Green Hydrogen Unlocked: Brande Hydrogen

Key learnings from operating
a pioneering pilot project

SIEMENS Gamesa
RENEWABLE ENERGY

Foreword

When we decided to devise a prototype to produce green hydrogen, we knew that we were entering uncharted territory. But the same could be said of the wind turbine business, which began when there was neither a regulatory framework nor a business case for the production and sale of renewable energy.

The determination of the wind industry pioneers to see beyond the immediate hurdles is inspirational. The challenges ahead when looking at how to scale green hydrogen production should not be allowed to compromise the importance of green hydrogen as the only viable alternative source of energy for hard-to-decarbonize sectors.

Our Brande Hydrogen test facility in Denmark is at the forefront of green hydrogen production, using an electrolyzer which can be powered either by the grid or directly by a wind turbine. The project allows us to test a range of options, including off-grid offshore, which has the potential to provide the industrial-scale volumes needed to achieve net zero.

The Brande project will inform our technology roadmap as we build our interest and capabilities in the entire green hydrogen production value chain. We are investing internally, talking to governments and regulators and are engaging across the entire ecosystem to advocate the importance of green hydrogen.

Many of the challenges which emerged at Brande Hydrogen – safety, partnerships, hardware and software, regulation and distribution – will also be relevant to the GW-scale plants of the future. The project's importance in the development of the green hydrogen industry is already established, with further innovations to come.

We are proud to be an early adopter of green hydrogen, and trust that the learnings shared in this paper will help to drive the industry forward, at scale and at speed.

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Siemens Gamesa Renewable Energy

Content

Introduction

One of the most challenging aspects of the climate emergency is how to address emissions from the hard-to-decarbonize sectors – heavy industry, heavy transportation, industrial agriculture.

The only net-zero option to reduce emissions from these energy-intensive industries is based on green hydrogen – hydrogen produced by electrolyzers powered by a renewable source.

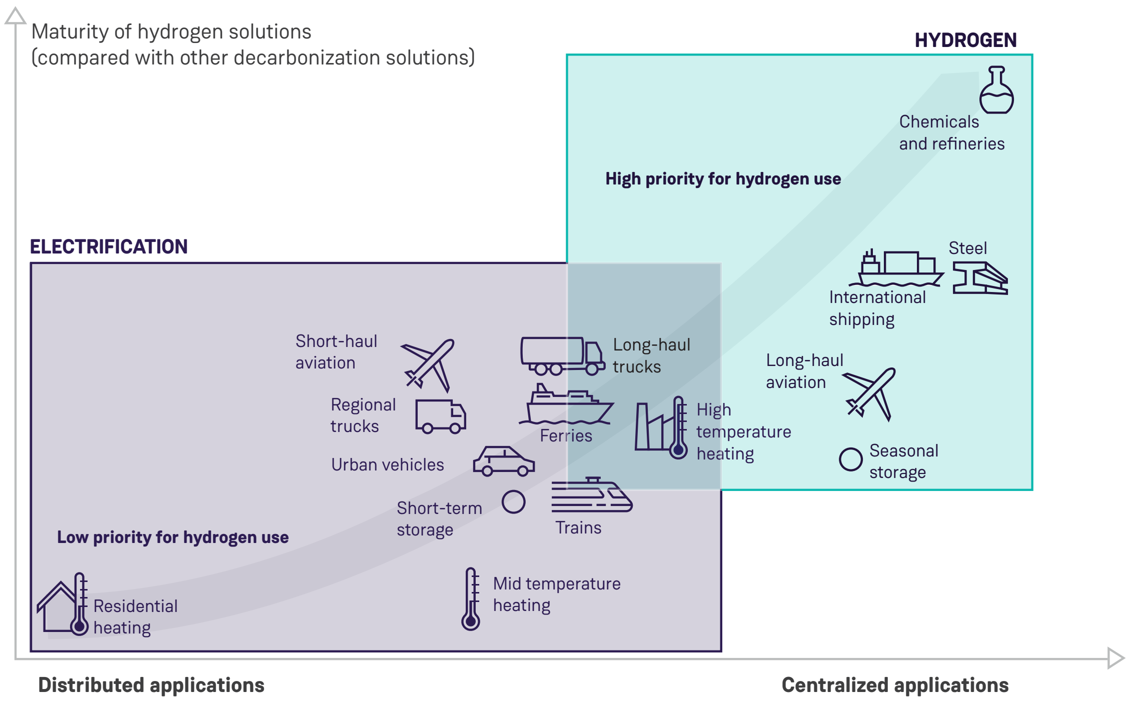
Green hydrogen is also part of the conversation around energy security[2]. As Europe frees itself from Russian fossil fuel imports, a significant proportion of which is used to power heavy industry, the changes in supply patterns create an immediate and sustainable market opportunity for green hydrogen.

As one of the earliest proponents, Siemens Gamesa first began working on a green hydrogen prototype project in Denmark in 2021. Today, Brande Hydrogen is producing green hydrogen, using an electrolyzer which can be powered by the grid or directly from an onshore wind turbine, with the hydrogen used as fuel for some of Copenhagen's taxi fleet.

While the size of the Brande prototype is modest, the learnings and takeaways will be relevant as the size, ambition and scope of green hydrogen projects increase.

The scale-up needed to get from where we are today to where the targets are is vast but achievable. Brande Hydrogen, the first proof point, is just the start.

Green hydrogen use cases[1]



Source: IRENA

How the Brande project came into being

When talking about a paradigm shift in how to power the hard-to-decarbonize sectors, it's appropriate that the Brande prototype was incubated in Siemens Gamesa's dedicated innovation unit.

Initially, the aim was to look at off-grid production, or island mode, mainly for large-scale power plants offshore, where winds are stronger.

But the focus shifted early on to develop an energy management and control system for an onshore plant capable of combining wind, electrolysis and batteries in new ways. One of the first learnings to share is the necessity to be flexible during the innovation and prototyping stage.

The hybrid plant is grid connected and can be implemented as an upgrade to existing wind farms, or for green field projects.

However, the configuration of the energy management and control systems allowed for the implementation of some test scenarios for off-grid production. Off-grid will be the preferred option for offshore use where the turbine is coupled with the electrolyzer to produce hydrogen at sea, whereas off-grid onshore will support turbines located in rural and remote areas to produce hydrogen for distribution by pipes rather than electricity exported by cables.

Brande Hydrogen comprises a single

3-MW turbine connected to a 400-kW electrolyzer

which is used to split water – sourced from the mains supply – into oxygen and hydrogen.

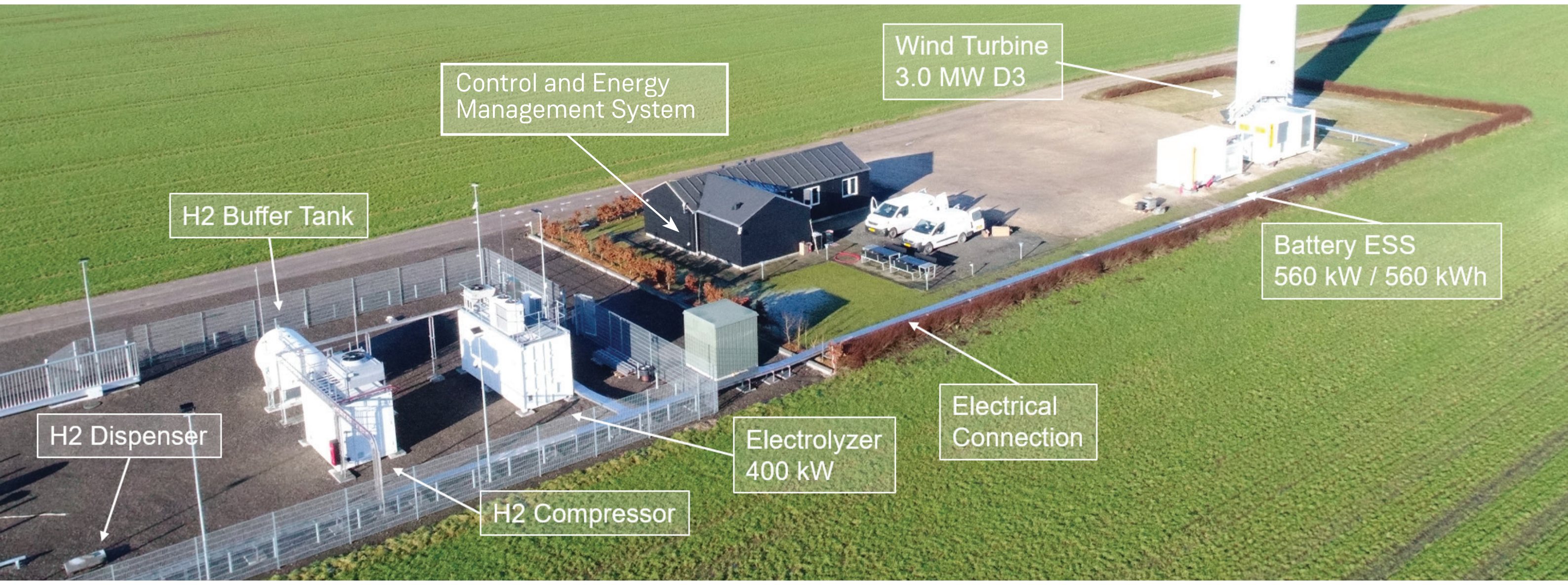
The hydrogen produced is compressed and stored onsite in a specialized tube trailer. Once full, the tube trailer is coupled to a truck and driven to Copenhagen by our partner Everfuel, where it fills the hydrogen fuel cells to power some of the city's publicly owned taxis. Meanwhile, an empty tube trailer is brought to the site, connected to the dispenser and begins to be filled up again.

Overall, the project has set out what it meant to achieve – produce green hydrogen using an electrolyzer with the option of being powered directly by a wind turbine, and then find an offtaker to use the green hydrogen. It has offered insight into how to handle and operate a hydrogen facility, develop procedures and processes while building experience which we will benefit from in upcoming projects.

Additionally, it validates our own belief that production of green hydrogen at sea, independent of an electricity grid, is achievable.

The following chapters examine some of the key issues that emerged during the Brande Hydrogen project. Ultimately, they will need to be considered in order for green hydrogen to reach its true potential.

Brande configuration[3]



Learnings by clusters

Safety and standards

Safety should be prioritized at every stage in the green hydrogen production process. When GW-scale contracts are signed, any capital or operating expenditure related to safety must be ringfenced and cannot be compromised.

Developing an intensive safety culture for green hydrogen production was a priority at Brande Hydrogen. However, hydrogen is not a new energy carrier – the oil and gas industry has been producing and distributing hydrogen for decades. There will be some continuity, but a future based on green hydrogen will create many new applications and use cases, standalone and as part of the emphasis on sector coupling during the transition to net zero.

This will encourage many new market entrants into hydrogen, including Siemens Gamesa, electrolyzer manufacturers, investors and offtakers, each of which will need to learn and adopt new safety processes.

Siemens Gamesa's safety culture has grown over the decades of installing and servicing the world's most powerful on- and offshore wind turbines, formalized under the 12 Life-saving Rules initiative. Training the basics to perfection, using virtual reality and physical training centers, in a globally consistent way, has underpinned our approach to safety for the wind industry and is being adopted with the same commitment for green hydrogen.

Standards help to support a safety culture, but if there are no standards in place, innovation can still take place. There are many examples of us doing something which had never been done, such as launching smart turbines with sensors to improve performance through data analytics. As a result, we have insight and experience of working with the relevant authorities to develop standards which will benefit the entire ecosystem.

Siemens Gamesa is part of a joint industry project launched this year by the classifications agency DNV[4]. The collaboration aims to create standards for reliable, safe and cost-efficient hydrogen production systems that use renewable energy-powered electrolysis to produce green hydrogen.

Some existing regulations for traditional hydrogen are ISO-standardized or covered by EU directives and can be adopted within the green hydrogen standards. Transportation rules are equally applicable to renewable hydrogen as they are to legacy hydrogen – it's the same gas with same flammability.

But the green hydrogen industry will need specific protocols. Off-grid offshore green hydrogen production is a long-term priority focus for us, but early projects will be grid connected. Moving the entire process offshore is a big step. Part of our responsibility as an early adopter is to set ourselves the highest health and safety standards as we start testing.

The entire ecosystem needs to accelerate the drive towards standardization as part of the plans to reach GW-scale targets. At Brande Hydrogen, for example, we realized that the interface for connecting and filling Everfuel's fleet of tube trailers were not standardized. A solution had to be developed in partnership. This small-but-significant issue is an example of not only where a lack of standards can potentially disrupt the supply chain but also how granular the standards will need to be.

Based on our experience of helping develop the standards for the wind turbine industry, we are introducing internal protocols that are future-proofed and able to respond to a market as it matures. There are future innovations to come at every stage and standards need to support paradigms which, today, are still on the drawing board.

Key Learning:

Safety is non-negotiable, and a collaborative effort is needed to bring standardization to the entire ecosystem.

Regulatory framework to support investment

Green hydrogen can be produced while standards are discussed and developed. However, a regulatory framework is needed to create the conditions for governments, investors, end-users and innovators to commit to GW-scale projects.

For example, until there is a regulated market mechanism for the sale of green hydrogen, the electrolyzer supply chain could be reluctant to invest without a guarantee that someone will buy the hydrogen produced.

But some manufacturers are prepared to accept the risk of scaling up production for a not-yet fully realized market. Today, investments tend to be based on leveraging existing partnerships and relate to how strategic green hydrogen is within their core operations. Harmonization of certifications, standards and regulations will take place as the green hydrogen industry matures. In the interim, many countries are finding ways to approve small-scale projects within their existing protocols.

Brande Hydrogen was approved relatively quickly as one of the Danish government's "official regulatory energy test areas". Looking ahead, other authorities will need be as responsive as the Danish government and find ways to speed up the authorization processes for all sizes of green hydrogen projects. Investors need to know that the authorities will approve a scheme within a schedule.

Delays in permitting and approvals for on- and offshore wind farms will directly impact the roll-out of green hydrogen, while the projects themselves will also need permits and approvals specifically for the production, distribution, sale and end-use of green hydrogen.

The global reach of the green hydrogen industry needs to be factored into the regulatory framework as well. New bilateral import and export agreements will characterize the transition towards decarbonization of heavy industry, transport and agriculture. Deeper layers of cooperation and coordination between local, domestic, regional and international regulators will be needed, in turn adding to the imperative for streamlining permitting and approvals.

As is often the case, the European Union is leading the way for regulations. This May it launched a consultation on the regulatory framework for renewable hydrogen, looking at two different areas of interest – firstly, defining "renewable hydrogen" and finding a consistent way to calculate the life-cycle emissions and greenhouse gas savings from renewable hydrogen as per the new definition[5].

The need to formalize green hydrogen regulations has been accelerated in response to the European Commission's REPowerEU initiative[6], which increased the already ambitious 2030 targets for green hydrogen production in Europe.

Elsewhere, the United States has been working on its Hydrogen Program Plan since 2020 and has included a range of incentives for green hydrogen within the Inflation Reduction Act[7], signed into law this summer.

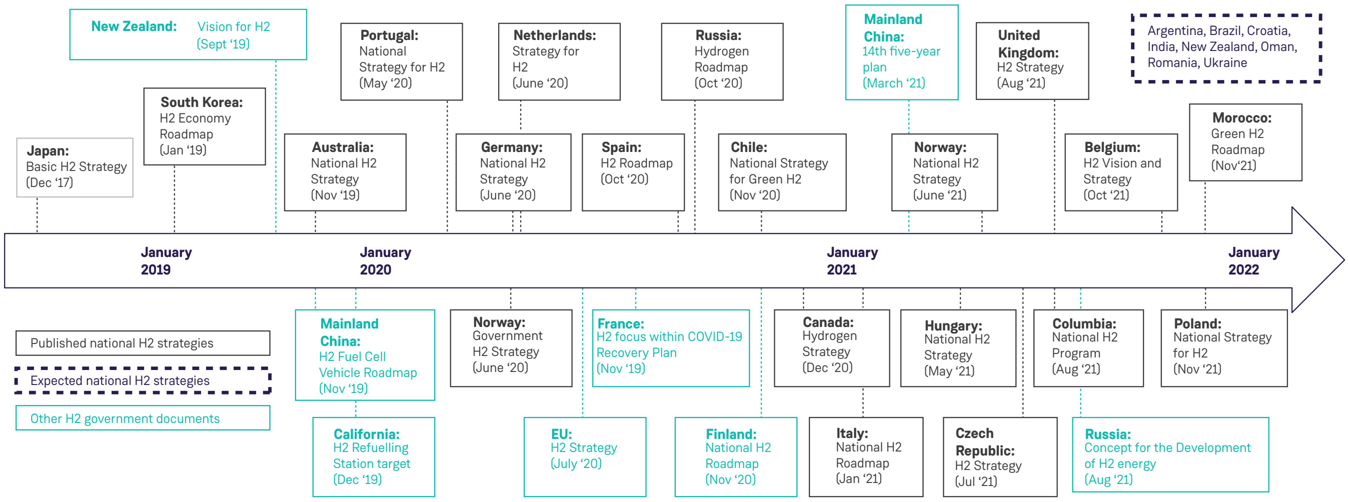
Australia's hydrogen strategy was launched in 2019 and China's government has recently set targets for 2025. However, green hydrogen will have a global reach and many countries, some of which are not traditional energy producers, are exploring its potential.

While these commitments are always welcome, the regulatory context for these strategies needs defining. Creating market parameters will encourage investment in the next phase of green hydrogen production and accelerate the journey towards GW-scale, commercially viable power plants needed to decarbonize energy-intensive industries.

Key Learning:

It is important to maintain a strong commitment to investment and innovation in green hydrogen in advance of the European Union (and other jurisdictions) clarifying the rules.

Timeline of global policy and regulatory documents relating to hydrogen (selected reports)[8]



Hardware readiness – electrolyzers

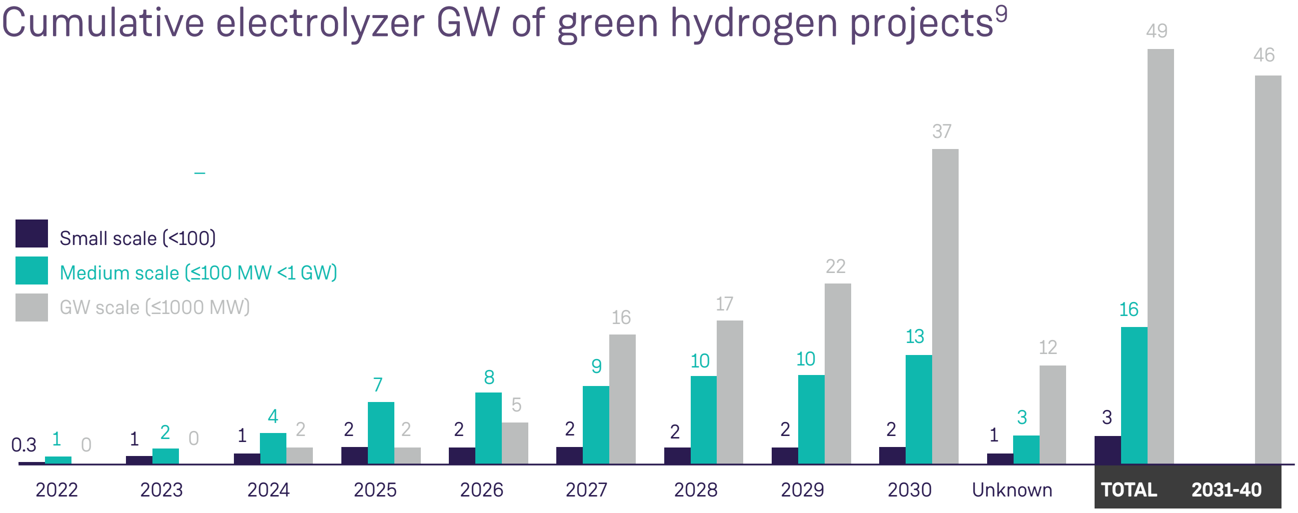
The fact that there are taxis using green hydrogen produced directly from power generated by a wind turbine, transporting the citizens of Copenhagen around their city, proves that there is technology available today which can produce modest but usable volumes of green hydrogen.

However, for GW-scale production plants, new hardware is needed, specifically, the electrolyzers which release the hydrogen molecules from water.

The electrolyzer industry and its supply chain of critical components is an emerging industry, and, as things stand, there is a shortfall between electrolyzer capacity on the market or in the pipeline, and what is needed to produce the volumes required. However, with billions of dollars of investment coming into the sector, the gap is likely to be closed.

There are an estimated 70 GW of green hydrogen projects coming onstream between now and 2030. This will create demand and competition for electrolyzers, improving time-to-market, in turn leading to innovation, cost reductions and operational improvements.

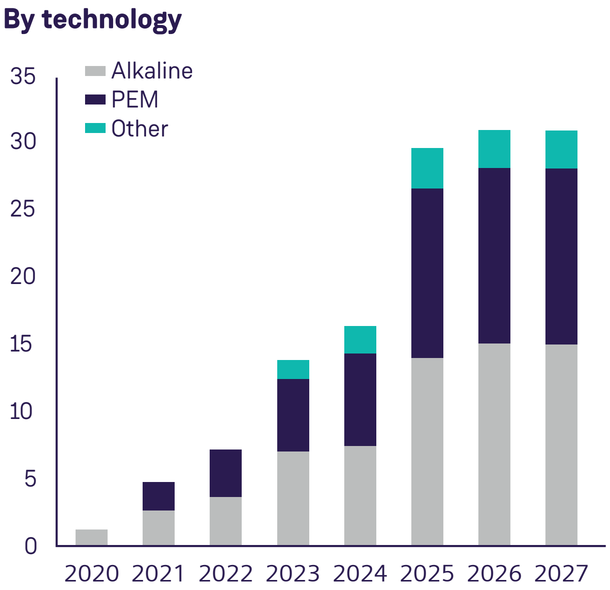
Cumulative electrolyzer GW of green hydrogen projects[9]

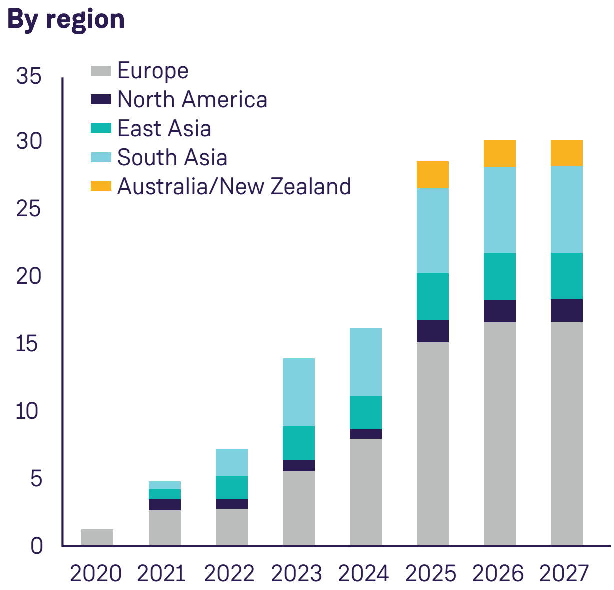


Source: BNEF H2 project database 1H2022

Electrolyzer manufacturing capacity[10]

Electrolyzer manufacturing capacity to jump after 2025 (GW/year)





Data accessed July 11, 2022.
PEM = proton-exchange membrane
Sources: S&P Global Commodity Insights; company announcements

The wind turbine sector industrialized in a relatively short period of time. However, the electrolyzer industry needs to achieve maturity and scale much quicker than the three decades it took wind. Today, electrolyzer manufacturers can focus on their strengths, knowing that turbines are mature and capable of delivering renewable electricity to drive the electrolyzers. The wind turbine manufacturers are also working on new ways to power electrolyzers directly from the turbine.

Elsewhere, the battery storage industry is less mature than wind but more mature than electrolyzers. At Brande Hydrogen, water-cooled lithium-ion batteries store any excess energy.

This method satisfies the needs of Brande Hydrogen volumes and the site configuration, but the best practice for storing energy to keep GW-scale projects in balance is still to be decided (as is the best way to store the hydrogen produced).

Hardware can be improved through partnerships and collaboration. A fully integrated offshore wind-to-hydrogen solution is being developed by Siemens Energy and Siemens Gamesa, connecting electrolyzers to offshore wind turbines using synchronized systems to produce green hydrogen at sea [11].

Key Learning:

The time-to-market for new electrolyzers can be accelerated in the immediate term by committing to projects, encouraging competition, investment and innovation. Validating use cases and providing clarity on end-users will also help drive the electrolyzer industry forward.

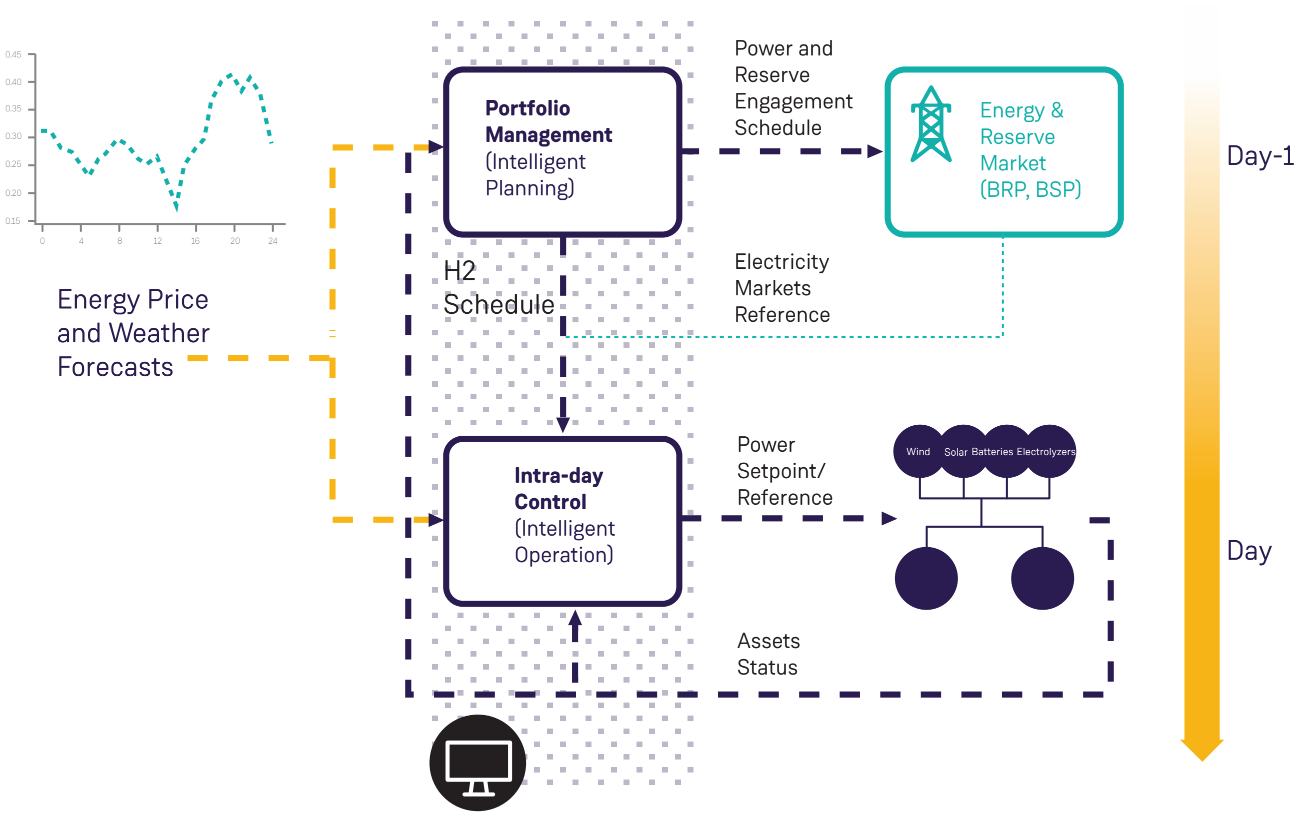
Energy management systems as the enabler

Energy management systems (EMS) and control units are fundamental to the commercial and operational success of any green hydrogen project. While the control unit makes all systems talk to each other on a millisecond-level to ensure their smooth and safe operation, thus being more a technical necessity, the real added value lays in the EMS. EMSs provide algorithms to commercially optimize the operation of the integrated assets (e.g., wind turbines, a PV plant, a battery and an electrolyzer) based on the data that is fed into them, like day-ahead power prices, the hydrogen price, grid service commissions, wind and solar projections, combined with historical data from across the globe – wind patterns, predictive maintenance, price and demand forecasting.

Energy management and control systems (EMSs) underpin the operational and commercial success of any project and are fundamental to the industrialization of green hydrogen production. Many familiar features of today's EMSs will be retained, but the potential for green hydrogen to serve new value streams will require bespoke development and new features for the next-generation EMSs.

Brande Hydrogen's energy management system was configured to be a real-world project for the integration algorithms, creating the intellectual property and other early adopter advantages for Siemens Gamesa. Real-world learnings are always more valid than simulations, and this commitment aligns with our belief that actions speak louder than words[12].

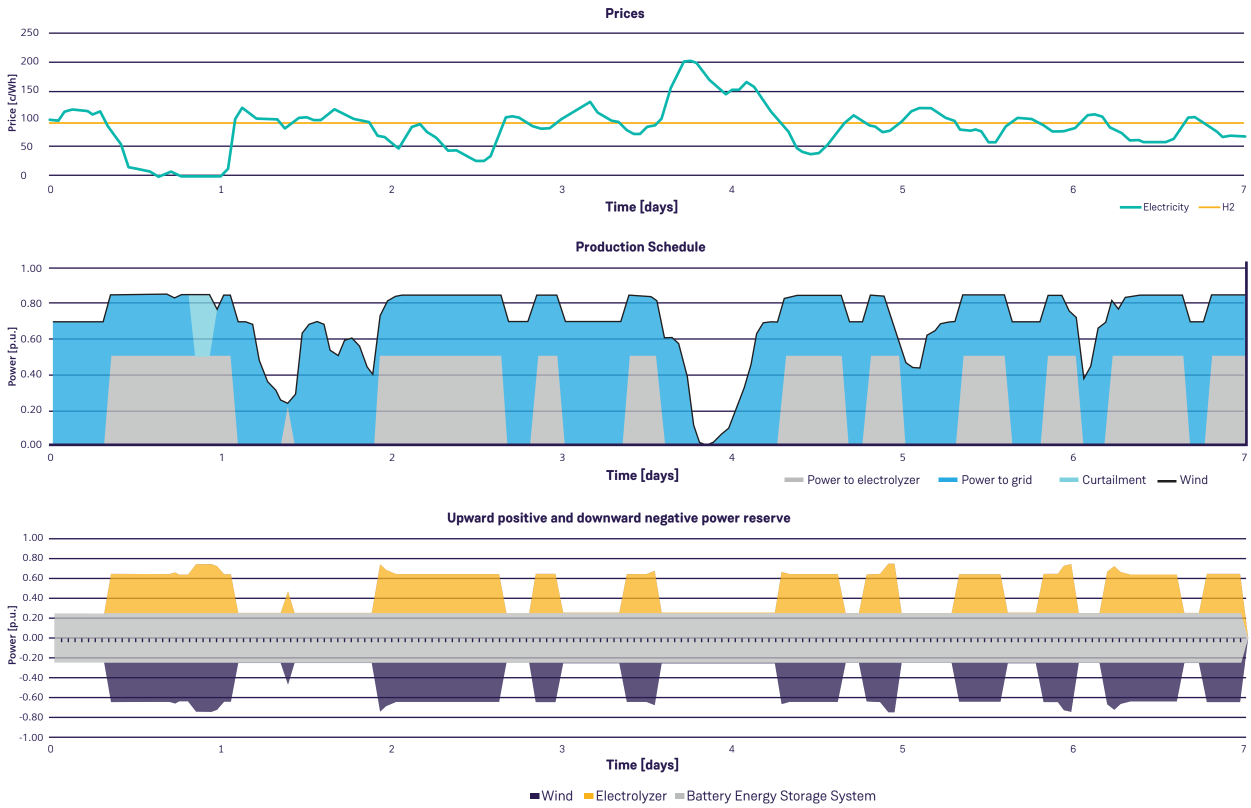
Brande EMS overview[13]



The EMS running the Brande project has a modular structure. The management module balances day-to-day operations with the long-term portfolio management. The intra-day controller module on the other hand takes care of the asset usage under uncertain conditions during the day. The controller module is flexible and can either follow the management module recommendations or capture the available wind power for hydrogen production with or without a connection to the public grid.

EMSs are dependent on the data fed into them. Historical and real-time data from across the globe – wind patterns, predictive maintenance, price and demand forecasting – are among the data sets which can contribute to the effective configuration of an EMS. The figure below shows the operation of the management module for a week. The price of hydrogen remains stable, while the price for electrical power varies at different times of a day. Under the given wind conditions, the optimum asset utilization then suggests several time slots when generating hydrogen is better than generating electrical power for the grid. It also suggests that there is some surplus power available as reserve which can be traded for other grid services.

Brande EMS example: Connecting prices, production and power reserves[14]



Since Brande Hydrogen is an R&D project that operates without profitability pressure, we can test and learn various EMS configurations. We are starting to test how best to apply two-phase engagement controls. We've looked at synching day-ahead nominations with an intra-day control to minimize deviations from our agreement with Everfuel, which obliges us to generate a defined amount of green hydrogen but also gives us the option to store and/or sell on any excess energy produced.

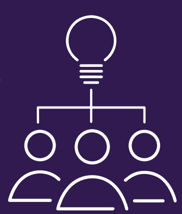
So, for this project, the focus for the EMS and controls is to work on integrating the hardware and software components so that everything is in place for future commercial decisions to be made based on the real-life data.

A green hydrogen native energy management system for offshore island mode production at scale will emerge, based on existing functionalities and factoring in new requirements from green hydrogen. Our initial experience at Brande Hydrogen is that the ability to control wind turbines will have a direct and positive role in controlling many aspects of how electrolyzers will need to function in the future. They will need to function as effectively when powered by a turbine as they do when powered by the grid.

This learning has inspired us to develop and test a plant controller capable of not only controlling the wind turbine, electrolyzer and battery but also orchestrating the power flow between this hardware and the grid. The control system will help to ensure that the green hydrogen is being generated by electricity produced by the co-located wind turbine. The controller can also be configured in ways which can stabilize and support the grid.

Key Learning:

Energy management systems and control units are fundamental to the commercial and operational success of any green hydrogen project. They can enable plant owners to leverage additional value streams which can support the overall business aims of a project.



Human resources

Green hydrogen skills will be in demand. Building up a talent pool for an emerging industry would be challenging enough, even before factoring in the widely reported talent shortages and staff issues which are dominating many sectors[15].

At Brande Hydrogen, we were able to call on our team of prototype engineers who specialize in bringing small-scale projects through from concept to production. Across the project there were other areas where we called on in-house expertise, such as optimizing the turbine, testing the EMS and forecasting wind resources.

At the same time, we could outsource tasks which are not currently within our remit to our partners, but in a way that allowed us to learn about these tasks on the job.

Succeeding in the end-to-end green hydrogen value chain requires the ambition to take ownership of maintenance, service and installation of the various parts of the production process. Expertise can be achieved by cross-training existing staff, recruiting new team members or by finding ways to collaborate more closely with partners in terms of shared human resources.

The future generation of green hydrogen experts and advocates can be encouraged through formal partnerships with academics and universities, as will engaging with secondary and further educational institutions on education and apprenticeships.

The industry faces intense competition in technology and IT. The skills needed to develop, integrate and maintain the energy management and control systems for a GW-scale green hydrogen production plant are in demand from other sectors as well.

Key Learning:

Green hydrogen businesses will be built upon a combination of recruiting new staff, retraining existing talent and formalizing knowledge sharing with external partners.

Business case and costs

The regulatory framework and market mechanisms for green hydrogen are still being worked out, which creates risk for investors who can find it difficult to validate a business case when the regulations could change.

The obvious business case for green hydrogen is to transition existing hard-to-decarbonize sectors from fossil fuels to green hydrogen. In the medium-to-long term, new use cases and commercial opportunities will emerge and co-exist with legacy demands.

A common proposal is to create a market which supports HPAs (hydrogen purchase agreements), mirroring the theory and practice of power purchase agreements (PPAs) which established wind and solar energy within the existing markets. Standards and processes to allow gas blending on existing networks, or to build new dedicated networks that will accelerate the trading of hydrogen as we do today with electricity, are gaining traction around the globe as well.

However, in commercial terms, the cost of green hydrogen needs to come down in order for heavy industry to commit to HPAs. But one of the major drivers of cost reductions would be firmer and more substantial commitments to HPAs from heavy industry.

Brande Hydrogen was never going to be defined by net profit, but costs and revenues were always analyzed. We learnt that transporting green hydrogen in tube trailers to fill fuel cells for immediate use in light transportation vehicles is viable practically - and to an extent financially - for small volumes. But this would not work for GW-scale plants, where alternative distribution options need to be considered and costed.

Many factors influence the cost and therefore the business case. Innovations from within the electrolyzer industry are vital to maximize the commercial viability of a site, optimizing the amount of green hydrogen produced from the energy inputted. However, the main cost for producing green hydrogen today is the cost of the renewable energy needed to power the electrolyzer, whether that is the cost of developing and maintaining off-grid operations or the cost of using electricity from the grid.

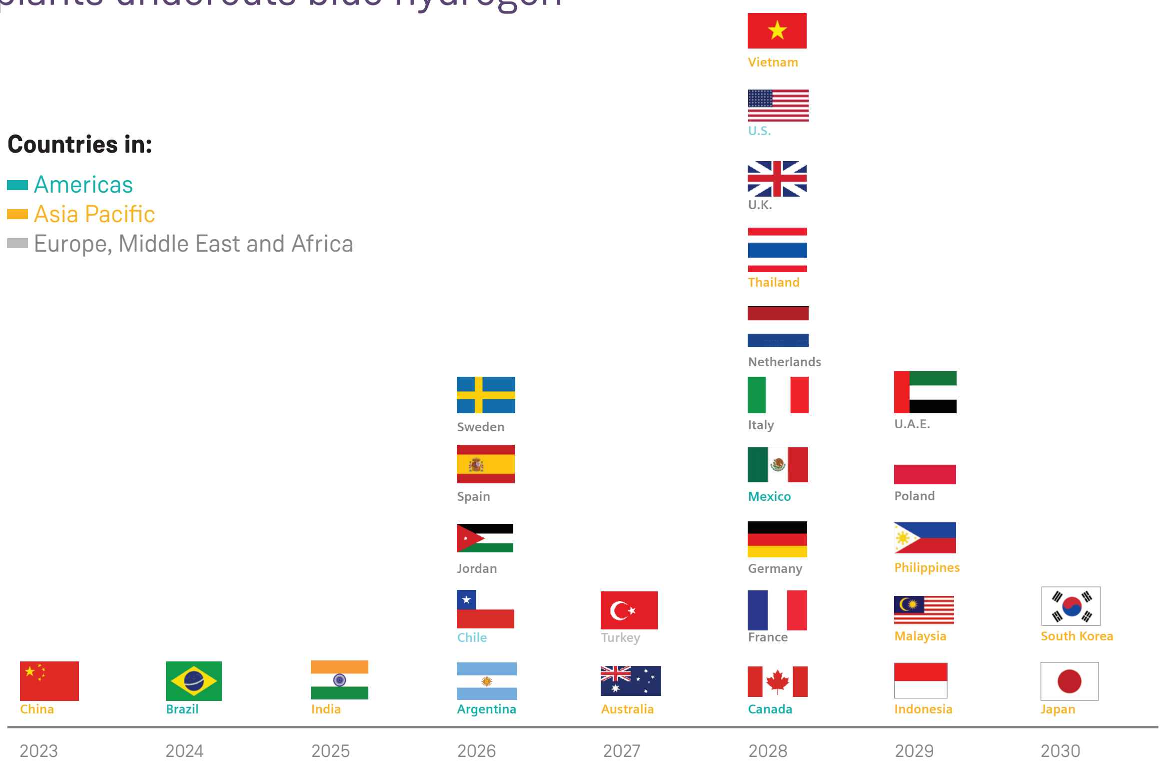
Regulators and governments can drive the market by incentivizing end users to switch to green hydrogen. Provisions for this are included in the green hydrogen measures within the U.S. government's Inflation Reduction Act.

Further ahead, mandating the use of green hydrogen is an option.

The German government is also trying to address this cost imbalance. The H2Global pilot project will encourage end-users in Germany and the EU to buy green hydrogen from outside of the EU and the EFTA by subsidizing the cost difference through a dedicated state-backed intermediary[16]. This will encourage the transition to green hydrogen by creating cost parity for users, in turn, creating a stronger market, wider awareness and validated business cases.

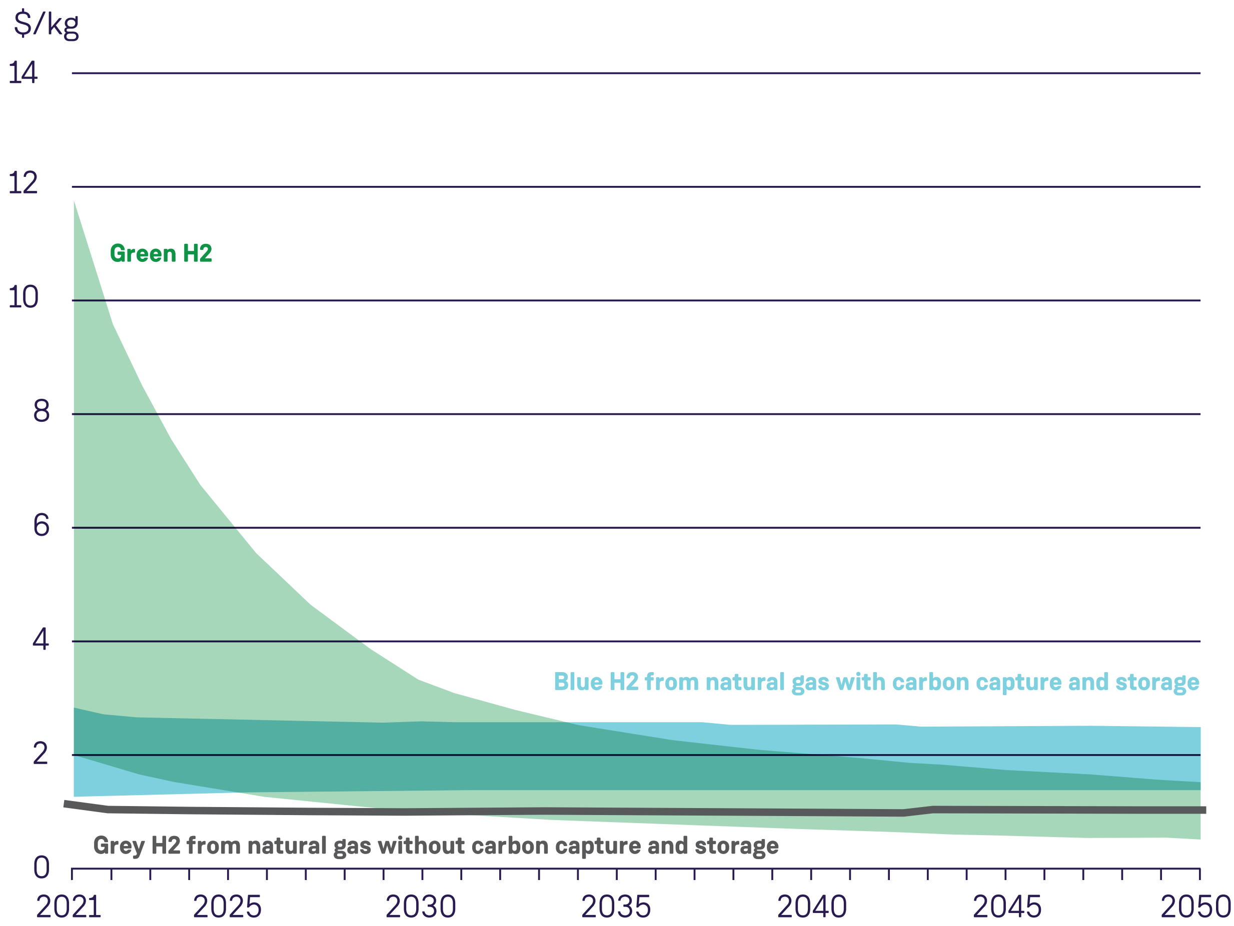
We and our partners are developing the technology building blocks required, so that the technology part is ready to scale. The need for governments to find a commercially viable mechanism for green hydrogen is pressing.

Year when hydrogen from new green plants undercuts blue hydrogen[17]



Source: BloombergNEF. Note: Assumes optimistic alkaline electrolyzer cost scenario (Chinese for China, otherwise Western) and 20-year gas price outlook averages.

Green hydrogen's progression toward price parity[18]



Key Learning:

Many factors which contribute to the viability of a business plan are still in flux. Even with this uncertainty, investments need to be made today in order to build the momentum and establish a commercially sustainable long-term future for green hydrogen.

Supply chain and ecosystem

Siemens Gamesa is familiar with a complicated global supply chain. We have engineers and manufacturing facilities, but we rely on partners for support in procuring various components – from blades to gearboxes to generators and controls – to us on time and to the right specs.

At Brande Hydrogen, managing a different type of supply chain was important to explore. The supply chain for green hydrogen production will be even more complex than the supply chain for wind turbines. Thinking ahead to GW-scale projects, supply chain management will become even more critical in terms of making these power plants operational in the first place.

Brande Hydrogen has led us to approach the green hydrogen supply chain as an “ecosystem of partnerships”, rather than as a linear progression of delivered products and contracted services. For example, we worked very closely with our main offtaking partner Everfuel. We learned about non-standardized interfaces for filling tube trailers, different purities and pressure of hydrogen, micro-impacts of weather conditions and managing the unexpected. We looked ahead at how we could tap into Everfuel’s existing and proposed network of green hydrogen pipelines and filling stations across Europe.

At every touchpoint we treated our suppliers as partners, an approach which we believe is essential to speed up the roll-out of green hydrogen and create an industry which is commercially viable and safe as well as being as significant contributor to the fight against the climate emergency.

Key Learning:

Partnerships and collaboration will characterize the green hydrogen supply chain.

Building on the Brande Hydrogen project

The initial success of the Brande prototype supports further expansion onsite. By increasing the capacity and volumes produced we will be stress-testing the processes we have put in place, generating new data points which allow for further development of the EMS.

The focus will be to prepare the hardware and software requirements for onshore and offshore production of green hydrogen with and without a direct connection to the grid.

We will continue to work with our existing partners while bringing in new ones in order to develop best practice for integrating and optimizing the assets at each and every stage of the green hydrogen production process.

Elsewhere, advanced discussions are taking place on a number of new projects which build on the learnings from the Brande pilot. These projects move beyond prototypes and will expand our knowledge of production and familiarize Siemens Gamesa with different green hydrogen business models.

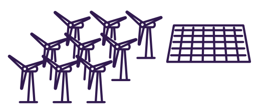
One project close to final approval, on an existing site, puts Siemens Gamesa in charge of producing green hydrogen and servicing our turbines. The site owner is responsible for finding the offtakers and for managing the EMS, which has been installed by Siemens Gamesa.

Meanwhile, another project is bringing us even closer to end-to-end green hydrogen production. We will have commercial and technical responsibility for an entire site, not dissimilar to how Brande Hydrogen was structured, although there is a stronger financial imperative at play. We will produce and sell the green hydrogen, running the whole operation and EMSs ourselves.

The learnings from our pilot at Brande and the projects outlined above will also contribute to our ongoing joint venture with Siemens Energy to develop an industrial-scale system capable of harvesting green hydrogen from offshore wind. The long-term aim is for Siemens Gamesa to become the leading hybrid technology partner, asset manager and service partner.

Options and alternative models for targeted hydrogen solutions[19]

Siemens Gamesa is developing on-and offgrid technology for targeted hydrogen solutions.

ON-GRID	**ON-GRID and OFF-GRID**	**OFF-GRID**
ONSHORE Produce H2 and electricity with already existing wind turbine solutions utilizing Energy Management System (EMS) technology. Goal is to optimize power and hydrogen revenues, while harvesting grid service revenues. 	OFFSHORE New Decentral Offshore Hydrogen Production (DOHP) solution developed in phases for both on-grid and off-grid operational capabilities. 	ONSHORE New setup to establish onshore wind-to-hydrogen wind farms operating independently from public grids 

Beyond the Brande project – a roadmap from kWs to GWs

A green hydrogen industry is maturing, but it is a relatively new and currently small player within the overall energy industry. As with any industry in its earliest stages, there are many areas where the regulations, standards and business models are under discussion. Green hydrogen is no exception.

However, this understandable uncertainty should not be a reason to put development on hold. As an early adopter and advocate of green hydrogen, Siemens Gamesa is pressing ahead with in-house innovation and external partnerships which means we will be ready when the proposed GW-scale projects start to become an actuality rather than an aspiration.

The transition to green hydrogen at scale will take time, but the foundations are being established, of which Brande Hydrogen is one of the pillars. Within the next five years or so, there will be more commercial and technical demonstration projects launched, all of which will contribute learnings to how green hydrogen is produced, distributed and used.

We also expect that the EU's policy for green hydrogen will have been debated and approved by the European Parliament, in turn generating the demand from industry for even more pilots and prototypes. The benefits of the U.S. government's recently announced Inflation Reduction Act will start to influence the global market.

In the medium term, a number of 100MW+-scale projects will be live, taking over where there is an existing demand currently satisfied by fossil-fuel-based hydrogen. With the legislation in place, pilot schemes will start to look at new use-cases for green hydrogen, spreading its influence and building up the addressable market.

From 2030 onwards, we anticipate that the green hydrogen revolution will rise up and accelerate across the globe. New use cases, validated by pilot schemes, will exist at scale, driven by the continuing reduction in the cost of green hydrogen production and the progression towards cost parity with current fossil-fuel based production methods.

Conclusions and key takeaways:

The regularity of extreme weather events is the most visceral example of how the climate is changing and the potential impact it has on how we live our lives. Time is ticking if we are to meet the requirements of the Paris agreement and to limit global warming to 1.5 degrees Celsius compared to pre-industrial levels.

In the specific context of green hydrogen, an industry is emerging but it needs immediate support from regulators and governments. Actions speak louder than words.

The short-term priorities for the green hydrogen industry, based on our learnings from the Brande project and our 40 years' experience of wind turbine design, manufacturing, installation and servicing, are;

a) Speeding up the approval processes for wind energy,

b) Rapid establishment of the rules and regulations for the green hydrogen market at scale,

c) Continued collaboration to create an ecosystem of partnerships which can support use cases during the transition to scale.

Each requirement can only be met through a combination of internal and external forces. Industry players are committed and are working closely with the European Union (and other jurisdictions) to ensure that regulations will encourage and support the green hydrogen revolution.

With the right people, the right partnerships and the right backing, green hydrogen is no longer a possibility but a promise. Getting to scale, quickly and safely, is a challenge which can be met, and our experience and learnings from Brande Hydrogen provide many of the building blocks.

Sources

[1] https://www.irena.org/publications/2022/Jan/Geopolitics-of-the-Energy-Transformation-Hydrogen

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