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# Hydrogen's New Horizon—Scaling Up Clean Hydrogen for the Power Sector

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The use of hydrogen as a fuel source dates back nearly 200 years, when it powered nineteenth-century air balloon travel. Later, it became important as a chemical feedstock. Today, it holds potential as one of the most promising fuels of the future. The expanded use of hydrogen is receiving increasing support from governments and the private sector to green industrial processes and power generation.

## WHY HYDROGEN?

Demand for hydrogen has increased steadily since the 1970s for oil refining and fertilizer production. But in recent years, with the growing urgency to address climate change, there has been heightened attention to hydrogen given its climate change abatement potential. Hydrogen can be produced and burned with zero emissions, helping to decarbonize hard-to-abate sectors such as power, mining, and long-haul transport, as well as heat-intensive industrial processes like metal smelting and refining.

This new horizon for hydrogen is predicated on the use of “green” hydrogen—produced by splitting hydrogen from oxygen in water through electrolysis using renewable energy—as part of the clean energy transition. Green hydrogen is distinct from the conventional types of hydrogen, including “grey,” extracted by splitting natural gas into hydrogen and carbon dioxide (with the $CO_2$ released into the atmosphere); “brown,” sourced from coal; and the low emission "blue," coupling "grey" with carbon capture, utilization, and storage (CCUS). In addition to being a robust technological approach to creating a reliable, affordable, and clean energy system, it complements renewal energy generation, such as solar and wind, by reducing their intermittency drawbacks.

Commercial viability for green hydrogen remains elusive, however. Most conventional hydrogen production stems from fossil fuels such as natural gas and coal. Encouragingly, clean hydrogen is enjoying unprecedented political and private sector support. For example, Japan is targeting zero greenhouse gas emissions by 2050, and the European Union (EU) aims to become a climate-neutral zone by then as well. The EU’s implementing ambitious plans for hydrogen as part of its energy transformation strategy laid out by the European Commission in 2020. One of the ways this strategy aims to boost clean hydrogen use is by creating critical mass in supply, targeting a sixfold growth in the installed capacity of green hydrogen electrolyzers within the decade.

The private sector has been moving, too, with the formation of several coalitions, including some led by IFC clients, with an overall objective to create critical demand for hydrogen while looking to achieve economies of scale and production cost reduction on the supply side.

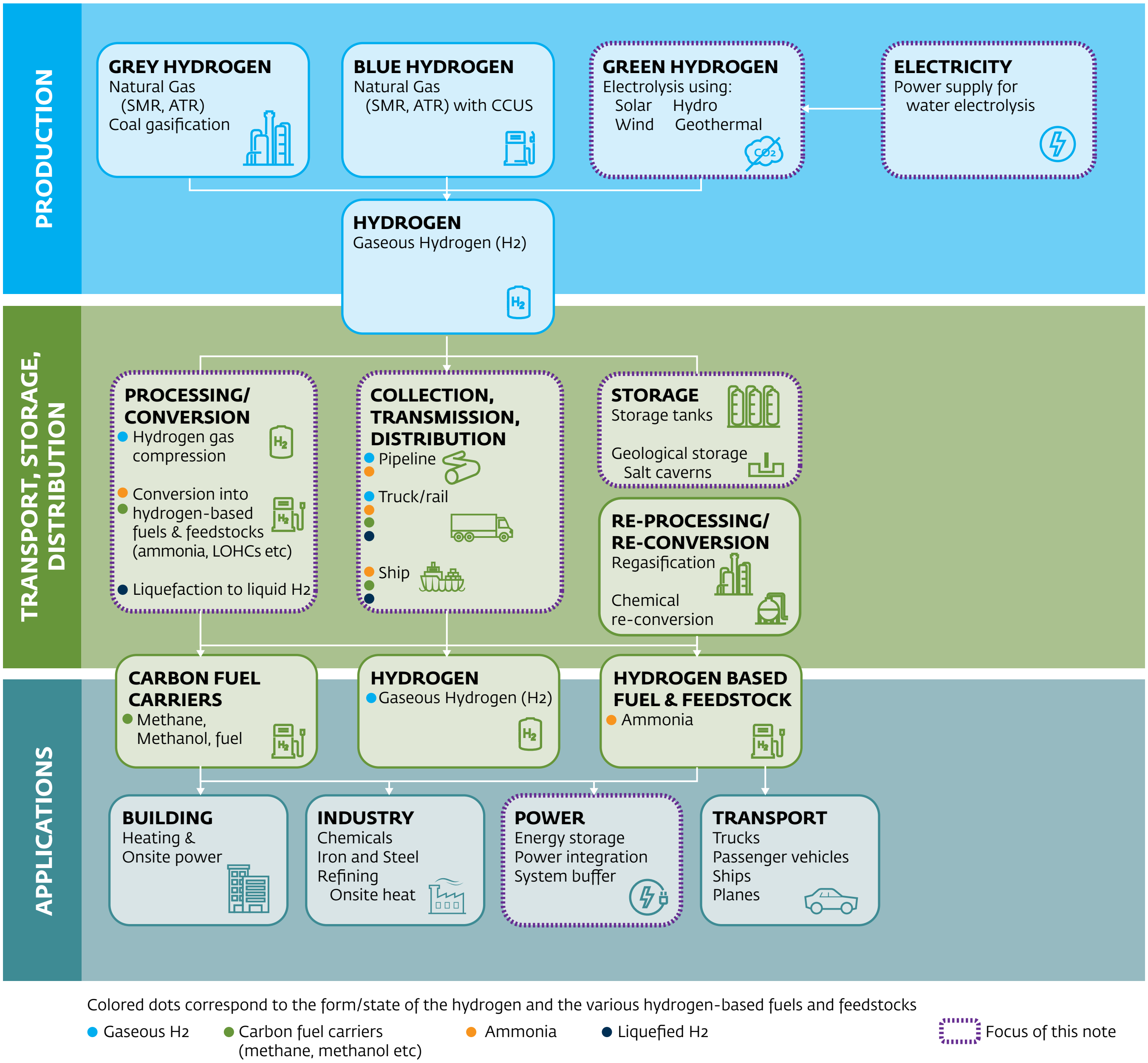
## HYDROGEN BASICS

According to the International Energy Agency (IEA), around 70 million metric tons (MT) of hydrogen are produced in dedicated facilities worldwide, with 99.6 percent of that sourced from hydrocarbons. An additional 48 MT of hydrogen comes as a by-product of other processes. By the end of the decade, hydrogen production is expected to increase by almost 30 percent.

Total hydrogen demand was about 115 MT in 2018. Nearly two-thirds of this (about 70 MT) was for refining and ammonia production, with the remaining one-third (about 45 MT) for ethanol production and other uses. According to Wood Mackenzie, of the 85 countries that currently use hydrogen, 10 account for 70 percent of global demand. China and the U.S. are the largest consumers at 21 percent and 19 percent, respectively.

Figure 1 illustrates the main pathways for hydrogen production, storage, distribution, and end-use applications.

FIGURE 1. **HYDROGEN VALUE CHAIN AND APPLICATIONS**




*Source: Carbonomics: The Rise of Clean Hydrogen*

## THE COST CHALLENGE

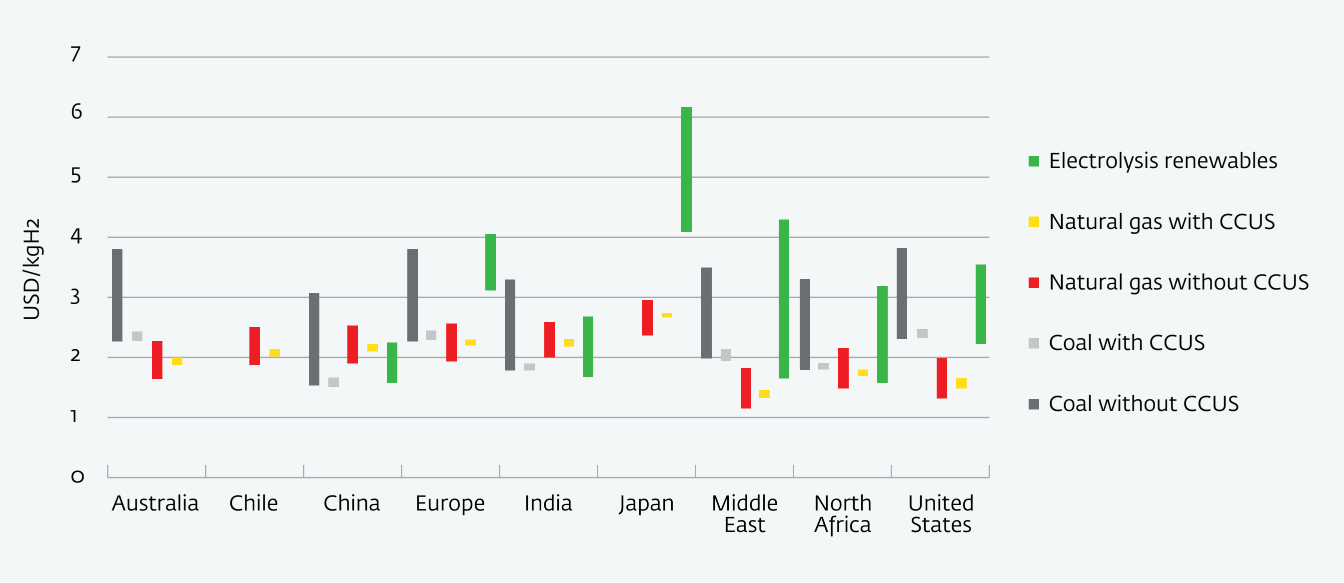
According to Wood Mackenzie, in 2020 green hydrogen currently accounts for only a tiny fraction of global hydrogen production, equivalent to 0.1 percent. The lack of clean hydrogen alternatives reflects market reliance almost exclusively on conventional hydrogen, contributing heavily to $CO_2$ emissions. The IEA found that emissions resulting from the traditional production of hydrogen equaled those produced by Indonesia and United Kingdom combined. Greater use of green hydrogen in the next decade should change that.

In 2020, about 48 gigawatts (GW) of green hydrogen projects were announced for launch by 2030, and several of these projects are on a GW scale. Many private sector-led initiatives are helping to accelerate hydrogen production and deployment of clean hydrogen. These include the World Hydrogen Council and the UN Green Hydrogen Catapult—a coalition of seven leading energy companies working towards a 50-fold acceleration in global hydrogen production capacity by 2026.

One barrier to increased uptake is that green hydrogen production costs are significantly higher than grey or blue hydrogen. Grey costs range between $1/kg and $2/kg. When paired with CCUS for blue hydrogen, costs increase by 50 cents/kg, according to the IEA. Meanwhile, green hydrogen costs range between $3/kg and $6/kg. It is particularly sensitive to power prices, plant utilization rates, and capital costs—with the electrolyzer representing the most significant expenditure. Consumption of hydrogen at the production site optimizes the all-in cost of hydrogen. Hydrogen transportation and storage significantly increase the overall price of the gas, potentially tripling its value at the delivery point.

Achieving cost parity with blue hydrogen would require a swift drop in renewable energy generation and electrolyzer costs. For the commercial viability of green hydrogen today, the power generation source would need to run at a minimum of half capacity on average, with the electricity price at $20–$30 per MWh. Currently, renewable energy power plants run at a capacity factor of 20–50 percent, with solar at the lower end of this range and wind at the higher end. Renewable electricity prices are typically in a range of $20–$80 per MWh. In addition, the cost competitiveness of green hydrogen is radically different across geographies, as shown in Figure 2.

FIGURE 2. **HYDROGEN PRODUCTION COSTS IN MAJOR PRODUCING ECONOMIES, 2019**




*Note:* Bars indicate hydrogen production costs, including carbon pricing between near (~$25/t$CO_2$) and long (~100/t$CO_2$) term.

*Source:* IEA, *The Future of Hydrogen*

Countries with abundant renewable energy resources and a large, competitive power generation market—such as Chile, those in North Africa and the Persian Gulf—can produce green hydrogen at the $2/kg benchmark. Similarly, the existence of relatively abundant renewable energy (like hydro) at cost-competitive rates and low wholesale spot market prices provides a favorable environment for the uptake of green hydrogen, particularly in countries such as Brazil, Colombia, and Mexico.

One relatively simple way to lower the cost of producing hydrogen is to use surplus renewable energy in the production process. Since electricity accounts for about 65 percent of production costs (through the electrolysis process), using excess capacity from renewable energy could be seen as a quick win for reducing green hydrogen production costs. According to the International Renewable Energy Agency (IRENA), wind and solar contributions to global electricity generation are forecast to increase from 10 to 63 percent by 2050, creating an opportunity to use surplus energy for hydrogen production.

Access to affordable and commercially proven electrolyzers is another issue. China has a cost advantage in manufacturing the established and commonly used alkaline electrolyzer, which sells for $200 per kWh. European manufacturers are investing heavily in nascent, albeit more expensive electrolyzers, to compete with alkaline technology. The push for this new generation of electrolyzers, such as the proton exchange membrane, aims to better integrate production with renewable energy sources by quickly reacting to the fluctuations typical of renewable power generation. Other improvements include eliminating the electrolyte solution used in alkaline electrolyzers and relying on treated water instead.

Globally, new policy and demand-side initiatives are emerging as part of a push to achieve green hydrogen cost competitiveness by 2030. Among these initiatives are significant investments in research and development into more efficient technologies, the introduction of tax benefits, carbon pricing incentives, and the inclusion of hydrogen in energy legislation to create the economies of scale needed to bring down the costs of clean hydrogen. IRENA projects that electrolyzer costs will drop by 40 percent as of 2030, assuming 100 GW of installed capacity by then.

## OVERCOMING TECHNICAL OBSTACLES TO HYDROGEN IN POWER PLANTS

Power plants that use high volumes of green hydrogen are still in their infancy. The industry must address several economic, safety, and technical challenges before hydrogen can become a mainstream solution for power generation.

For example, when operating a power plant with hydrogen-fueled equipment, the amount of hydrogen in the fuel mix will determine the power turbine's reconfiguration. A low concentration of hydrogen could mean adjustments only to the gas turbine controls. However, a higher concentration might involve altering or completely changing combustion controls, flame sensors, gas detectors, valves, purge systems, or sealing systems.

Managing nitrogen dioxide (NOx) emissions from blending hydrogen and natural gas is another major issue. Maintaining a hydrogen concentration level of about half can keep NOx emissions at relatively low levels.

In a sign that hydrogen is gaining traction, major power turbine manufacturers—including GE, Ansaldo, Siemens, and Mitsubishi Hitachi Power Systems—are upgrading their gas turbines to allow for the use of hydrogen, despite the challenges. These manufacturers provide an engineering, procurement, and construction guarantee on the technology, repurposing, and emission levels of gas turbines using hydrogen.

## GETTING HYDROGEN FROM POINT A TO POINT B: DISTRIBUTION AND STORAGE

A key question for the hydrogen economy is how to build on existing energy infrastructure. This includes natural gas assets such as the roughly three million kilometers of global gas pipelines, storage facilities such as pressurized tanks, salt caverns, depleted natural gas or oil reservoirs, and aquifers, shipping, trucks, and transport corridors.

About 85 percent of hydrogen is either produced or consumed onsite, primarily as chemicals, with the rest transported by truck or pipeline. Transport and storage costs will play a significant role in the competitiveness of hydrogen since they are between 1.5 and five times the price of natural gas per unit of energy. While these extra cost considerations may favor business models with onsite storage and consumption, some countries are developing long-distance and international distribution with offsite storage solutions.

Natural gas pipelines could be a good option for transporting hydrogen at scale. Energy transmission capacity in gas infrastructure is at least 10 times larger than the capacity of electricity grids. A critical mass of localized demand is needed, however. In addition, challenges related to the physical properties of hydrogen need to be addressed, such as embrittlement (fracturing) of steel pipes, hydrogen's lower energy density relative to natural gas, pipeline safety and associated upgrade costs, and other technical issues.

In addition to upgrading natural gas pipelines for hydrogen use, other distribution options include building new dedicated hydrogen pipelines and blending the gas into existing natural gas grids. Germany, Italy, the Netherlands, and the U.K. are pursuing the latter approach. Combining hydrogen with natural gas avoids the significant capital costs of developing new infrastructure. It also helps to decarbonize natural gas processes. Transporting hydrogen in liquid form is another viable approach, given an already-established supply chain infrastructure and that fact that it is far less complex than transporting hydrogen in gas form.

According to Wood Mackenzie, hydrogen, with long-term storage capabilities, is expected to play a significant role in the expanding energy storage needs market, estimated at 741 GWh of cumulative capacity by 2030. The ability to store and deliver hydrogen in multiple forms—pressurized, liquid, converted (either to ammonia or methanol), or absorbed (hydrides and liquid organic hydrogen carriers)—unleashes the potential for using the gas as a storage medium to accelerate off-grid generation solutions in developing countries.

## GREEN HYDROGEN'S TIME HAS COME

As noted above, hydrogen's application in power systems is receiving significant political and financial support from governments. A collective push from the private sector is emerging amid expectations that costs will fall and efficiencies will continue to improve. While there are still many unknowns, hydrogen's future as an energy source looks bright.

These dynamics in the energy space are in line with the IFC Global Energy and business development approach. We are supporting clean energy innovation and working with developing countries to build sustainable opportunities over time. Regions and countries with rising renewable energy deployment and falling costs represent attractive environments for IFC to engage with the private sector on developing hydrogen as a decarbonizing solution for power generation and long-term energy storage.

IFC is already working with clients in emerging markets on green hydrogen initiatives. We are also keenly watching the creation of hydrogen hubs, combining renewable energy generation with green hydrogen production, transport, storage, and local or international use. Such hubs can offer practical applications and technical insights for hydrogen development in emerging markets, helping to de-risk new projects.

As we build relationships with clients and industry leaders, IFC is looking to the future, identifying new opportunities to scale up the use of hydrogen as a power source in line with public policies and private sector interests.

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This note was authored by Jorge Gallon, Senior Investment Officer, and Alessandra Salgado, Associate Industry Specialist at IFC. It is part of the Emerging Energy Solutions series. For more information, visit www.ifc.org/energy and www.ifc.org/infrastructure.

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