Sweden (employing 17 MW of electrolysis for heating steel before rolling), and one in India (using 5 MW of electrolysis for methanol production).

> "GLOBAL HYDROGEN USE REACHED *95 MT IN 2022* WITH *STRONG GROWTH* IN ALL MAJOR CONSUMING REGIONS, EXCLUDING EUROPE"

Europe suffered a hit to industrial activity due to the sharp increase in natural gas prices.

TRANSITIONING TO SUSTAINABLE ENERGY SOURCES

Transitioning to sustainable energy sources is crucial for addressing pressing environmental, economic, and geopolitical challenges. It reduces greenhouse gas emissions, mitigates climate change, enhances energy security, fosters innovation and job creation, and promotes long-term economic stability. Embracing sustainable energy sources is a key step towards building a resilient and environmentally responsible global energy infrastructure for future generations.

UNDERSTANDING HYDROGEN ENERGY

The predominant technique for hydrogen generation presently involves natural gas reforming, wherein steam and natural gas undergo a reaction facilitated by a catalyst. This procedure, constituting 47% of the overall hydrogen production in 2021, yields 'grey' hydrogen along with by-products of carbon dioxide and carbon monoxide, both contributing to global warming.

On the other hand, electrolysis currently represents a minor fraction of hydrogen production, amounting to only 4% in 2021. The greenhouse gas emissions resulting from electrolysis depend on the source of the electricity used in the process.

Exibit 1: Deloitte Australia and Global Hydrogen Demand Growth Scenario Analysis, Nov 2019, COAG Energy Council - National Hydrogen Strategy Taskforce
[3] IEA (2023), Global Hydrogen Review 2023, IEA, Paris https://www.iea.org/reports/global-hydrogen-review-2023, License: CC BY 4.0

EXHIBIT 2: DIFFERENT FORMS OF HYDROGEN

COLOUR	BROWN	GREY	BLUE	TURQUOISE	YELLOW	PINK	GREEN
ENERGY SOURCE	Black/brown coal	Natural Gas	Natural Gas	Natural Gas	Mixed origin grid energy	Nuclear	Wind, solar, hydro, geothermal
TECHNOLOGY	Gasification	Natural Gas Removing	Natural Gas Removing + Carbon capture	Pyrolysis	Electrolysis	Electrolysis	Electrolysis

Electrolysis powered by electricity derived from renewable sources is the essential method to be expanded for the increased production of 'green' hydrogen.

DIFFERENT FORMS OF HYDROGEN

Green hydrogen, also known as "clean hydrogen," is manufactured by utilising clean energy derived from surplus renewable sources like solar or wind power. This process, known as electrolysis, involves splitting water into two hydrogen atoms and one oxygen atom. also known as "clean hydrogen," is manufactured by utilising clean energy derived from surplus renewable sources like solar or wind power.

Blue hydrogen receives its designation when the carbon produced during steam reforming is captured and sequestered underground using industrial carbon capture and storage (CCS) techniques.

This categorisation as blue stems from the containment of emissions beneath the Earth's surface, rendering it, in some contexts, as carbon neutral. Nevertheless, there is a viewpoint suggesting that labelling it as "low carbon" might be more precise, given that 10-20% of the generated carbon remains un-captured.

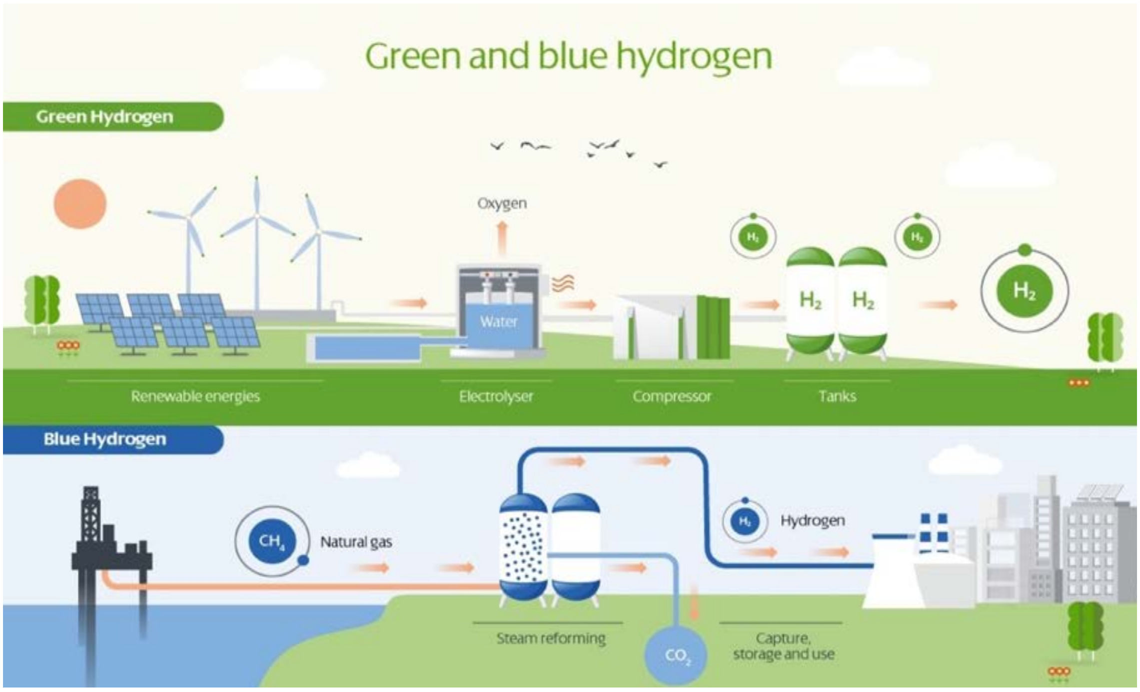
Grey hydrogen stands out as the prevailing variant and is produced from natural gas, also known as methane, using the technique of "steam reforming."

This method results in emissions that are relatively lower compared to black or brown hydrogen, where **black** (derived from bituminous coal) or **brown** (derived from lignite coal) coal is employed in the hydrogen production process.

HYDROGEN PRODUCTION METHODS

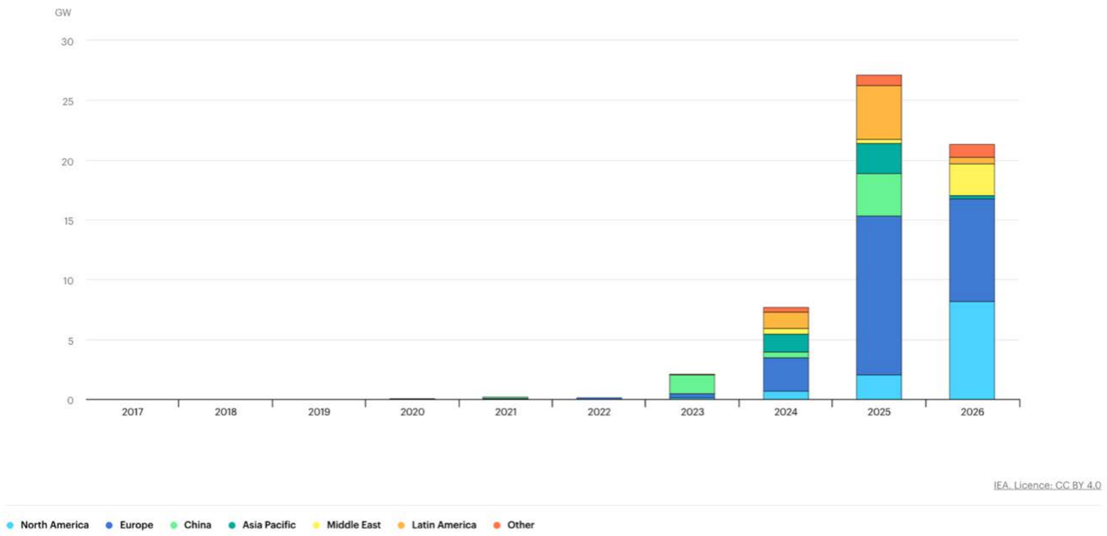
Electrolysis
Electrolysis is the process of using an electric current to split water (H2O) into hydrogen (H2) and oxygen (O2).

EXHIBIT 3: DIFFERENCE BETWEEN BLUE AND GREEN HYDROGEN



[4] Difference between green and blue hydrogen https://www.iberdrola.com/about-us/what-we-do/green-hydrogen/difference-hydrogen-green-blue

EXHIBIT 4 - CAPACITY ADDITIONS FOR HYDROGEN ELECTROLYSIS PROJECTS BY ANNOUNCED START DATE, 2017-2026



- Mechanism: Water is usually split into hydrogen and oxygen at the anode and cathode, respectively, in an electrolyser. The most common types are alkaline electrolysis, polymer electrolyte membrane (PEM) electrolysis, and solid oxide electrolysis cells (SOEC).
- Advantages:
  - o Zero greenhouse gas emissions if powered by renewable energy.
  - o Flexible and scalable for various applications.
- Challenges:
  - o Relatively high energy consumption.
  - o Initial capital costs can be significant.

Steam Methane Reforming (SMR)

Steam methane reforming is a method of producing hydrogen from natural gas (methane) through a chemical reaction with steam.

- Mechanism: Methane and steam are reacted at high temperatures (700-1100°C) and pressure in the presence of a catalyst, leading to the production of hydrogen and carbon monoxide.
- Advantages: Established and widely used method. Cost-effective at a large scale.
- Challenges: Produces carbon dioxide as a by-product, contributing to greenhouse gas emissions. This requires a constant supply of natural gas.

Biological Hydrogen Production

- Process: Uses micro-organisms or algae to produce hydrogen through biological processes like fermentation or photosynthesis.
- Advantages: Can use organic waste as a feedstock.
- Challenges: Efficiency and scalability are often limiting factors.

Thermochemical Water Splitting

- Process: Involves the use of heat to drive chemical reactions that result in the separation of hydrogen from water or other feedstock.

Coal Gasification

- Process: Converts coal into a synthesis gas (syngas) consisting of hydrogen, carbon monoxide, and other gases.
- Advantages: Utilises coal resources.
- Challenges: Produces carbon dioxide and other pollutants.

UREA AND THE IMPORTANCE OF HYDROGEN

Urea is an essential compound in agriculture, primarily used as a fertiliser due to its high nitrogen content. The production of urea involves the reaction of ammonia (NH3) with carbon dioxide (CO2) under high pressure and temperature in the presence of a catalyst, typically iron. Hydrogen plays a crucial role in the production of urea in several ways:

Ammonia Synthesis

The Haber-Bosch process, which is used to produce ammonia, relies on hydrogen as one of its primary reactants. Hydrogen reacts with nitrogen to form ammonia according to the equation: N2 + 3H2 =>2NH3. Ammonia is a precursor for urea production.

Urea Synthesis

In the production of urea, ammonia is combined with carbon dioxide to form urea and water. The reaction involves the use of hydrogen in the synthesis of ammonia, which is then utilised in the urea synthesis process.

[5] Source - IEA, Capacity additions for hydrogen electrolysis projects by announced start date, 2017-2026, IEA, Paris https://www.iea.org/data-and-statistics/charts/capacity-additions-for-hydrogen-electrolysis-projects-by-announced-start-date-2017-2026, IEA. Licence: CC BY 4.0

Hydrogen as a Feedstock
Hydrogen can also serve as a feedstock for various processes involved in urea production. It can be used in hydrogenation reactions to purify raw materials or remove impurities, improving the efficiency and quality of urea production.

The importance of hydrogen in urea production underscores its significance not only in agriculture but also in the broader context of industrial processes.

USES OF HYDROGEN

TRANSPORTATION

Hydrogen Fuel Cells in Vehicles
Hydrogen fuel cells are electrochemical devices that convert hydrogen and oxygen into electricity, with water vapor as the only by-product.

In the transportation sector, these fuel cells are used to power vehicles, providing a clean alternative to traditional internal combustion engines. Advantages include zero-emission operation, longer driving ranges, and shorter refuelling times compared to electric vehicles relying solely on batteries.

Advancements in Hydrogen-Powered Transportation
Ongoing research and development efforts focus on improving the efficiency and affordability of hydrogen-powered vehicles.

Innovations include advancements in fuel cell technology, the development of lightweight and durable hydrogen storage solutions, and the establishment of a comprehensive refuelling infrastructure.

INDUSTRY

Hydrogen in Manufacturing Processes
Industries such as steel and glass manufacturing utilise hydrogen as a reducing agent in various processes. It can replace conventional fossil fuels, contributing to lower carbon emissions and sustainable industrial practices.

Hydrogen's high heat conductivity and reactivity make it valuable in metal production and other industrial applications.

Use of Hydrogen in Refining and Chemical Industries
Hydrogen is a crucial feedstock in the production of ammonia, methanol, and various chemicals. It is used in hydrocracking and desulfurisation processes in oil refining, enhancing the quality of refined products.

The versatility of hydrogen in chemical reactions makes it a key component in the synthesis of a wide range of industrial chemicals.

POWER GENERATION

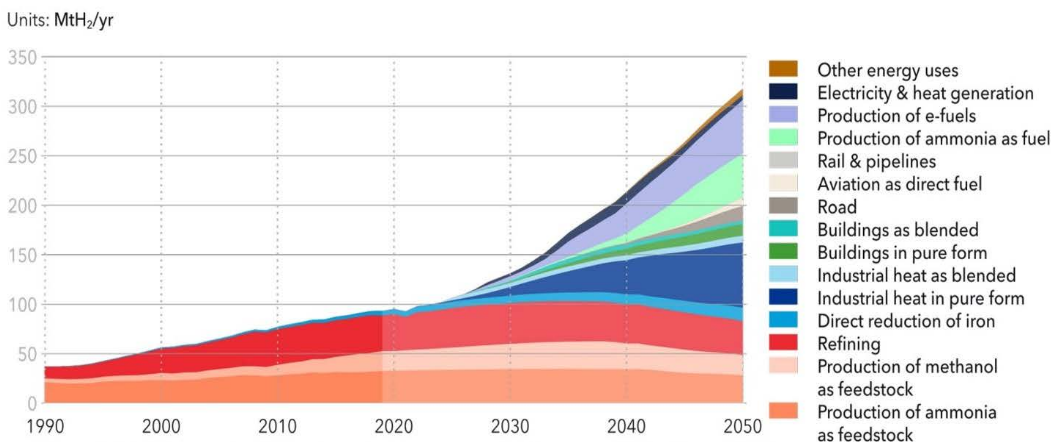
Hydrogen as a Clean Fuel for Power Plants
Hydrogen can be used as a fuel in gas turbines and engines for power generation. This process emits only water vapor as a by-product, making it a clean and environmentally friendly energy source.

Power plants utilising hydrogen can play a role in providing reliable and dispatchable electricity while minimising environmental impact.

Integration with Renewable Energy Sources
Hydrogen serves as a storage medium for excess energy generated from renewable sources like wind and solar. Through a process called electrolysis, surplus electricity is used to split water into hydrogen and oxygen.

This stored hydrogen can be later converted back into electricity through fuel cells or used directly in industrial processes, providing a means to balance the intermittent nature of renewable energy.

EXHIBIT 5 - DELOITTE, INDUSTRY UTILISATION GROWTH



[5] Deloitte, Australian & Global Hydrogen Demand Growth Scenario Analysis, IEA Future of Hydrogen (2019), IAE Global Hydrogen Review (2021) USGS Mineral Commodity Summaries (1990-2022), IFA (2022)
[6] IEA, Paris https://www.iea.org/data-and-statistics/charts/capacity-additions-for-hydrogen-electrolysis-projects-by-announced-start-date-2017-2026, IEA. Licence: CC BY 4.0

ADVANTAGES OF HYDROGEN ENERGY

ZERO EMISSIONS

Environmental Benefits
One of the primary advantages of hydrogen energy is its potential for zero emissions during use. When hydrogen is used in fuel cells to generate electricity, the only by-product is water vapor. This contrasts sharply with traditional fossil fuels, such as coal or natural gas, which release carbon dioxide and other pollutants into the atmosphere.

Contribution to Mitigating Climate Change
Hydrogen's zero-emission profile aligns with global efforts to combat climate change.
By replacing conventional, carbon-intensive energy sources, hydrogen contributes significantly to reducing greenhouse gas emissions, making it a key player in the transition to a more sustainable energy landscape.

Energy Density
Comparisons with Other energy carriers, Hydrogen boasts high energy density meaning it can store anddeliver large amounts of energy in a relatively small volume. This is particularly advantageous for applications where space is limited, such as in transportation, where hydrogen fuel cells can provide longer ranges compared to batteries.

Suitability for Various Applications
The high energy density of hydrogen makes it versatile for a wide range of applications. It can be used not only in fuel cells for vehicles but also in industrial processes and power generation. This versatility allows hydrogen to address diverse energy needs across different sectors.

VERSATILITY

Flexibility in Storage and Transportation
Hydrogen can be stored and transported in various forms, including gas, liquid, or even as compounds like ammonia. This flexibility in storage and transportation allows for efficient distribution and utilisation across different industries and geographical locations. Transportation requires significant safety precautions.

Potential for Grid Balancing and Energy Storage
Hydrogen can play a crucial role in balancing the variability of renewable energy sources like wind and solar. Excess electricity generated during peak renewable energy production periods can be used to produce hydrogen through electrolysis.

This hydrogen can then be stored and later used to generate electricity when renewable energy production is low, acting as a form of energy storage and contributing to grid stability.

V. CHALLENGES AND DISADVANTAGES

PRODUCTION CHALLENGES

Cost Implications
The production of hydrogen, particularly through methods like electrolysis, can be economically challenging. The costs associated with the necessary technologies and infrastructure can be high, impacting the competitiveness of hydrogen against other energy sources.

Integrated Energy CEO, David Cavanagh stated "the cost challenge is being actively addressed with the development of enhanced technologies and scaling deployment, so that there are now hydrogen technologies which competitive as well as sustainable in applications particularly in transport and power generation."

Energy-Intensive Production Methods
Common methods like steam methane reforming require significant energy input. This raises concerns about the environmental impact and overall efficiency of hydrogen production, especially when the energy used comes from non-renewable sources.

STORAGE AND TRANSPORTATION

Safety Concerns
Hydrogen is a highly flammable gas, and its storage and transportation pose safety challenges. Ensuring the safe handling of hydrogen throughout its lifecycle, from production to end-use, requires stringent safety measures and regulations.

Cavanagh stated "The safety performance of the hydrogen industry in transportation in the modern era is good with more than 72,000 vehicles on the road worldwide and more than 1000 hydrogen refueling stations, and continuing improvements in hydrogen safety standards and protocols globally."

Infrastructure Requirements
The existing infrastructure for storing and transporting hydrogen is limited. Developing a comprehensive and widespread infrastructure, including pipelines and storage facilities, involves considerable investments and poses logistical challenges.

ECONOMIC AND REGULATORY HURDLES

Government Policies and Incentives
The successful adoption of hydrogen energy depends on supportive government policies and incentives. Inconsistent or inadequate policies can hinder investment and slow down the growth of

6 IEA, Capacity additions for hydrogen electrolysis projects by annunced start date, 2017-2026, IEA, Paris https://www.iea.org/data-and-statistics/charts/capacity-additions-for-hydrogen-electrolysis-projects-by-announced-start-date-2017-2026, IEA. Licence: CC BY 4.0
7 https://www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy
7.2 Package for the future – Hydrogen Strategy, May 2023, https://www.iea.org/policies/11561-package-for-the-future-hydrogen-strategy

the hydrogen sector. Clear and stable regulatory frameworks are essential for encouraging private sector involvement.

Market Dynamics and Competition
Hydrogen must compete with established and often cheaper energy sources. The market dynamics include the availability and pricing of alternative energy carriers, impacting the growth of the sector. Competing with conventional fuels may be a hurdle, especially in regions where fossil fuels are deeply entrenched in existing energy systems.

VI. GLOBAL TRANSITION TO A HYDROGEN ECONOMY

NATIONAL STRATEGIES

The global transition to a hydrogen economy involves various countries developing and implementing strategies to harness hydrogen as a key component of their energy landscape. Several leading nations are actively shaping national strategies to integrate hydrogen into their energy mix, driven by the need for sustainable and low-carbon energy solutions.

Some of the key players in the global transition to a hydrogen economy include;

Australia boasts the largest pipeline in the world as outlined in Feburary 2023 in the National Hydrogen Strategy. The Energy and Climate Change Ministerial Council (ECMC) agreed to a Review of the 2019 National Hydrogen Strategy to ensure it positions Australia on a path to be a global hydrogen leader by 2030 on both an export basis and for the decarbonisation of Australian industries.

> "AUSTRALIA BOASTS *$300 BILLION* OF POTENTIAL HYDROGEN *INVESTMENTS*, DOMESTIC AND LARGE EXPORT PROJECTS"

The focus areas for Australian investment are industry, transport, grid firming, chemicals and metals production. There are up to *AU$300 billion* of potential hydrogen investments, including projects that are focussed on domestic use as well as large export projects.7

Cavanagh emphasises "the notable recent commitments include FID on the Fortescue PEM50 large scale hydrogen production in Queensland commencing in 2025, and the Federal government commitments to the Townsville Hydrogen Hub in Queensland announced by the Prime Minister ($60 million) and the $140 million committed to support the Pilbara Hydrogen Hub, to be in production in 2028."

Germany has been a pioneer in promoting hydrogen with a target of production capacity of 10 GW built by 2040. The ambitious target is met with *EUR 7 billion* in government investments earmarked for developing green hydrogen. This includes a *EUR 2 billion* to establish international trade partnerships with countries with more favourable production conditions for green hydrogen, and build large production facilities using German technologies. 7.2

Japan has a strong focus on hydrogen as a key element in its energy future. The Basic Hydrogen Strategy, launched in 2017, envisions Japan as a "hydrogen society." Prioritising both green and blue hydrogen production, with an emphasis on international collaboration and partnerships. There has been significant investment made in hydrogen-related R&D and infrastructure development.

South Korea's Hydrogen Economy Roadmap, introduced in 2019, outlines plan for hydrogen expansion. Targets include a substantial increase in hydrogen production capacity and widespread adoption in various sectors. Focus on fostering international partnerships and collaborations for technology exchange. The Roadmap outlines goal of producing 6.2 million fuel cell electric vehicles and rolling out at least 1200 refilling stations, 41000 hydrogen buses by 2040.7.3

China has integrated hydrogen into its broader clean energy goals. The 14th Five-Year Plan (2021-2025) emphasises the development of a hydrogen economy. China targets to bring 50,000 hydrogen fuel-cell vehicles on the road by 2025 and to build a number of hydrogen refuelling stations.

The plan targets green hydrogen production using renewable feedstock resources to reach 100,000-200,000 tonnes per year by 2025. The strategy aims to scale up both green and blue hydrogen production capacities. Substantial investments in R&D and infrastructure to support hydrogen utilisation.7.4

The United States are actively developing its hydrogen strategy as part of its commitment to decarbonisation. In 2021, Congress passed a Bipartisan Infrastructure Law (BIL) authorising US$62 billion for the U.S. Department of Energy (DOE), including US$9.5 billion for clean hydrogen.

The roadmap includes target strategic, high-impact uses for clean hydrogen. Specific markets include the industrial sector (e.g., chemicals, steel and refining),

7.3 Korea Hydrogen Economy Roadmap 2040, https://www.iea.org/policies/6566-korea-hydrogen-economy-roadmap-2040
7.4 IEA, Hydrogen Industry Development Plan (2021-2035), https://www.iea.org/policies/16977-hydrogen-industry-development-plan-2021-2035
7.5 U.S. National Clean Hydrogen Strategy and Roadmap, https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap
Exhibit 5 IEA, Global hydrogen demand in the Net Zero Scenario, 2022-2050, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-hydrogen-demand-in-the-net-zero-scenario-2022-2050, IEA. Licence: CC BY 4.0

heavy duty transportation, and long-duration energy storage to enable a clean grid.

Initiatives like the Hydrogen Energy Earth shot created to reduce the cost of clean hydrogen by addressing critical material and supply chain vulnerabilities and design for efficiency, durability, and recyclability. Together with investment in midstream infrastructure (storage, distribution). 7.5

RESEARCH AND DEVELOPMENT

ONGOING PROJECTS AND ADVANCEMENTS IN HYDROGEN TECHNOLOGY

Currently, the majority of globally produced hydrogen is classified as "grey," originating from natural gas. In the absence of a carbon emissions pricing mechanism, grey hydrogen is cost-effective (€1 to €2 per kilogram). However, this exacerbates the challenge of enhancing environmental sustainability.

On the other hand, green hydrogen utilises renewable electricity for electrolysis, breaking down water molecules into hydrogen and oxygen. Because green hydrogen doesn't rely on fossil fuels, it presents a more sustainable long-term solution for decarbonising economies. Nevertheless, green hydrogen, with current costs ranging from €3 to €8/kg in certain regions, is more expensive than its grey counterpart.

> “26 COUNTRIES HAVE *COMMITTED* TO *INTEGRATING* HYDROGEN INTO THEIR FUTURE ENERGY SYSTEMS”

The most favourable markets for green hydrogen production are those with abundant, cost-effective renewable resources. [8]Regions like the Middle East, Africa, Russia, the US, and Australia, for instance, could potentially produce green hydrogen for €3 to €5/kg presently. In Europe, production costs vary from €3 to €8/kg, with the lower end of this spectrum achievable in locations with access to low-cost renewable energy plants.

However, it is anticipated that production costs will decrease over time, driven by the continual decline in renewable energy production costs, economies of scale, insights gained from ongoing projects, and technological advancements.

Consequently, the economic viability of green hydrogen is expected to improve. Cavanagah states that in many cases this means that green hydrogen can outperform the grey alternative over the project lifecycle when economics and environmental aspects are considered.

GLOBAL POLICY AND REGULATORY SUPPORT FOR HYDROGEN

Governments have established targets for the implementation of hydrogen technologies in both existing and new applications, with a particular focus on industry and transportation. For instance, [9]Japan is striving to achieve a presence of 800,000 Fuel Cell Electric Vehicles (FCEVs) on roads by 2030, while the European Union is aiming to satisfy 42% of industrial hydrogen demand through renewable fuels of non-biological origin (RFNBOs) by the same deadline.

While these targets convey a commitment to hydrogen adoption, they alone are insufficient to motivate market players to significantly increase the use of low-emission hydrogen due to the associated higher costs. To foster a conducive investment environment, it is crucial to implement robust policies and regulations, extending beyond mere target-setting.

Such measures should include both supportive initiatives to encourage project developers and penalties for non-compliance. Various potential support measures exist to stimulate demand for low-emission hydrogen in both traditional and emerging applications.

These measures range from prioritising hydrogen and hydrogen-based fuels, such as mandates for low-emission hydrogen in existing applications, to technology-neutral sectoral approaches that emphasise overall decarbonisation.

An example of the latter is the use of Carbon Contracts for Difference (CCfD), wherein the government covers the cost difference between the CO2 abatement expenses of a project and a CO2 reference price, leaving the selection of emission reduction technology to the discretion of the project developer.

To date, the political attention directed towards hydrogen has not yielded significant gains for investors. However, a shift may be on the horizon following recent policy announcements and updates in national energy strategies. The emphasis by policymakers on promoting clean hydrogen production and deployment serves as a crucial foundation for investment decisions, potentially paving the way for a rapid expansion of opportunities.

National objectives and targets have manifested as

7.5 U.S. National Clean Hydrogen Strategy and Roadmap, https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap
[8] Green hydrogen economy - predicted development of tomorrow. (n.d.). PwC. https://www.pwc.com/gx/en/industries/energy-utilities-resources/future-energy/green-hydrogen-cost.html
[9] IEA (2023), Global Hydrogen Review 2023, IEA, Paris https://www.iea.org/reports/global-hydrogen-review-2023, License: CC BY 4.0

policies in 26 countries committed to integrating hydrogen into their future energy systems.

Noteworthy policy developments include subsidies and tax breaks, such as the US Inflation Reduction Act (IRA), which offers production tax credits of up to USD 3 per kilogram for eligible hydrogen production.

This incentive could position low-carbon hydrogen competitively against steam methane reformation-produced hydrogen, consequently driving the adoption of electrolysers. Even prior to these incentives, the International Energy Agency (IEA) projected a potential 30% reduction in the cost of green hydrogen by 2030, attributed to declining renewable costs and the expansion of hydrogen production.

Various regions are actively encouraging direct investments in hydrogen. For instance, the European Union has established a [10]Hydrogen Bank and allocated EUR 3.6 billion to 41 clean energy projects, with a significant portion earmarked for hydrogen initiatives. Similarly, the UK's Powering Up Britain plan has allocated GBP 240 million to a Net Zero Hydrogen Fund, aimed at supporting the expansion of small and innovative projects.

While addressing the need for clarity and standardisation, efforts are underway to enhance market interoperability and eliminate barriers to increased production. [11]A recent report by the IEA called for an internationally agreed framework based on emissions intensity, moving away from the impractical colour-based classification scheme currently used for hydrogen. This shift is seen as essential for creating a more practical basis for contracts underpinning investments.

Also in 2023 the World Trade Organisation (WTO) released a world hydrogen trade toolkit with practical guidance and tools to reduce barriers to the efficient flow, enhance world trade, including related services and capital for hydrogen following support from Integrated Energy, with éthica capital.

While the exact role of hydrogen in the energy transition and the feasibility of scaling up production and usage remain uncertain, it is clear that tangible project commitments are now being made across a spectrum of potential investment opportunities, particularly in the commodities, utilities, transportation and capital goods sectors.

FUTURE PROSPECTS AND EMERGING TRENDS

It is anticipated that until 2030, there will be a gradual and consistent increase in hydrogen demand driven by diverse applications within the industrial, transportation, energy, and building sectors.

Collaborative efforts across different industries will lead to the formation of new partnerships for the advancement of hydrogen projects. [12]The costs associated with hydrogen production are anticipated to witness a significant reduction of approximately 50% by 2030, followed by a continual decline, albeit at a slightly slower pace, until 2050.

[13]Projections suggest that, by 2050, the production costs for green hydrogen in select regions such as the Middle East, Africa, Russia, China, the US, and Australia will range between €1 to €1.5 per kilogram. Conversely, regions with limited renewable resources, such as significant parts of Europe, Japan, or Korea are expected to have production costs around €2 per kilogram, potentially leading them to import green hydrogen from other areas.

Even regions blessed with abundant renewable resources but constrained by densely populated areas may resort to hydrogen importation due to limitations on producing green electricity for immediate consumption or conversion to hydrogen. Notably, several large countries, including the US, Canada, Russia, China, India, and Australia, exhibit both competitive and non-competitive hydrogen production regions, fostering the possibility of establishing domestic trading within these nations.

The global landscape is likely to witness the emergence of export and import hubs akin to existing oil and gas hubs, albeit with the participation of new stakeholders situated in renewable-rich regions.

éthica capital and Greenco. membership

Australia has positioned itself as a key player in the hydrogen global trade landscape, boasting half of the trade projects by export volume. This is owed to its rich renewable resources and strategic proximity to the burgeoning Asian market, poised to become a major importer of low-emission hydrogen and hydrogen-based fuels.

The confluence of supportive government policies and the strategic initiatives of project developers is driving a substantial influx of capital into the low-emission hydrogen sector. Notably, the IEA Global Hydrogen Review 2023 report indicates that spending on electrolyser installations hit an unprecedented milestone in 2022,

[11] JP Morgan, The Role of hydrogen in energy transition, October 2023, https://am.jpmorgan.com/content/dam/jpm-am-aem/global/en/sustainable-investing/jpm54375-pi-hydrogen-s-role-in-energy-transition-v8.pdf
[12] Green hydrogen economy - predicted development of tomorrow. (n.d.). PwC. https://www.pwc.com/gx/en/industries/energy-utilities-resources/future-energy/green-hydrogen-cost.html
[13] Green hydrogen economy - predicted development of tomorrow. (n.d.). PwC. https://www.pwc.com/gx/en/industries/energy-utilities-resources/future-energy/green-hydrogen-cost.html

reaching AUD 0.9 billion globally double the 2021 value based on operational and under-construction projects.

An additional USD 0.7 billion was invested in 2022 for projects under construction, particularly those focusing on producing low-emission hydrogen with carbon capture, utilisation, and storage (CCUS). These investments are projected to culminate in reaching the envisioned AUD 61 billion spending on electrolyser installations by 2030, as outlined in the Net Zero Emissions by 2050 Scenario.

The innovative landscape is thriving, with start-ups or scale-ups dedicated to hydrogen-related technologies and businesses securing record-breaking amounts of early and growth-stage equity in 2022. Early-stage deals, totaling AUD 990 million, matched the stellar performance of 2021, marking nearly a fivefold increase from 2020. Meanwhile, growth- stage funding, requiring more substantial capital but supporting less risky innovation, more than doubled to AUD 4.5 billion. Notably, this achievement is even more remarkable considering the mere 1% overall increase in growth-stage equity funding for energy firms, which reached AUD 51 billion. The trajectory signals a promising and robust future for Australia's position in the global hydrogen market.

With a growing demand for Hydrogen and emergence of Hydrogen related technologies, build your project with equity, debt or non-dilutive funding with éthica capital.

éthica capital, Green Bond Corporation SARL (GBC) and Carbon Capital Corporation (CCC) form part of The Green Bond Corporation Group (GBC Group). Combining deep expertise and global thought leadership in sustainable finance, infrastructure development and carbon-based financing. Collectively combining technical expertise and funding that aligns with your environmental and humanitarian goals, empowering your business to achieve greater success and create a meaningful positive impact.

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