Green hydrogen today, tomorrow, and in 2030

A collaborative thought leadership piece between VoltaChem and Advisian.

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Chapters

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We need to find a way to continue living our lives while working towards our net zero goals, respecting the Paris Agreement and pursuing a fair and just energy transition for all. And low-carbon fuels including hydrogen play a significant role in that journey"

Nicola Knight,
Director, Low-carbon, Advisian

"

An integral understanding of technology, international supply and demand development and legislation is crucial for the effective implementation of green hydrogen projects.

Martijn de Graaff,
Program Director, VoltaChem

Executive Summary

As climate change intensifies, global energy systems need to rapidly transition away from the unabated use of fossil fuels like coal, oil, and gas. And while renewable electricity is gaining an increasing share of energy production in Europe and around the world, it's not suited to every industrial application. Some energy-intensive industries – such as refining, ammonia production, and steelmaking – depend on other fuels and feedstocks.

Green hydrogen is touted as a sustainable alternative to carbon intensive fossil fuels. It's well suited to the energy-intensive demands of heavy industries. But globally, green hydrogen production and use haven't yet matched its decarbonization potential.

In collaboration with VoltaChem, this paper examines green hydrogen's standing within European energy systems today, before considering the demand, supply, and technology challenges that will influence the scale of green hydrogen production in Europe in 2025 and 2030. This is in response to the EU's ambition to realize 40 GW of electrolyzer capacity by 2030.

The authors evaluate this target, by addressing and posing various questions related to the emerging green hydrogen economy, presenting a comprehensive picture of the factors that will determine whether green hydrogen remains a niche market for the foreseeable future, or whether this clean-burning energy carrier and feedstock can transform current energy systems within the current decade.

The authors aim to initiate conversation by simplifying the current situation while provoking discussion and interaction amongst, and with the readers. To support this, the authors have posed open-ended questions for the readers throughout the article.

1.0 An introduction to green hydrogen

Today, hydrogen is a critical feedstock for heavy industrial processes such as oil refining, fertilizer production, and petrochemical manufacturing. According to the International Energy Agency (IEA)[1], global demand topped 94 Mt in 2021. And this number is rising every year.

However, almost all hydrogen produced today comes from CO_2-intensive processes that use natural gas or coal as a feedstock. These production processes – when not equipped with carbon capture, utilization, and storage (CCUS) technologies – do not align with global ambitions to reach net zero CO_2 emissions by mid-century. But an environmentally sustainable alternative is emerging, which has the potential to decarbonize industry wherever renewable energy is viable. Green hydrogen production uses readily available technologies – renewable electricity and electrolyzers – to split water into hydrogen and oxygen with no inherent carbon emissions.

Because of this decarbonization potential, countries all over the world are competing to be leaders in the green hydrogen market. Large-scale green hydrogen projects and ambitions are announced almost every day, whether they be a standalone initiative or a green energy park for a hub. However, the scale of these announcements raise a question about the reality and practicality of executing all these projects.

Europe has ambitiously set a target of 40 GW of green hydrogen capacity by 2030. This ambition poses several challenges that the region will need to overcome in order to meet the scale of hydrogen demand at a competitive price. This includes building a supply chain for electrolyzer manufacturing at scale, ensuring the availability of renewable electricity and water, and providing sufficient storage, and transport infrastructure. Although the likes of the Hydrogen Council, Hydrogen Europe, and the H2 Science Coalition have played a role in encouraging dialogue, research and development, data sharing and investment, tangible progress in green hydrogen development is still lagging.

1: https://www.iea.org/reports/hydrogen

2.0 The hydrogen industry today

As industries and regions explore viable pathways to reach net zero, the challenges to produce, transport, and use green hydrogen at scale require both fast and viable solutions.

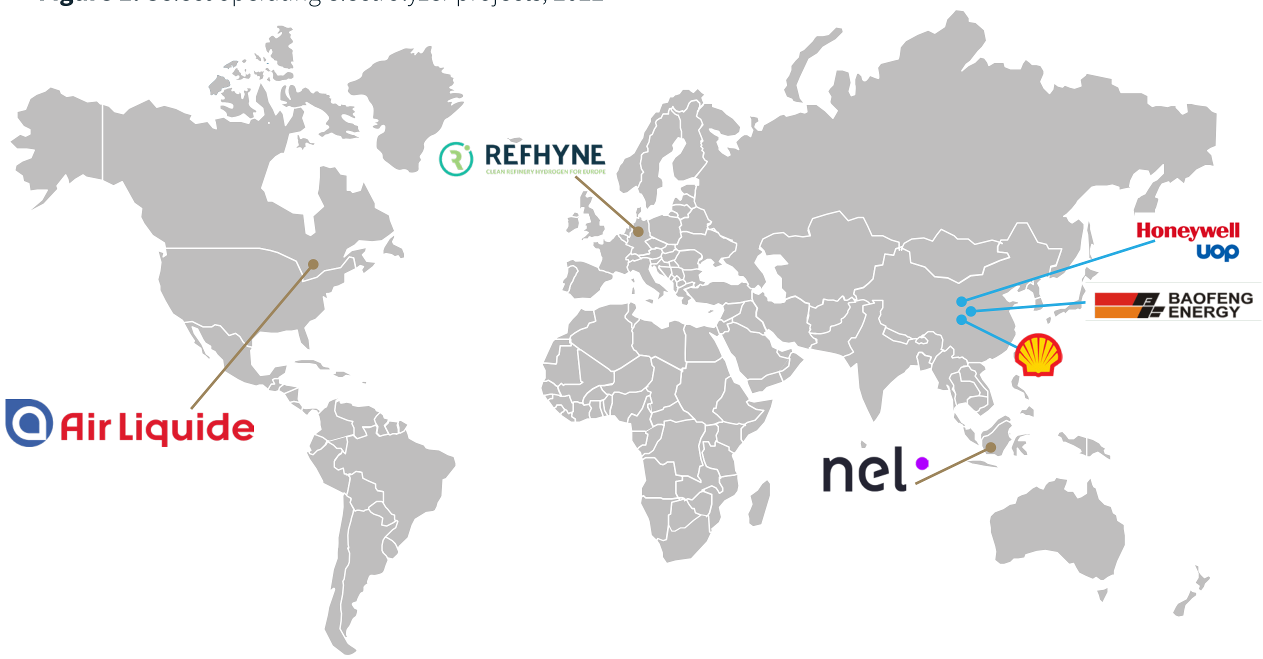
While green hydrogen technology has promised large-scale decarbonization potential for decades, actual production today is small in the context of global energy demand.

There are currently around 50 electrolyzer-based projects around the globe with a cumulative installed capacity of 300 MW. China has the largest green hydrogen plant in operation today based on a 30 MW electrolyzer. Figure 1 maps out select projects over 5 MW. While this capacity is insufficient to make a dent in reducing global CO_2 emissions, it will make a significant contribution to the acceleration of green hydrogen technology development as these electrolyzer projects inform learning curves.

Because some of these electrolysis projects don't use renewable energy, verifying carbon intensity isn't always easy. It also means the hydrogen produced from electrolysis isn't strictly green. But these projects lay the foundations and infrastructure for grids that will supply renewable energy in the future.

How quickly these projects drive scale in the green hydrogen industry, however, depends on demand, supply chain development, and how technology evolves over the coming decade.

Figure 1: Select operating electrolyzer projects, 2022



Note: Only projects with electrolysis capacity > 5 MW, we have filtered out lab scale or research type projects and only focus on industrial developments. However, this excludes several projects, such as green hydrogen production for public transport in parts of the UK, Europe, and Asia. Icons highlight project partners, including developers, licensors, and technology providers.

2.1 Demand analysis

The demand for green hydrogen is pivotal to its growth, as it creates an appetite for further development; if there is a growing demand for the product supply will increase to satisfy market needs. While green hydrogen has gained traction in recent years, tangible uptake has been minimal. Demand varies across industries and end-consumers, which impacts green hydrogen uptake and integration into industrial facilities and applications.

The key barriers to demand growth include:

1. **Product replacement**

Where hydrogen demand is based on consumer adoption of technologies such as fuel cell vehicles, demand will be affected by the average time for product replacement.

2. **End-user adoption**

Early adoption of green hydrogen-based products such as low carbon steel typically come with a price premium. Education and incentives can increase user willingness to spend more.

3. **Speed of innovation** (piloting, demo-in steps)

The lag between a concept and its industrial-scale application can determine demand, especially if the production process is continuously being optimized.

4. **Policy drivers**

Favorable legislation and subsidies (higher CO_2 price, reduction of free carbon market allowances, etc.) can rapidly increase the uptake of new technology and processes in industry.

5. **Industry equipment replacement**

The older the plant and its equipment, the more operators are likely to be receptive to new technology.

Table 1 provides a matrix used to evaluate the demand for green hydrogen in different industries. These indicators include:

1. **Technology readiness**

This parameter considers the novelty and complexity of the technology, its current uses, potential for technological advancements, and position on learning curve.

2. **Rapid uptake potential**

This parameter considers the challenges in integrating technology, from retrofitting equipment to installing new equipment.

3. **Business case**

This parameter analyzes the ratio of grey to green fuel consumed in the industry to understand the financial business case of the switch.

4. **Incentives/legislation**

This parameter considers any legislation or subsidies currently in place for CO_2 abatement in the industry.

5. **Availability of alternatives**

This parameter considers all alternate low-carbon fuels to green hydrogen available for similar operations in the industry.

6. **Demand**

This parameter considers the amount of green hydrogen demand in the industry.

This evaluation shows which industries are most likely to create demand for green hydrogen in the short run, as technology and legislation evolve.

Table 1: Key parameters for enabling green hydrogen demand in different industries, 2022

	Refining	Fertilizer	Chemical	Steel	Transport	Industrial Heating	Domestic Heating
Technology Readiness	High	High	High	Medium	Medium	Medium	Low
Rapid Uptake Potential	High	High	Medium	Medium	Low	Medium	Medium
Business Case	Medium	Low	Medium	Low	Medium	Low	Low
Incentives/ Legislation	Medium	Medium	Low	Medium	Medium	Low	Low
Alternatives	High	High	High	Medium	Low	Low	Low
Volumes	High	High	Medium	High	Medium	Medium	Low

High **Medium** **Low**

Note: there are few alternatives to low-carbon hydrogen in the refining, fertilizer, and chemical industry, thus, it is marked as high to reflect these favorable conditions.

2.1.1 Hydrogen-consuming industries

According to the IEA, global hydrogen demand has grown more than threefold since 1975, driven mostly by production growth from three major demand sectors – refining, ammonia production, and chemicals production.

Refining
Green hydrogen can be used to replace conventional (grey) hydrogen in the refining industry. The technical integration of green hydrogen in a refinery is well understood. The volumes required are high and there are few to no zero-carbon alternatives.

Although green hydrogen is a viable decarbonization pathway for refiners, the industry has still not seen large uptake. Only the Shell Rhineland Refinery has an operational electrolyzer on-site today in the EU. While legislation, such as the Renewable Transport Fuel Obligation (RTFO) in the UK or the EU Emission Trading System (ETS), provide some incentives to produce low-carbon fuels, there is a general lack of refining-specific legislation or subsidies in the EU.

Ammonia and fertilizer industry
The ammonia and fertilizer industry is another promising contender for green hydrogen demand due to high production volumes and lack of carbon-free alternatives.

The Carbon Border Adjustment Mechanism (CBAM) agreement includes cement, aluminum, fertilizers, electric energy production, iron, and steel. The review process recommends adding organic chemicals, plastics, hydrogen, and ammonia but this has not yet been adopted.

Although there are currently no operational green ammonia plants at a commercial scale, a few countries (such as Morocco and Saudi Arabia), are pioneering efforts for demonstration plants.

Chemicals
Hydrogen is used in the production of methanol, a key chemical building block. Methanol derivatives are used as fibers, plastics, and adhesives. Green hydrogen can replace conventional hydrogen in this process to create more sustainable chemicals.

Although there is a lack of subsidies in effect today to incentivize green chemicals production, industrial consumers are spearheading the uptake in some cases. For example, Maersk has announced interest in operating a fleet of methanol vessels to help meet its net-zero targets. This increase in demand will incentivise the production of green methanol.

Emerging industries
While there are efforts to integrate green hydrogen into industrial and domestic heating, mobility, and steel production, these markets are still in relatively early stages of development.

In the case of heating, fit-for-purpose pipelines to transport green hydrogen are yet to be installed on a large scale. In mobility applications, fuel cell vehicles (FCEV) are still not price-competitive or prevalent. The availability of alternatives, namely electrification, restricts the business case for green hydrogen in this application, except for in long-haul vehicles where infrastructure and the technical limitations of electric vehicles may make FCEVs more favorable.

While the steel industry is an emerging consumer of green hydrogen, the technology for this application is still in development. Having said that, steel is predicted to become the largest consumer of green hydrogen by 2030, as highlighted in Hydrogen Europe's Clean Hydrogen Monitor report (2021)[2].

Natural gas trade
Natural gas trade will also impact the green hydrogen supply chain. While the medium- to-long-term implications of the war in Ukraine are unclear, the conflict may result in an increase in demand for green hydrogen. This is due to Europe's need to transition from Russian gas imports to locally produced alternative sources of energy.

2: https://hydrogeneurope.eu/clean-hydrogen-monitor-2022/

How will expected reduction in oil and gas demand impact the demand for green hydrogen in refineries?

2.2 Supply analysis

If green hydrogen demand is set to grow significantly through 2030, aspiring producers will need to overcome the challenges of producing and transporting hydrogen to end users at scale.

Green hydrogen production faces strong competition for renewable electricity supply in Europe. Today, approximately 30% of the region's electricity is from renewable sources, which will need to more than double by 2030 to meet its decarbonization targets. In addition, green hydrogen production also competes with existing water demand as it has a large water footprint for feed and process cooling.

Which supply model, onsite or offsite is expected to become more prevalent? Is this industry related or time-sensitive?

Sourcing renewable electricity for electrolysis
Renewable electricity availability will determine whether green hydrogen production will be sufficient to meet the growing demand from industry.

Due to its relatively high load hours, wind power could help generate the renewable electricity required by the EU target of installing at least 40 GW of green hydrogen l electrolyzer b. However, it is not feasible to reserve all renewable energy potential for green hydrogen production.

Establishing electrolyzer capacity to produce green hydrogen
Electrolysis is not a new technology, but the green hydrogen industry has yet to develop a supply chain for electrolyzer production. It remains a predominantly bespoke, low volume, project-oriented operation, associated with high prices, extended lead times, limited flexibility, and little security of electrolyzer supplies. This is in stark contrast to more common processes such as grey hydrogen production from steam methane reforming (SMR).

Technology providers will need to accelerate the learning curve to develop a mature electrolysis equipment supply chain. This can be done by adopting practices from similar industries like the fuel-cell and solar-PV markets. These practices include drawing and implementing cost-down roadmaps, standardization, open-source IT solutions, multiple supplier sourcing, and predictive maintenance.

Transporting green hydrogen to end users
Green hydrogen will reach end users either directly or through a series of steps that require conversion, transport, and reconversion. It is important to understand the supply chain, as illustrated in Figure 2, which consists of multiple options.

Figure 2: Green hydrogen distribution pathways

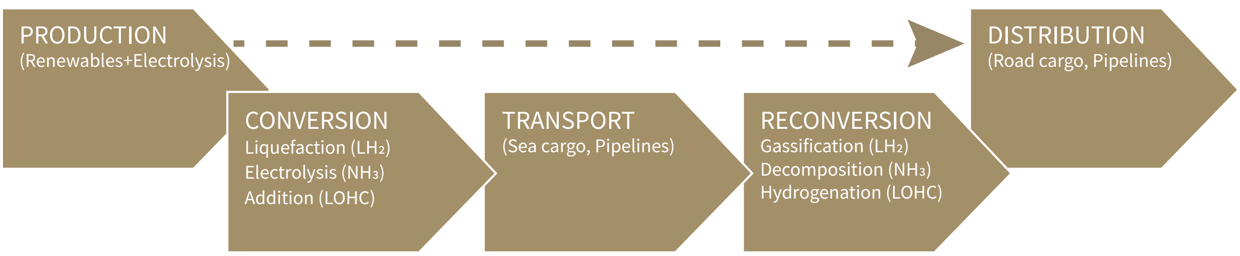


Table 2 compares the different supply models highlighting the pros and cons of both. The table also analyzes the rate of deployment of each model and identifies business case examples for both.

Table 2: Green hydrogen supply models

	Pros	Cons	Rate of deployment	Business Case Examples
Off-site Production near renewable electricity	• Reduced electrical lines cost • Economies of scale • Easier large-scale storage • Faster renewable electricity capacity expansion • Secure supply of electricity and hydrogen • Reduce stress on grid • Enforces the need for a more robust backbone of gas pipelines - which will also help in scenarios of excess demand and reduced supply and connect storage facilities with end users • Freedom to optimise production system based on cheapest electricity price	• Increased (geo) political interference and risks • Potential for monopolisation of hydrogen supply • Higher risks - larger investment, higher project bankability risks • Increased cost of transport of hydrogen via pipelines, LOHC, ammonia, or methanol • Hydrogen carrier technology and commercials needed to evaluate import prices • Green hydrogen volumes constrained by the speed of the RE capacity expansion	• Technology not available yet • High risk, high gain • In planning/financing stage • Dependent on industrial uptake • Investment before the market is available • Higher bankability value - larger assets • Requires political willingness to create connectivity of pipelines	• PosHYdon • NorthH2
On-site Production near end-user	• No need for transport and storage of green hydrogen • Robust and localised energy balancing service • Energy independence (minimal political interference) • Opportunity to integrate renewables into local grid • Create a home market for electrolysers	• Increased stress on powergrid capacity (already a huge challenge in many locations) • Better certification system required to ensure that Intermediate step for large electricity is green • Limited resources including financial support, operational capacity of grid infrastructure • Adverse Impact on other grid electricity users (increased demand response)	• Technology available • Medium risk, medium gain • Intermediate step for large scale deployment • Currently operational • Dependent on localised uptake build when demand is available • Electrical infrastructure for direct-wire will take longer to develop than pipelines • More flexibility for a regular supply of hydrogen (combination of SMR and electrolysis), thus shorter time to market	• REFHYNE • Hydrogen Holland • Hydrogen Future

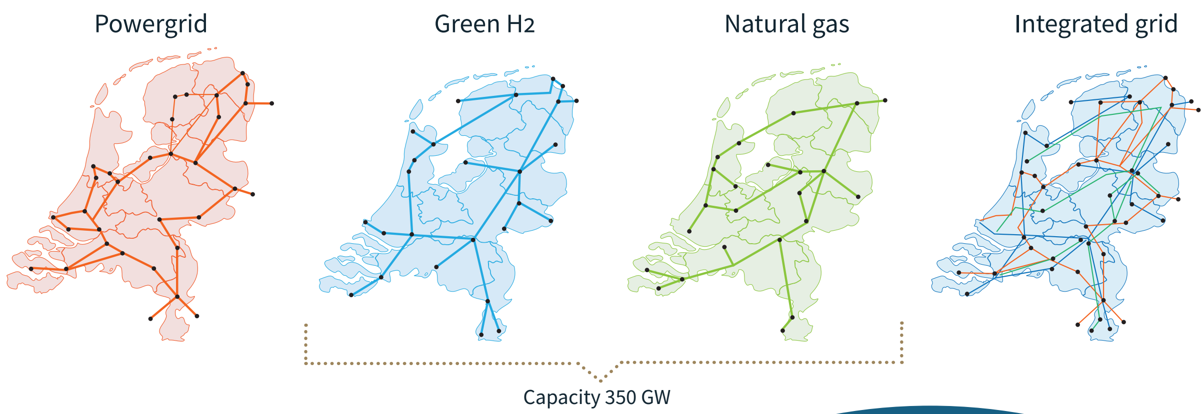
Since the transport potential of green hydrogen is similar to that of oil, natural gas, and chemicals, there is an opportunity to retrofit existing infrastructure, such as natural gas pipelines , to transport hydrogen. Retrofitting will reduce capital investment requirements and boost the supply network.

However, retrofitting is not without its challenges, particularly with regards to safety. Technical challenges such as pipeline embrittlement and potential leaking prevent existing infrastructure from transporting 100 percent green hydrogen. The European Hydrogen Backbone (EHB) is in the process of strategizing the retrofit of pre-existing natural gas pipelines and laying out new hydrogen pipelines to connect parts of Europe for a centralized hydrogen supply. Current targets are to introduce up to 5 percent hydrogen in existing pipelines by 2025. To date, tests have been conducted to confirm that up to 20 percent by volume of hydrogen may be safely blended into current natural gas transmission infrastructure. This would make up only about one percent of the total volume of natural gas in circulation.

With green hydrogen carrier technologies being fragmented and at varying states of maturity, infrastructure is not the only challenge the green hydrogen supply chain needs to address. From liquid hydrogen (LH_2) to ammonia (NH_3) to liquid organic hydrogen carriers (LOHCs), de-risking and implementing the lowest cost transportation method will require further technical development and capital investment.

As electrolysis technology matures, developers will be confronted by the challenge of which transmission networks to build – power grids or pipelines. Where electrolysis units are built, either within proximity of renewable energy sources or demand hubs, will determine the type of transmission network needed and the capital and operating costs involved. Figure 3, sourced in collaboration with TNO, shows a vision of the networks within the Netherlands where the power, hydrogen, and natural gas grid co-exist to facilitate off-site and on-site green hydrogen production.

Figure 3: Gasunie: a vision of an integrated power/NG/GH grid in the Netherlands



What are the emerging industial trends due to the Russia / Ukraine conflict? Will green hydrogen development decelerate, as countries revive more established means for energy i.e., coal, natural gas?

2.3 Technology and risks

While electrolysis has been around since the 1920s, the process only accounts for 0.1 percent of dedicated hydrogen production today. This is because more commercially viable methods, like producing hydrogen from natural gas, continue to dominate the market. For green hydrogen production capacity to reach 40 GW by 2030, electrolyzer manufacturing capacity needs to further develop.

1. Materials

From electrodes and porous transport layers to membranes and catalysts, the market needs to strike a balance between the costs and uses for materials and their performance and durability.

2. Reliability in performance

Electrolyzer producers need to design electrolyzer stacks that can handle more power (higher current density), improve efficiency and enable larger stack sizes. They also need to reduce consumption of critical, costly, and scarce materials such as lithium, all while guaranteeing electrolyzer performance over a sufficiently long lifetime.

3. System size

Modularity in electrolyzers is key for standardization and automation. The ability to control individual stacks in an electrolyser would help with system optimization, integration, scalability, and design of the balance-of-plant. This modular approach will ease the upscaling process for large capacity electrolyzers. Without an automated electrolyzer manufacturing system, the electrolyzers aren't standardized products and are prone to manufacturing variability, resulting in quality and assurance issues. As a result, manufacturing costs for electrolyzers remain high and product quality varies. This creates challenges when integrating into large, complex systems.

Figure 4: Typical timescale for product maturation

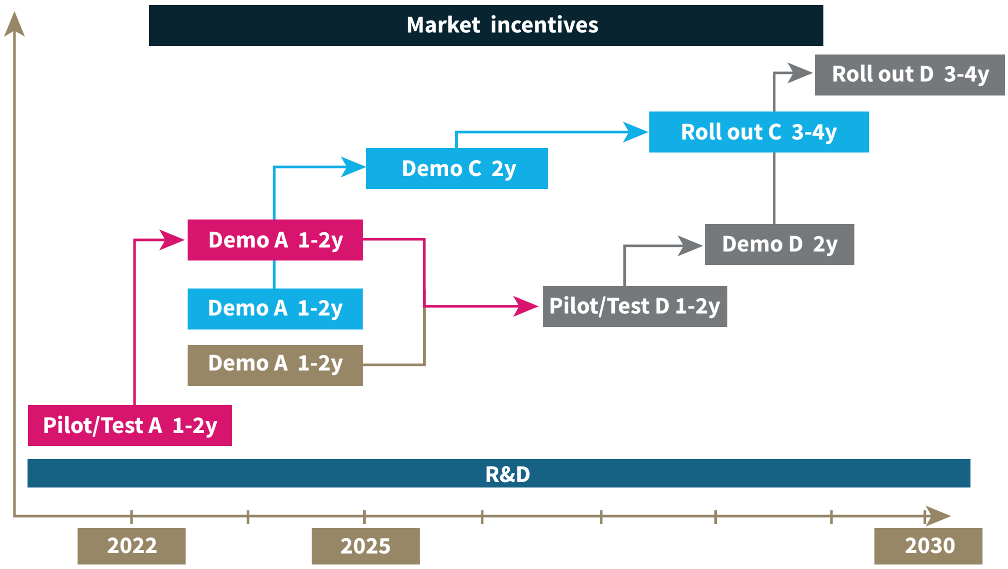


Figure 4 highlights the timescales of the innovation and commissioning cycle for electrolyzer technology. Given that currently available technologies are not yet ready for large scale roll-out, time should be allocated to R&D, technology optimization and de-risking. In addition to favorable market conditions and policy incentives, it takes typically eight years for a technology to go from a stage of pilots and testing to demonstration to commercial roll-out. This means that the perspective for 2030 will be determined by technologies being successfully developed and piloted in the coming three to five years.

How will the standardization of electrolyzer production help accelerate timelines for larger scale deployment?

3.0 The hydrogen industry tomorrow, 2025

A 2025 snapshot showing when select projects are expected to come online is shown in Figure 5. These projects are selected based on their development status, economic feasibility, the potential to secure funding, and regional policies.

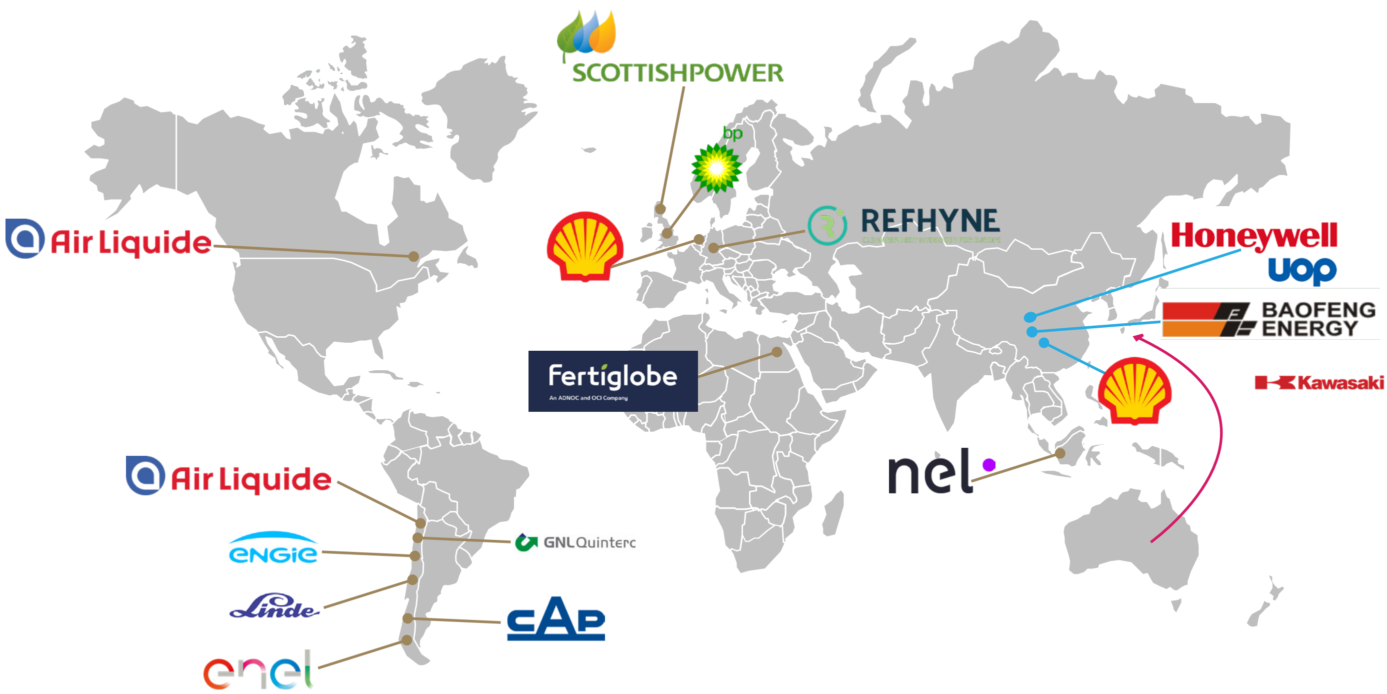
Europe is at the forefront of upcoming industrial-scale electrolysis plants, with predictions showing up to 1.3 GW of green hydrogen production capacity coming online by 2025. Globally, analysts predict over 30 GW of green hydrogen production in 2025.

While most of these developments are for refining, other industries such as ammonia, steel, chemicals, and transport are positioned to become significant consumers of renewable hydrogen. Thus, a more cluster-like approach can be expected in the medium to long run as synergies are created across industries.

In a gigawatt-scale hydrogen economy, the business model is expected to be based around multi-purpose energy hubs. One example of such a hub is the recently announced HyGreen Teesside project, which is forecast to have 60 MW electrolytic capacity online by 2025, supplying green hydrogen for heavy-duty vehicles and industrial use. Hydrogen trade, in the form of derivatives, is also expected to grow. For example, exports from Australia to Japan are currently being tested by the Suiso Frontier, the world's first liquid hydrogen carrier ship.

In the wake of COP 27, Egypt is looking to install a 200 MW electrolyzer as part of a broader plan to develop a robust green hydrogen industry. When realized, this would be the largest green hydrogen project to date and will allow for increased technical learnings, financial evaluations, and partnerships.

Figure 5: Select forecast global operating electrolyzer projects, 2025



Note: this is not an exhaustive list of all projects. This is a limited list based on project announcements in the public domain. Icons highlight project partners, including developers, licensors, and technology providers.

4.0 The hydrogen industry in 2030

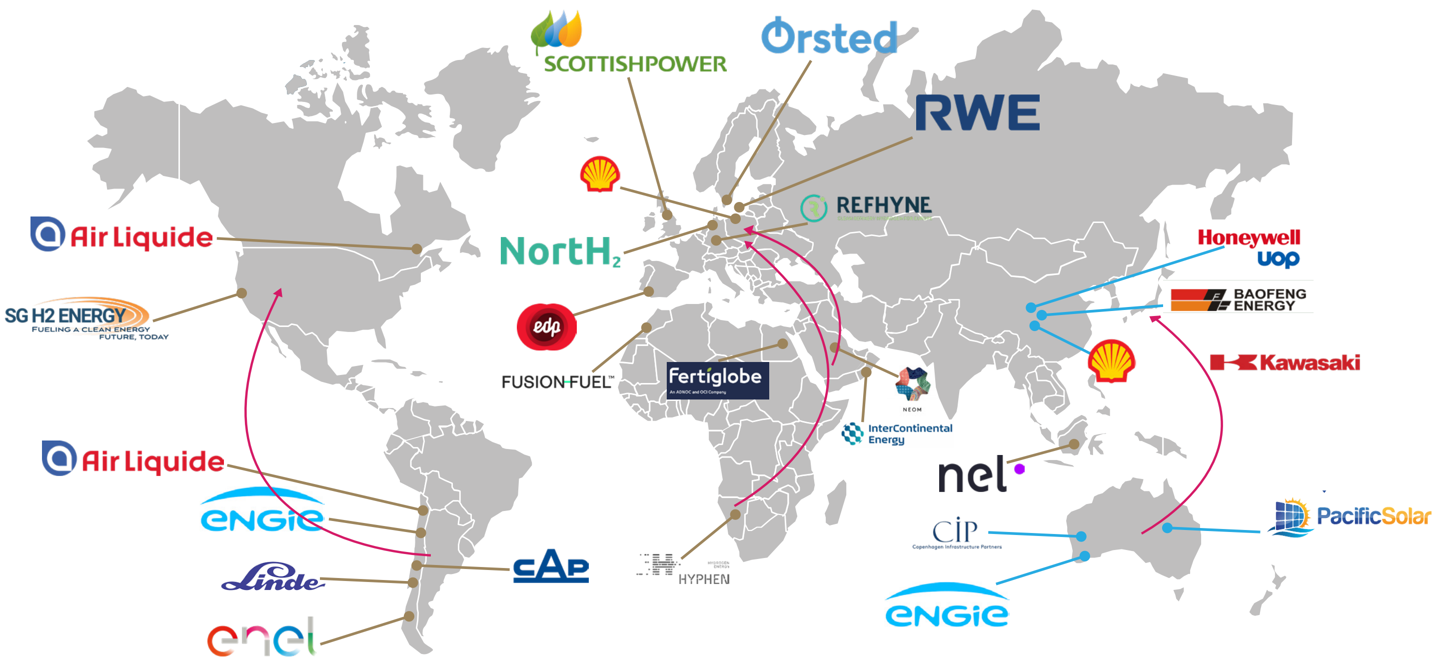
In 2030, we will have a visionary map (as shown in Figure 6), showing a fully integrated system where demands are met by local production and by increased trade of green hydrogen. Globally, analysts predict 114 GW of green hydrogen production by 2030. Although the focus of this paper is on the European sector, Asia Pacific (primarily Australia) and the Americas are expected to have large-scale developments in operation. One such project is the Asia Renewable Energy Hub, which is expected to go online by 2028 and export green hydrogen and ammonia from Western Australia to Asia.

Green hydrogen is expected to be traded from regions of abundant renewable energy sources (solar, wind, hydro, and geothermal) to developed economies with robust decarbonization plans.

This includes the transport of hydrogen via LOHC, methanol, or ammonia from Australia, South America, the Middle East, and northern Africa to Europe and the Americas.

For this vision to come to fruition, various aspects of the green hydrogen development process need to be evaluated, and more importantly, aligned. A robust market for green hydrogen, technical and infrastructure advancements, and a better understanding of the risks and challenges of electrolyzer technology are all key to an efficient and effective green hydrogen economy.

Figure 6: Select forecast operating electrolyzer projects, 2030



Note: this is not an exhaustive list of all projects. This is a limited list based on project announcements in the public domain. Icons highlight project partners, including developers, licensors, and technology providers.

5.0 Conclusions and timelines

The green hydrogen economy is currently in its inception but has gained a lot of interest as a low carbon intensity fuel and feedstock. With countries and corporations racing to meet net-zero targets, innovations in electrolyzer technology are moving forward to improve the feasibility of green hydrogen production and use. Studies show the potential for green hydrogen to become less expensive than grey hydrogen in areas with preferable renewable energy resources and as carbon trading and taxing mechanisms become more stringent.

Although there is a 250 GW global pipeline of announced projects for green hydrogen within this decade, the complexities of supply, demand, and technology development are crucial in the successful roll out of these projects. Identifying and incentivizing demand to support ambitious production targets, subsidizing and optimizing the supply of green hydrogen, and accelerating the innovation of cheaper, more environmentally sound electrolyzers, are key aspects of this energy transition.

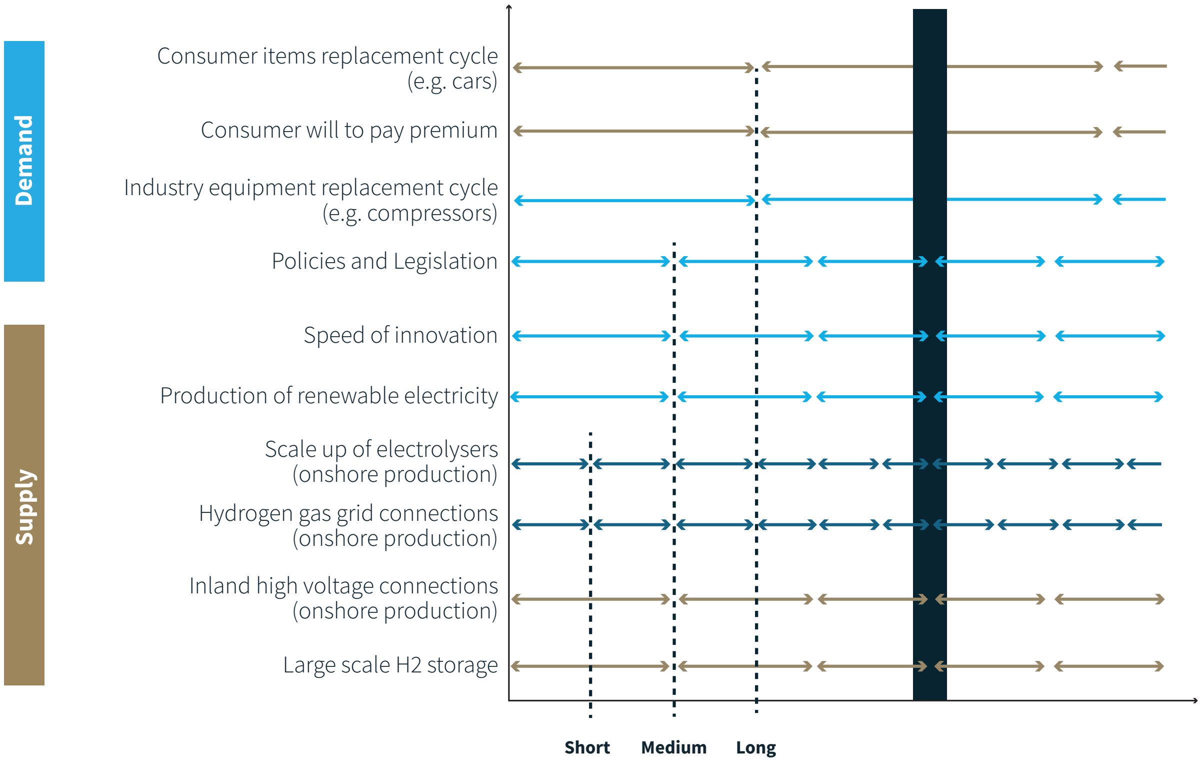
Today the refining, chemicals, and ammonia industries are spearheading the consumption of green hydrogen, with the steel and mobility sectors showing growth rates higher than previously expected. This demand is crucial to ensure a competitive market driven by innovation and sustainability efforts.

The supply of green hydrogen is dependent on geopolitical location, demand profile, power generation infrastructure, and modes of transport available to each site. These determine whether an electrolyzer plant will be located on-site for consumption, off-site as a centralized producer with product transported through pipelines and trucking, or offshore on wind farms to minimize the need for additional electrical infrastructure.

Alkaline electrolyzers have been in use for almost a century, but more sophisticated designs are now either commercially available (proton exchange membrane electrolyzers) or in development (solid oxide and anion exchange membrane electrolyzers). Research and development is crucial in the successful roll-out of new electrolyzer technologies. Materials used, the size of plants, and reliability in performance also play a significant role in their uptake.

It's clear that a robust green hydrogen economy is very complex with many moving parts. Figure 7 illustrates the life cycles of these aspects. This summary diagram visualizes the cycles of each aspect with the long run expected to be around seven to 10 years, medium around four to six years, and short at around one to three years.

Figure 7: Barriers and timescales for the transition



Consumer items replacement cycles: Consumers are expected to upgrade household items (cars, energy providers, etc.) in the long run.

Consumers will pay a premium: Consumer awareness-driven changes are expected to have an impact over a long period of time.

Industry equipment replacement cycle: Industry processing equipment has up to 20 years of operating lifetimes and thus, is expected to be replaced in the long run.

Policies and legislation: Legislation-driven changes are expected to have an impact in the medium run since getting the legislation approved may take up to three years.

Speed of innovation: Pilot testing and demonstration plants are expected to take up to five years and are thus updated in the medium run.

Production of renewable electricity: Large-scale production of renewable electricity is expected to come online in the medium run.

Scale-up of electrolyzers: Heavy investment and R&D in the scale-up of electrolyzers mean that they are expected to come online in the short run, with a 500 MW electrolyzer expected to go online by the end of 2022.

Hydrogen gas grid connections: Ongoing research and development in upgrading natural gas pipelines to transport pure hydrogen is expected to give successful results in the short run.

Electrical infrastructure: Inland high voltage connections to allow for the electrolysis with renewable electricity is expected to come online in the long run.

Large scale H2 storage: Large-scale hydrogen storage in salt caverns or pressured tanks are expected to become commercially viable in the long run.

Figure 7 shows that if these development timescales are not shortened, the supply, demand, and technology drivers will not come to an agreement until it is too late. Thus, collaboration and data sharing, increased investment in demonstration plants and renewable electricity potential, open discussion of technical challenges, and quicker turnover of green legislation is key in determining the future of green hydrogen.

References

1: https://www.iea.org/reports/hydrogen

2: https://hydrogeneurope.eu/clean-hydrogen-monitor-2022/

We aim to generate discussions from this thought leadership piece. So, please reach out to the authors if you have any comments or questions.

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Erica joined the decarbonization team as a consultant from the University of Bath. She is currently specializing in green hydrogen supply chain and legislation. She has worked on a variety of projects helping with market research, configuration and feasibility studies, licensor selection, business development, and sales. She joined the low carbon team to start looking for opportunities in the renewable sector, namely circular economy of plastics and green hydrogen.

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He focuses on future generations of proton exchange membrane (PEM), anion exchange membrane (AEM) and solid oxide electrolysis cells (SOEC) technologies, addressing issues such as scale-up, safety and operating strategies. Arend supports various industry sectors in defining energy transition paths, based on green hydrogen as a common denominator. These projects range from technical and engineering assistance to strategic decision support.

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Roald is a researcher and advisor dedicated to issues involving sustainable innovation and energy transition. His primary areas of interests include scaling up innovation eco systems, accelerating innovation in the context of the energy transition, and industry transformation. In recent years, Roald has contributed to the identification and development of opportunities in the field of electrolyzer manufacturing and green hydrogen production.

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