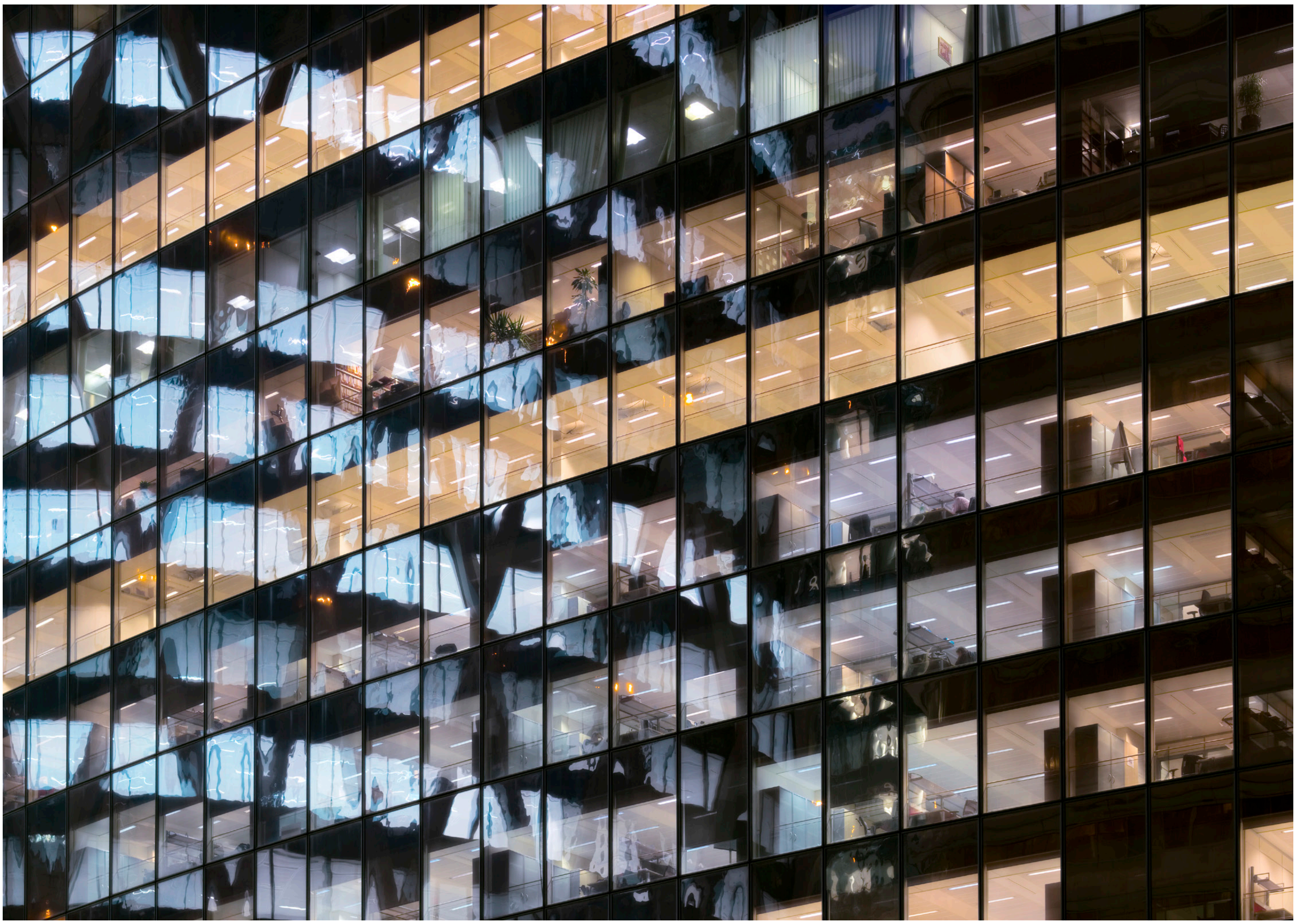
Hydrogen: New Ambitions and Challenges

February 2024



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In addition to its role in the oil refining and chemical industries, hydrogen is now emerging as a vector of clean energy delivery. There is genuine interest and investment worldwide as governments and businesses seek to develop this budding industry as part of their energy transition goals. Nevertheless, significant challenges lie ahead to bring this industry up to scale.

Key Takeaways

- Low-carbon hydrogen requires innovation from industry, a pragmatic and cooperative approach to classification by governments and customer commitments to a premium product.
- There are currently positive signals, but challenges remain in each of these areas to reduce development costs and thus deploy capacities at scale.
- The transition to low-carbon hydrogen is unlikely to happen at a speed and scale to transform the business environment for European regulated gas infrastructure companies in the coming five years.
- With the emergence of a low-carbon hydrogen economy and looming regulatory resets (post 2030), gas network operators may already be adapting their balance sheets to navigate a more uncertain environment.

Introduction

A new industry is emerging to deliver low-carbon hydrogen to energy markets. New companies are being founded and new business models are being designed. Pilot plants are expanding to commercial scale, and industrial parks increasingly look to develop regionwide linkages in “hydrogen hubs” and “hydrogen valleys.” Intense efforts are underway to reduce production costs and to find economically viable ways to transport hydrogen. Meanwhile, governments worldwide are working on the detailed design and implementation of subsidy or support regimes, working with conviction that net-zero targets, or even deep reductions in carbon footprint, will require a contribution from low-carbon molecules as well as low-carbon electrons.

A striking characteristic of this emerging industry is that interest and investment are genuinely worldwide: there is scope for some part of the hydrogen supply and value chain in advanced, industrializing and developing countries alike.

This cross-divisional report by S&P Global Commodity Insights and S&P Global Ratings describes the opportunities and challenges facing the nascent clean hydrogen industry. While the opportunity is genuinely global, there are significant challenges. There are specific implications for gas infrastructure operators in the European market in particular.

These challenges fall into three main categories: **cost reduction and elimination of bottlenecks**, **definition and classification**, and **customer commitments**. All must be overcome to realize a global vision in which hydrogen plays a vital part in a transformed energy system.

The global vision

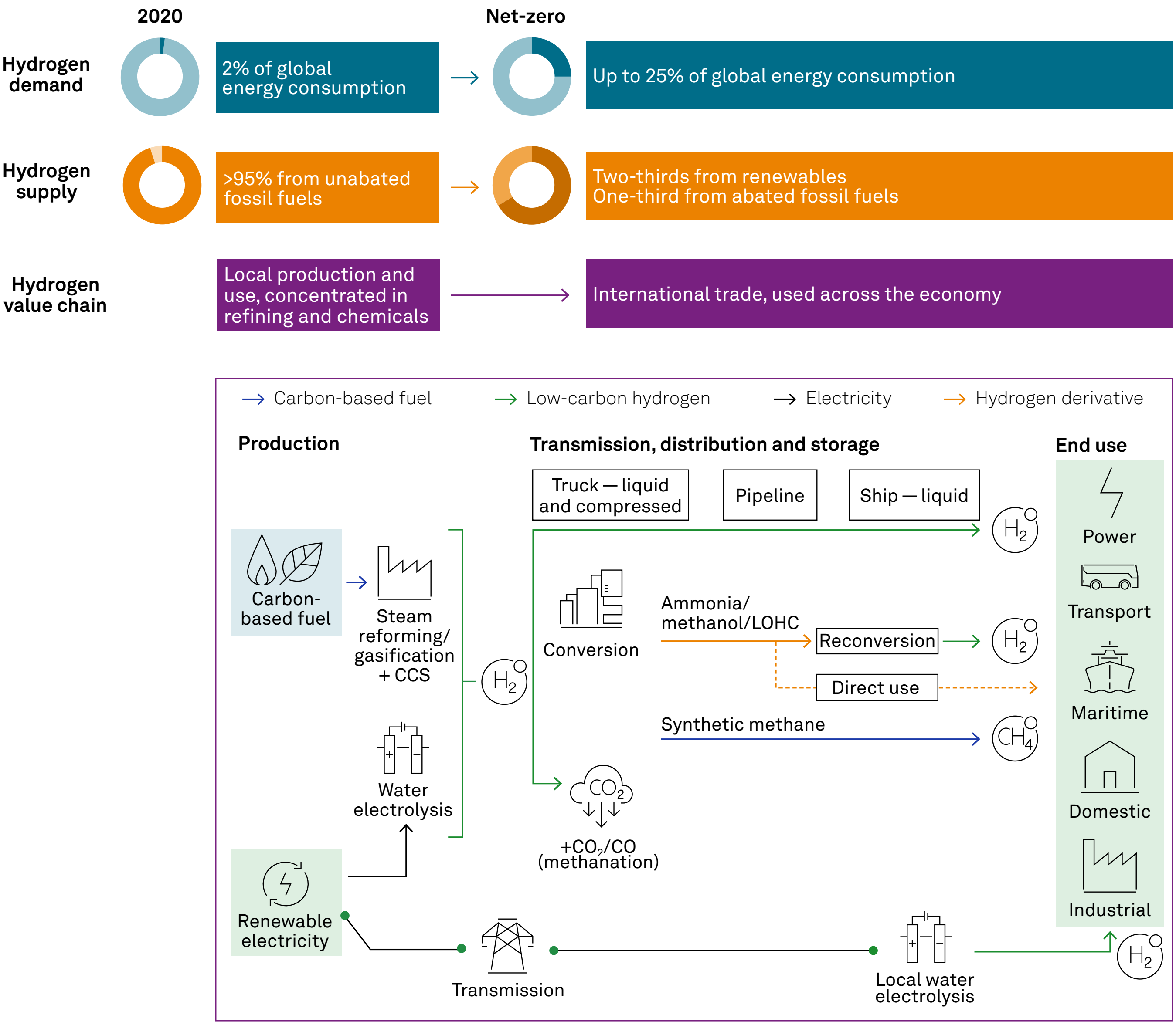
Hydrogen is an important feedstock for the oil refining and chemical industries, primarily supplying local needs. Manufacturing hydrogen today accounts for about 2% of the world’s energy consumption. It is essentially an industrial gas, the majority of which is made from fossil fuels (natural gas, and to a lesser extent, coal) in a highly carbon-intensive “steam reforming” process. Some hydrogen is a by-product of oil refining and chemical processes and can be fed back for the benefit of other processes in the plants where it is sourced.

However, there is a clear vision to transform this into an industry that delivers energy to a wide variety of uses. Technologies to decarbonize the making of hydrogen could transform it into a vector for delivery of low-carbon energy to its new customers. Chart 1 shows the ambitious scale of this transformation, as hydrogen moves from being mainly an industrial gas to becoming a low-carbon energy carrier.

In almost every corner of the globe, there is an emerging overlap of business interests and political ambitions that strongly favors this development of hydrogen and hydrogen derivatives as a carrier of low-carbon energy.

Chart 1

The evolution of the hydrogen market: from industrial gas to low-carbon energy carrier



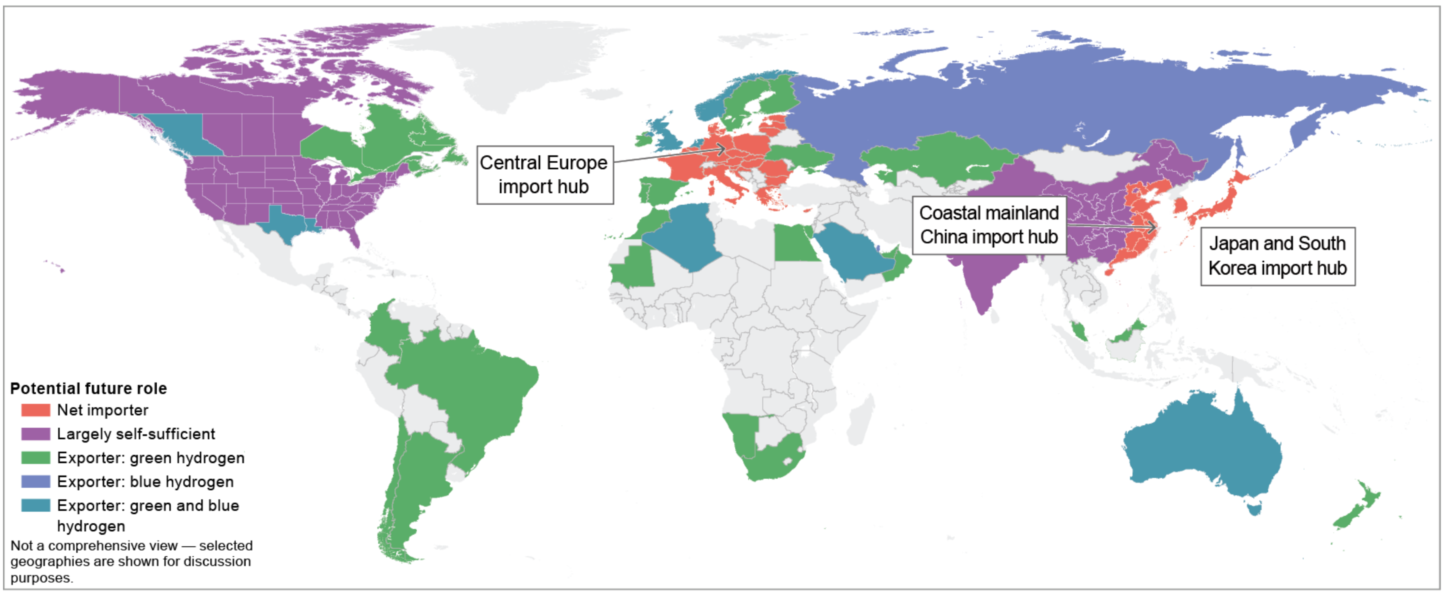
Data compiled January 2023.
H_2 = hydrogen; LOHC = liquid organic hydrogen carriers; CCS = carbon capture and storage;
CO_2 = carbon dioxide; CH_4 = methane.
Source: S&P Global Commodity Insights.

Based on the global engagement of S&P Global's customers and partners, a picture has emerged of future possible trade in low-carbon hydrogen. The pattern of hydrogen trade could emulate the current international trade in the major fuels: coal, oil and gas. Chart 2 illustrates how the worldwide interest in low-carbon hydrogen may evolve into a global trading system. Under this scenario, countries with favorable wind and/or solar resources (and in some cases, developed hydroelectric or nuclear industries) will become "producers," as will traditional oil and gas producers, making use of carbon capture technologies; industrialized regions with more limited resources (coastal China, Japan and South Korea in east Asia; Germany, Italy and Central European countries) will become net importers, while some countries that are both resource-rich and industrialized may be largely self-sufficient.

In all countries colorized on the map, governments have announced strategies that point their industries toward low-carbon hydrogen as part of their energy transition plans. In many, these strategies either have been, or are in the process of becoming, translated into specific subsidy, tax break or other support policies. Prominent among these are the United States, with its three-pronged support of the Inflation Reduction Act, the Bipartisan Infrastructure Law and the hydrogen component of the Energy Earthshots Initiative; India, with its Green Hydrogen Policy (February 2022); and China, whose Hydrogen Development Plan (March 2022) is delivering results that include what is currently the world's largest "green hydrogen" facility: the 260 MW electrolyzer set in Kuqa, Xinjiang, supplying hydrogen to the nearby refinery at Tahe. While Europe currently lags China, installed capacity is expected to grow strongly as production support auctions around the continent get underway.

Chart 2

Potential map of future trade in low-carbon hydrogen (and its derivatives)



Data compiled Feb. 9, 2024.
Source: S&P Global Commodity Insights: 2012276.

Geographical range is one part of the hydrogen story. Perhaps more important is the range and diversity of business interest. Appropriately for an emerging industry, a wide variety of business models are developing.

For this highly diverse vision to succeed, three serious challenges must be overcome: cost reduction and elimination of bottlenecks; harmonization of definitions and classification of low-carbon hydrogen; and lining up robust customer commitments to buy. The remaining years of the 2020s will reflect whether — and if, so how — they will be surmounted.

Cost reduction and elimination of bottlenecks

Definitions and classification of low-carbon hydrogen

Customer commitments to buy

Challenge 1: Reducing costs, overcoming bottlenecks

General cost conditions

There is intense focus on finding ways to reduce cost in the whole clean hydrogen supply chain. The capital and operating costs of production — whether from methane reforming, separation and storage of carbon, or electrolysis — are an important element. But so too are the questions of infrastructure, pressure and storage. There are various technical options for infrastructure to deliver hydrogen to the customer, whether for local use, for long-distance transportation by pipe or truck, or across the world by ship in the form of ammonia, methanol, a liquid organic hydrogen carrier or liquefied hydrogen. These "delivery costs" can typically more than double the production cost for each unit delivered to a customer. Hydrogen must also be delivered at suitable pressures and purities for different types of customers to use, and most uses also require hydrogen to be stored. Cost is added at each stage.

In all these areas, businesses are working to identify the least costly route for their own interests and business models, and to work out means of reducing those costs.

The costs of infrastructure, storage and pressure management are likely to face similar new cost drivers that arise from general economic conditions and from particular project complexities.

Supplying primary energy for hydrogen manufacture — Future risks

Hydrogen, and especially low-carbon hydrogen, is not an energy source. It is a vector by which other energies can be delivered in a low- or zero-carbon way to customers with specific energy needs. As such, the cost and scale factors for these energies can be more important than the cost chain for hydrogen itself.

- **Natural gas prices:** Natural gas is the main feed for steam-methane reforming (SMR) and auto-thermal reforming (ATR) manufacture of hydrogen, and its price is typically set in a global market. Its price responds to the vagaries of commodity market conditions, with all their uncertainties. In the past three years, the feed price of gas into "grey" hydrogen manufacture (carbon-intensive manufacture, with no carbon capture) has varied in most parts of the world by a factor of two or three. The impact on the cost of hydrogen can hence be substantial.

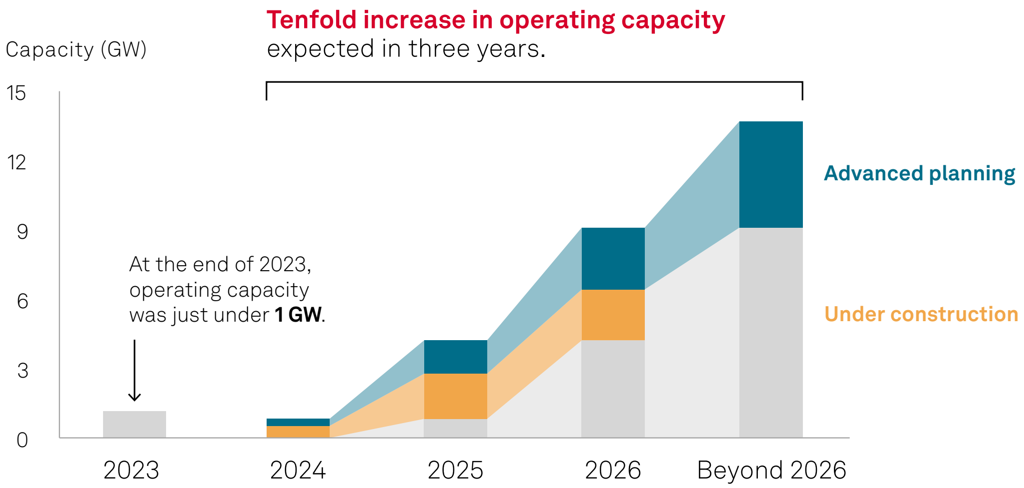
- **Cost of renewable electricity generation:** It is widely expected that the cost of generating renewable electricity will continue to fall, reducing future operating input costs. This expected declining cost has an influence on the attractiveness of electrolytic hydrogen over the larger-scale processes of methane reforming with carbon capture and storage. Nevertheless, it remains uncertain.

- **Direct competition for renewable sources with all other much-needed electrification needs:** For example, in the EU, we estimate that producing 5 million metric tons of green hydrogen per year would require about 35 GW of electrolyzer capacity (plus 50-150 GW of renewable generation capacity, which may in turn absorb one-eighth of total EU renewable capacity). Renewable power feed will compete directly with the higher-ranking goal of electrification of final demand.

Chart 3 shows that the currently operating 1 GW of electrolysis capacity is likely to increase tenfold within about the next three years.

Chart 3

10 GW of electrolysis capacity is under construction or in advanced planning stage



As of Jan. 5, 2024.
GW = gigawatt.
Source: S&P Global Commodity Insights.

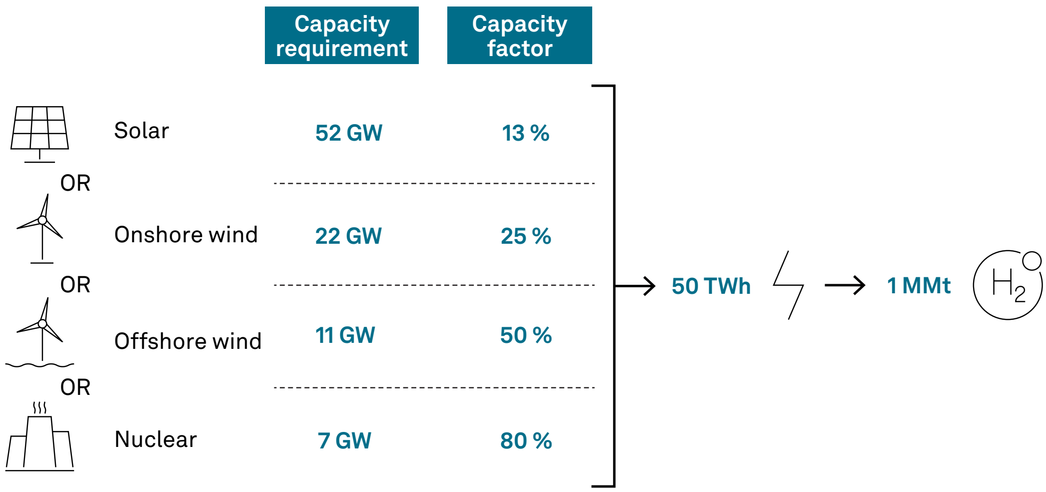
Furthermore, there are important government initiatives to stimulate more new projects through auctioning. In Europe, for example, a European Hydrogen Bank, backed by €800 million from the European Union's Innovation Fund, will lead auctions for renewable hydrogen production (offering winners a fixed-price payment per kilogram of hydrogen produced for up to 10 years of operation).

Even as plans come to reality, and with costs declining, the principal challenge for low-carbon hydrogen production via electrolysis is the sheer scale of new renewable generating capacity that is required.

Chart 4 shows the renewables or low-carbon power needed in order to produce 1 million metric tons (MMt) of low-carbon hydrogen from electrolysis. The operating capacity factors of the various forms of low-carbon electricity generation — solar, onshore and offshore wind, and nuclear power — determine how much capacity must be available to the hydrogen producer.

Chart 4

Electricity requirements for hydrogen from electrolysis



Data compiled Dec. 2, 2022.
GW = gigawatt; MMt = million metric tons; TWh = terawatt-hour.
Based on typical European capacity factors.
Source: S&P Global Commodity Insights.

As illustrated,[1] 50 TWh of electricity — equal to 5 billion cubic meters of natural gas, or about 80,000 barrels per day of oil — is required to make 1 MMt of hydrogen.[2] Chart 4 shows that over 50 GW of solar power (assuming a 13% capacity factor) would be needed [3] to generate the required amount of electricity to manufacture just 1 MMt of low-carbon hydrogen from electrolysis. For nuclear power, with a higher capacity factor, 7 GW of fully operational capacity would be needed, limiting electrolyzer feedstock to dedicated low-carbon power. These are huge numbers, and bear in mind that a primary call on new electricity capacity in most parts of the world will be to support the direct electrification of customers' final energy uses.

Separately, it is clear that methane reforming, with carbon capture, will be a part of the low-carbon hydrogen future, alongside electrolysis. Final investment decisions for large projects have been taken in Europe and the United States and more are expected in 2024–2025.

Planning bottlenecks

Furthermore, for low-carbon electrolytic hydrogen to take off in the next five years, planning bottlenecks will have to be removed. Chart 5 shows the typical lead times in Europe for planning for wind power (offshore and onshore) and for solar power. These are significantly longer than the lead times either for electrolysis projects or for the construction of large electrolysis manufacturing facilities. The contrast is striking, and the main bottleneck is clear.

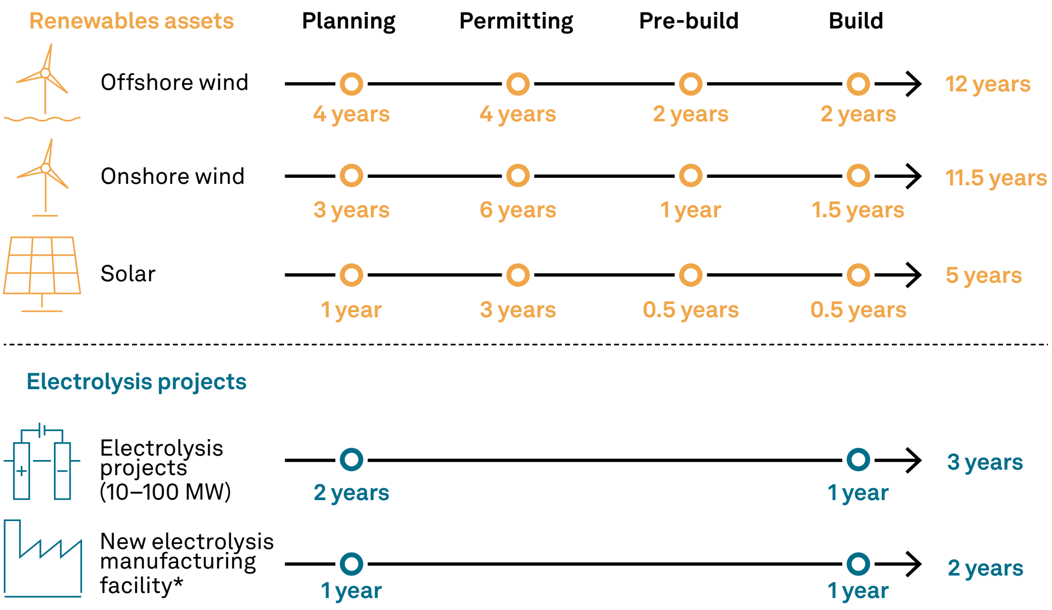
[1] Electrolyzer efficiency is modeled as 70%.

[2] The world consumes about 800 times this amount of gas each year, and about 1,200 times as much oil every day.

[3] In other words, seven nuclear power plants of 1 GW each, or over 12 million homes each with solar panels of 4 kW capacity, would supply enough electricity for just 1 MMt of hydrogen.

Chart 5

The planning bottleneck



Data compiled Jan. 5, 2024.
*Once Head of Terms/purchase contracts are in place.
Source: S&P Global Commodity Insights.

Challenge 2: Classification, definition and harmonization

Official classifications and definitions are paramount for a technology to fit into a taxonomy, opening the door to green credentials, financing and commercialization, at the domestic and international levels. For the latter, harmonization of these classifications could become crucial to envisage a global hydrogen economy.

As a result, a further challenge we see for a future electrolysis industry is the question of “additionality.” How can it be known that the dedication of a low-carbon electricity source to manufacturing hydrogen will not deprive another sector of the energy economy of the same low-carbon electricity? Will the “deprived” customer be obliged instead to consume high-carbon energy, such that there will be no overall reduction of emissions? What needs to be in place to ensure that new renewable capacity, dedicated to hydrogen manufacture, is in addition to the renewable electricity that is being built to decarbonize the wider use of electric energy?

This subject is being treated differently in different parts of the world. In many jurisdictions, the issue is addressed by requiring, over time, an increasingly closer match between electrolyzers’ hours of operation and the actual hours of output of wind and solar equipment on electric grids, and limiting the use of electricity from renewable facilities commissioned more than three years before the electrolysis. Harmonized rules, or some basis for mutual recognition of standards around additionality and time stamps, will be needed for international trade to develop rapidly.

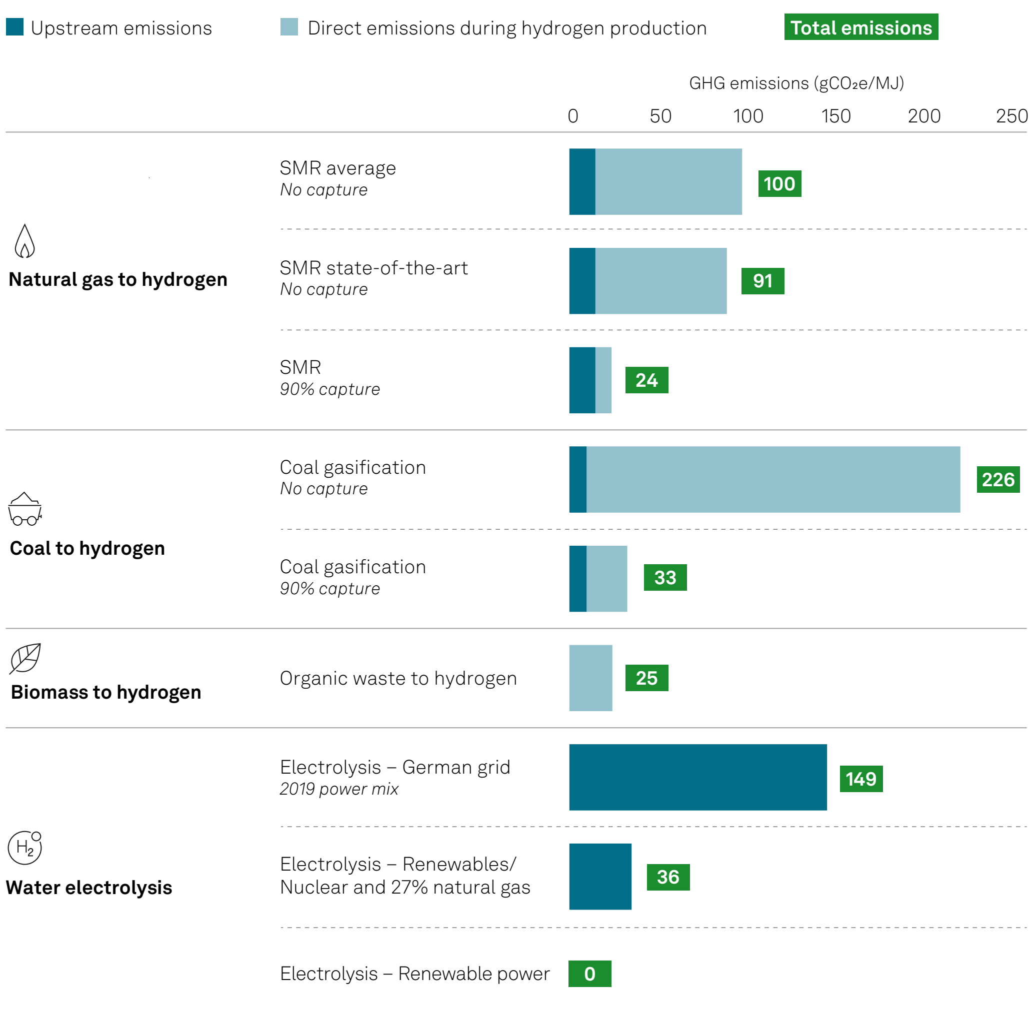
Broader issues in the development of standards are at stake as well. Chart 6 compares the carbon intensity of various technologies for making hydrogen — reforming of gas (or coal) with and without carbon capture, or with different levels of carbon capture, and electrolysis using electricity from dedicated (implicitly "additional") renewable or nuclear power, or with electricity "from the grid" — acknowledging that different grids have different carbon footprints depending on the mix of generating capacities.

Consultations have been underway for several years, yet there is little indication of what common international standards might be agreed. The International Partnership for Hydrogen and Fuel Cells in the Economy continues its important work toward setting ISO standards, and the International Energy Agency has drawn attention to the importance of the issue, but timelines are still far from clear.

These issues of additionality and low carbon definitions matter a great deal to any business whose planned activities and value creation depend on a clear recognition of the low-carbon character of their product or service in multiple markets and jurisdictions. Delays in finalizing the detailed rules have already caused some proposed projects to be postponed.

Chart 6

Carbon intensity of studied hydrogen routes, well-to-gate GHG emissions (gCO_2e/MJ)



Data compiled March 23, 2023.
GHG = greenhouse gas; gCO_2e/MJ = grams of carbon dioxide equivalent per megajoule; SMR = steam-methane reforming;
Biomass = sources that qualify under RED II definition.
Source: S&P Global Commodity Insights.

Challenge 3: Finding customers

Lower costs and harmonized definitions are two of the three main challenges to be solved in order for low-carbon hydrogen to take off as an energy vector in the coming five years.

But the most important criterion for takeoff, strongly influenced by the two previous challenges, will be the willingness of potential customers to sign up for *offtake* — to contract explicitly with suppliers to deliver low-carbon hydrogen.

S&P Global's industry partners are strongly signaling that, while cost reduction and regulatory harmonization are important, the focus now needs to turn to the demand side: finding reliable customers for low-carbon hydrogen (see Chart 7).

If production costs can be reduced, there will still be a geographical issue; hydrogen produced at this cost far from the end-use point will not stimulate demand. What matters is the effective cost of hydrogen delivered to the user at the end point. In markets where there is a carbon price, this can help move the dial in the direction of making low-carbon hydrogen competitive. Consumption mandates, such as European policies around RFNBOs (renewable fuels of nonbiological origin) or Japanese rules on cofiring of power plants, move the dial further — and give clues as to which sectors (in industry and transport, for example) may become first movers.

The critical test will be when customers sign up for long-term offtake, and with appropriate guarantees or assurances.

Chart 7

Which sectors in the European Union can be tempted, or obliged, to pay a low-carbon hydrogen premium?

Willingness to pay	Sector or end use	Alternative means of meeting European consumption targets
Refuel Aviation	Aviation	Bioliquids
↑	Maritime — from 2034	Bioliquids
	Refinery hydrogen	No target, but can be used to meet RFNBO target, as replacing existing production potentially lowers cost/risk
	Road transport	Electricity, Bioliquids
	Existing industrial use: Ammonia	Imports: Unabated ammonia and ammonia from abated natural gas
ETS	New uses: Iron and steel/power generation	No low-carbon hydrogen consumption targets; RED III includes a nonbinding renewable target only

Data compiled January 2024.
ETS = Emissions Trading System (EU); RED = Renewable Energy Directive;
RFNBO = renewable fuels of nonbiological origin.
Source: S&P Global Commodity Insights.

In this context, the focus on developing hydrogen hubs or hydrogen valleys, adopted by many countries with high ambitions for hydrogen as part of their energy transition strategies, is sensible and welcome. Industry recognizes that it will have to play its part for the hub/valley approach and structure to be successful.

Companies in the hydrogen supply chain are seeking innovative solutions to drive customer demand — over and above reducing the costs of production and infrastructure. New entrants to the business in the Americas and in Europe are looking to e-fuels or to synthetic methane as a means of delivering low-carbon hydrogen cost effectively into existing installed capital assets. Companies across the world are searching for customers who, for brand reasons, or to meet their own corporate net-zero or low-carbon targets, may be willing to pay a green premium. In some cases, initiatives are already visible from the customer side. Low-carbon hydrogen is in a nascent stage for all end uses. Refiners, chemical manufacturers, steel companies and haulage operators are proactively demanding a schedule for their suppliers' access to low-carbon hydrogen, to reduce the carbon footprint of their own supply chain. Government mandates for the renewable fuel content in these sectors provide an important incentive, along with brand concerns.

Such initiatives, both from hydrogen producer and consumer sides, will continue to flourish.

A closer look at Europe: Credit implications for gas network infrastructure

Significant growth in green gases could help assure the continued use of gas networks through the energy transition. Conversely, an uncertain or slow transition to low-carbon hydrogen or other renewable gases could raise the risk of steady decline in network throughput. This has implications for regulators as they assess and decide rates of return and determine the underlying value of the asset base. Declining throughput means a higher proportionate share of the cost of transport is attributed to each unit of gas that customers buy — unless the regulator, with customer costs in mind, resets either the allowed rate of return or the asset value, or both.

This risk of "regulatory reset" weighs on S&P Global Ratings' views of business risk profiles in the regulated gas network sector. In view of the challenges and uncertainties described above, repurposing natural gas pipelines to transport low-carbon hydrogen is unlikely to happen at sufficient speed, low enough cost or large enough scale to diminish the risk. Hydrogen-related investments by gas operators themselves are, for the most part, currently small scale — limited to pilot projects or to testing the resiliency of blending up to 15%-20% of hydrogen (by volumes) with natural gas. Our credit ratings base case reflects both reset risk and the marginal nature of these investments.

However, some transportation operators, particularly in Europe, may be assigned responsibility for deploying hydrogen "backbone" in their national markets and for connecting various markets throughout the continent. The investment programs of these operators could be both more material and more likely to be sympathetically reviewed by regulators, aligned with national energy transition priorities:

- In the Netherlands, for example, the state via its gas transmission system operator plans to build the hydrogen backbone with investments of about €1.5 billion by 2030, about 50% of which will be covered by government grants. Plans involve deploying 200 km of new pipelines, with the major effort devoted to adapting existing natural gas infrastructures.

- Germany's updated July 2023 National Hydrogen Strategy anticipates a backbone of 11,200 km by 2032. A start-up grid of 1,800 km of converted or newly built hydrogen could be partly supported from European funds by 2028, but Germany's traditionally private and regionally owned companies could play a significant role, with flanking governmental support through incentives such as contracts for difference.
- Backbone plans in Spain and the United Kingdom may only reach maturity in 2026; they are conditional, in Spain's case, on decisions on eligibility for European funding, and in the UK, on a broader governmental decision on whether hydrogen will have a role in the decarbonization of the heating sector.
- As well as these national-scale plans, some gas distribution grids could also be positioned to make local investments in direct connections between hydrogen producers and industrial end users at their operational sites. Such projects remain marginal for now.

An additional challenge in Europe is the lack of near-term regulatory frameworks for renewable gases infrastructure. Consequently, there is a transition period where gas transport operators may need to look to secure funding (private or state subsidies) in the absence of an enforceable regulation.

At this stage, we do not envision any potential material step-up in investments related to low-carbon hydrogen network infrastructures before 2030. Yet, the sector would need to be financially prepared should these heavy investments start to materialize. Funding strategies, financial policies and balance-sheet robustness in particular could be key areas of attention in order to preserve credit quality. These financial and investment decisions come at a time of uncertain natural gas demand evolution and still-unclear pickup potential on green gases. Regulatory support will also remain a major variable for the creditworthiness of these companies, affecting the timeliness of allowed cost recovery, tariff setting changes, and possible compensation for decline in gas usage. As regulatory periods end and new usages emerge, operators may face higher regulatory reset uncertainties.

Conclusion

Low-carbon hydrogen is a business that has already started to grow. It has strong political support and industry interest across the world. But the challenges identified above — cost and scale, planning bottlenecks, defining rules for what is "green" and lining up customers willing to commit to a product at a premium cost — mean that the transition to hydrogen is unlikely to happen at a speed and scale to transform the business environment for regulated European infrastructure companies.

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