Scaling up the hydrogen sector

Success factors and lessons learned from early-stage projects

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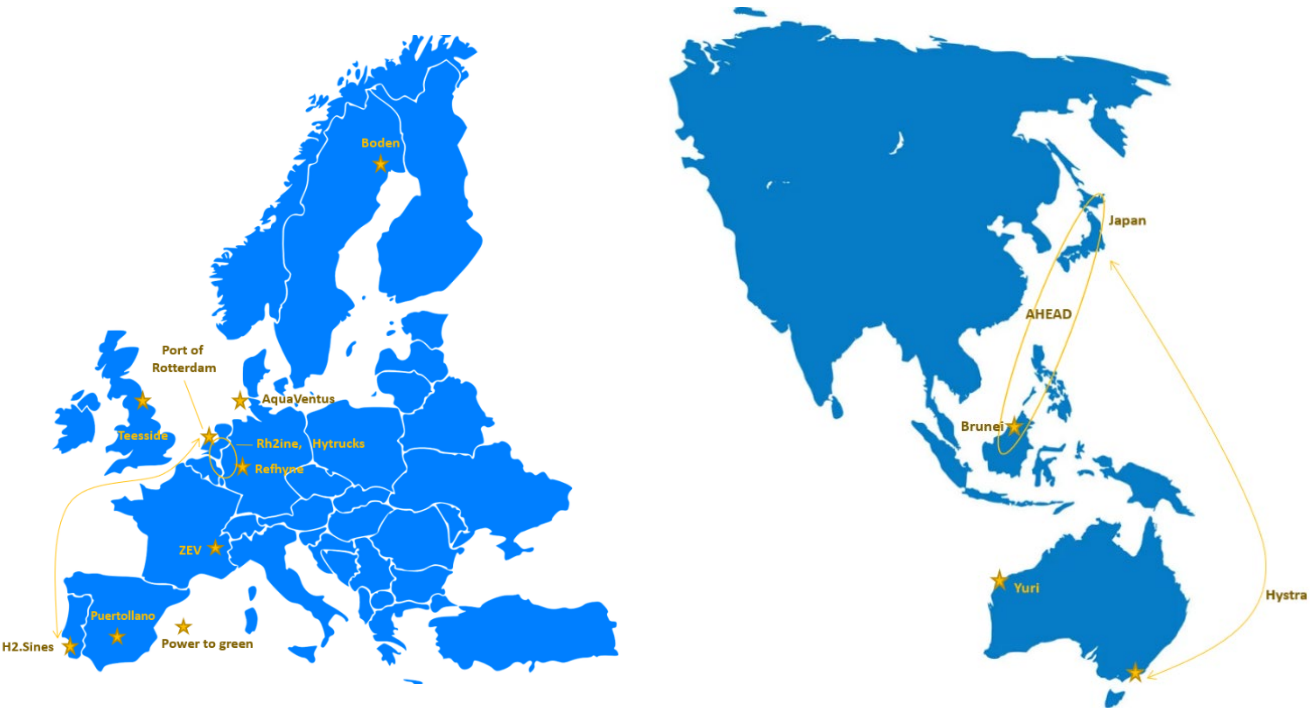
Key facts about early-stage projects

Hydrogen is forecast to be a key energy carrier of the future, ranging from 5% to 20% of final energy demand by 2050 in various energy scenarios.[1] In addition to being used for oil refining and chemical production as it has been for decades, hydrogen will play a new role in decarbonizing hard-to-abate sectors. Because of this, companies, governments and investors are joining their efforts to deploy hydrogen at scale to support this part of the energy transition. However, of the 700 large-scale project proposals worth over USD $200 billion, only about 10% have reached a final investment decision.[2]

During 2021 and 2022, WBCSD member companies and external partners shared their experiences from 14 emerging hydrogen projects with a community of experts via in-depth webinars. Each meeting focused on how to deal with barriers while designing, investing in and building hydrogen projects. Figure 1 maps the 14 projects, located in Europe and Asia.

The following analysis summarizes key lessons learned from these pioneering hydrogen projects, providing business developers and investors with insights into the factors that helped these projects reach final investment decisions. It aims to shorten the learning curve by identifying successful business solutions and the best dispositions to accelerate hydrogen deployment. Policymakers can also rely on this report to better understand how regulatory frameworks and the authorities' financial support have impacted the different projects.

Figure 1: Location of the 14 projects discussed in WBCSD webinars



Project archetypes

We have categorized the early-stage projects from the webinars into three different setups (archetypes) and identified their key features: industrial clusters, long distance between import and export facilities, and valleys. The following sections assign the 14 projects to each of the corresponding archetypes.

Industrial cluster

The lack of transport and storage infrastructure for hydrogen over longer distances leads to the organization of projects as a system of industrial facilities, from production to end-users, often called a *cluster* or *hub*.

The main characteristics of an industrial cluster:

- Hydrogen supply is close to industrial hydrogen demand;
- A few large offtakers secure the revenue stream from hydrogen sales – and hence the business model – thereby providing baseload demand;
- The project leverages existing infrastructure around industrial plants, often replacing existing grey hydrogen supplies;
- A port facility is often close by, adding the option to import or export hydrogen;
- There is usually greater social acceptance and the necessary political support to steer existing industrial areas toward greener energies.

1: Industrial cluster projects discussed in webinars

Name of the project	Companies	Objective	Expected operation start date	Final investment decision
Port of Rotterdam	Consortium		2027	
H-vision (Port of Rotterdam)	Consortium (12)	Blue hydrogen production		✗
Holland Hydrogen 1 (Port of Rotterdam)	Shell	400 MW green hydrogen production for oil refining	2025	✓
Porthos CCS (Port of Rotterdam)	Consortium (7)	CO_2 capture and transport by pipeline	2022	✗
Puertollano	Iberdrola	Green fertilizer production	2023	✓
Teesside	bp	Blue and green hydrogen supply for industrial uses		✗
AquaVentus	Consortium (7+)[3]	Green hydrogen produced offshore on wind turbines and transported via pipeline onshore	2035	
Refhyne	Shell	Green hydrogen for oil refining	2021	✓
Boden Green Steel	H2GreenSteel	Green steel production	2025	✓
Yuri	Engie, Yara	Green fertilizer production	2027	✓

Long distance between import and export facilities

Hydrogen is a versatile energy carrier; its production can use multiple feedstocks. The trading of hydrogen derivatives could provide economic benefits as hydrogen-importing countries can tap into cheaper electricity resources elsewhere compared to domestic ones. For long-distance import/export projects, companies manufacture hydrogen in areas with cheap renewable electricity and ship it far away, to large hydrogen consumption centers with high local decarbonization requirements.

The main characteristics of long-distance projects:

- Hydrogen supply and demand are connected internationally by shipping liquid hydrogen or derivatives (like ammonia);
- A port facility enables hydrogen derivative imports and exports;
- Standards and cooperation are central to the cross-border trade of hydrogen products.

Table 2: Long-distance projects discussed in webinars

Projects	Companies	Objective	Expected operation start date	Final investment decision
H2Sines	Consortium (20+)	Export of liquid hydrogen from Portugal to the Netherlands	2027	✗
Advanced Hydrogen Energy Chain Association for Technology Development (AHEAD)	Consortium (4)	Export of methylcyclohexane (MCH) from Brunei to Japan	Launched in 2020	✓

Valleys

Valleys are a third type of archetype focusing primarily on the mobility sector as an end-use of hydrogen. Hydrogen suppliers sell hydrogen to a network of refueling stations used by the light- and heavy-duty mobility sectors.

The main characteristics of a hydrogen valley:

- Production is located at or close to the refueling station and distributed through trucks or ships;
- The project usually secures part of the hydrogen offtake through pre-negotiated contracts with the mobility sector.

Table 3: Valley projects discussed in webinars

Projects	Companies	Objective	Expected operation start date	Final investment decision
Power to Green	Acciona	Green hydrogen system in Mallorca	2022-2023	✓
Zero Emission Valley (ZEV)	Michelin, Engie	Largest hydrogen mobility deployment project in France	2022	✓
RH_2INE	Consortium	Hydrogen for maritime transport on the Rhine	2025	✗
HyTrucks	Consortium	Deployment of 1,000 hydrogen trucks	2025	✗

We observed in the different projects discussed that an archetype can develop over time and connect to another archetype, such as a valley with an industrial cluster or an industrial cluster with a long-distance project. This creates hydrogen corridors, often connected across national borders, which make it possible to take advantage of the development of new infrastructure, attract greater numbers of hydrogen consumers and develop the sector on a large scale. In this context, most projects develop incrementally in phases, with a high degree of modularity to grow supply as demand scales.

Success factors to overcome challenges

The analysis of these 14 pioneering projects highlighted key success factors that have helped companies overcome some of the barriers to developing a hydrogen economy. Indeed, supplying decarbonized hydrogen for existing and new applications comes with market, infrastructure, technological, standardization and regulatory challenges.

- **[Market]** Electricity prices are the main cost driver for green hydrogen production. Achieving cost parity with fossil-based hydrogen or other energy sources will require tapping into cheap low-carbon electricity sources, often located far from areas with significant hydrogen consumption needs. Similarly, blue hydrogen production is exposed to natural gas price variability. The current cost of low-carbon hydrogen or hydrogen-based products – higher than fossil-based hydrogen – will need to decrease significantly to keep consumers from paying a premium for green hydrogen.
- **[Infrastructure]** Infrastructure operators face two choices: adapting existing natural gas infrastructure or deploying hydrogen-specific infrastructure. Hydrogen injection affects the integrity of the infrastructure (brittleness of steel, higher risk of leakage) and significantly impacts combustion parameters. Therefore, it challenges end-use compatibility while decreasing the energy per unit volume transported. The deployment of new infrastructure is a capital-intensive activity that faces numerous permitting issues, increasing delays in its deployment due to low social acceptance of new pipelines. It also represents a long-term project that may not be consistent with producer and consumer requirements and national greenhouse gas (GHG) reduction targets.
- **[Technology]** New facilities with low technological readiness levels are needed for decarbonized hydrogen value chains: production (for example, new electrolysis methods, carbon capture and storage (CCS), methane pyrolysis); transport (meaning liquefied organic carriers, bulk export of liquefied hydrogen) and storage (such as in salt caverns); end-use (for example, hydrogen-ready gas power plants).
- **[Standards]** The low-carbon hydrogen economy is still nascent: there are no organized markets, no operating rules for international trading, no standards or certification for hydrogen-based products (such as synthetic fuels), and no shared frameworks to monetize positive externalities, such as the GHG emissions reductions that decarbonized hydrogen can deliver compared to current energy carriers.
- **[Regulation]** The lack of targets or incentives to promote the use of low-carbon products inhibits many possible downstream uses for decarbonized hydrogen. This limits demand for industrial applications.

Note that the archetypes explained in the previous section address some of these challenges. Irrespective of their archetype, the projects discussed during the webinars have successfully implemented business models and developed technical solutions to overcome the abovementioned challenges. Table 4 outlines the six success factors identified based on the five challenges.

Table 4: Success factors to address barriers to hydrogen development

Success factors	Development barriers
Reduce the economic impact of electricity and natural gas prices on the project's business plan	**Market**
Improve the efficiency of hydrogen transportation and storage by building an integrated supply chain	**Infrastructure, technology**
Diversify revenue sources by securing offtake from a variety of hydrogen consumers	**Market, technology**
Build a heterogeneous financing structure	**Market, regulation**
Develop cooperation and partnerships with the entire project value chain	**Market, standards**
Ensure social acceptance from local project stakeholders	**All**

The following sections describe the success factors identified.

1. Reduce the economic impact of electricity and natural gas prices on the project's business plan

Electricity and natural gas prices are the most significant cost drivers for green and blue hydrogen production respectively. The projects seek the cheapest possible decarbonized energy sources and support mechanisms and to monetize the green premium under existing regulatory frameworks to decrease electricity and natural gas supply impacts. A key challenge is securing financial support to cover the higher cost of low-carbon hydrogen production and protect against high volatility in commodity prices. Public and private funding, new market design and policy support mechanisms are necessary to bridge the economic gap between low-carbon hydrogen and existing alternatives and, ultimately, to support the investment decision. Table 5 provides examples of the financial structures and support the projects leveraged.

Table 5: Reducing exposure to electricity and natural gas prices

Name of the project	Tool
Teesside	Carbon contract for difference in the UK
Refhyne	Green premium monetization under Renewable Energy Directive (RED) requirements
Boden Green Steel	Affordable renewable electricity

Rely on efficient incentives such as Contracts for Difference – Teesside, UK (bp)

Teesside's project benefits from an interesting support mechanism called Contracts for Difference (CfD) that helps reduce exposure to electricity and natural gas prices. This scheme covers operating expenses (in addition to capital expenditures, which are more often subsidy targets), representing the highest share of the total hydrogen production cost. The project receives a subsidy equal to the difference between a *strike price*, reflecting the cost of producing decarbonized hydrogen, and a *reference price*, reflecting the market value of carbon-intense hydrogen. The UK government has launched the CfD support mechanism as part of its national hydrogen strategy to support low-carbon hydrogen generation. It defines "low-carbon hydrogen" as emitting less than 2.4 kg of CO_2-equivalent emissions for every kilogram of hydrogen produced — including upstream emissions. In this context, the mechanism ensures that the government only subsidizes projects with a low carbon intensity, thus effectively reducing emissions from the energy system while providing a secure revenue stream to the project and helping satisfy investors.

Target a location with abundant affordable renewable electricity – Boden, Sweden (H2GreenSteel)

When producing green hydrogen, electricity accounts for approximately 70% of the total cost. H2GreenSteel was intentionally located in Boden, Sweden, to decarbonize the local steel industry, which is highly carbon-intense, because there is ample access[4] to hydropower at competitive prices in the long term.[5] The company aims to replicate this business model in regions where low-carbon electricity prices are structurally low (currently Brazil, Spain, North America), either because renewables are abundant and economical or because regulation mechanisms help reduce project costs. In particular, H2GreenSteel has developed a digitalized tool that helps to define design layouts and make technology choices for the hydrogen plant to secure access to abundant and affordable renewable electricity, allowing it to ring-fence ideal global green hydrogen production locations.

Benefit from RED credits to monetize the green premium – Refhyne, Germany (Shell)

The Refhyne II project will install a 100-MW polymer electrolyte membrane (PEM) electrolyzer at the Rheinland refinery in Cologne. Refhyne II follows 10-MW Refhyne I, currently Europe's largest PEM hydrogen electrolyzer, which began operations in July 2021. Shell's Refhyne project aims to achieve a viable business case based on Renewable Energy Directive (RED) credits that enable it to monetize the green hydrogen premium. The RED-compliant hydrogen could then apply to financial support mechanisms set by every Member State (such as CfDs) and allows energy suppliers to generate CO_2-free allowances, which can then be traded in the ETS market, adding new revenue streams. These credits label green hydrogen production complying with RED requirements and authorize producers to sell it to industrial sectors, which must use 50% green hydrogen by 2030 (including iron and steel, aluminum, chemicals, fertilizer, and cement). Additionally, the project benefits from a €32 million grant from the Clean Hydrogen Partnership, which recognizes its innovative nature. This partnership follows on from previous Fuel Cells and Hydrogen Joint Undertaking (FCH JU) funding programs, which provided approximately €1 billion in funding over several years to drive the creation of cutting-edge hydrogen technology.

2. Improve the efficiency of hydrogen transportation and storage by building an integrated supply chain

The energy efficiency of the value chain is one of the main factors influencing the total cost of hydrogen and its supply, and consequently, its competitiveness with other energy alternatives. For instance, industrial clusters take advantage of their compactness and existing assets to minimize hydrogen transportation losses. In the opposite way, offshore wind-to-hydrogen projects attempt to achieve higher capacity factors by going further out to sea, but then face high energy losses associated with cable transport of electricity. As a result, there is a growing trend for these latter projects to produce hydrogen directly at sea and export hydrogen rather than electricity to the coast, to maximize energy efficiency and lower project costs.

Table 6 highlights the different setups or solutions that the various projects have chosen to optimize hydrogen transport, storage and delivery. Note that an optimized supply chain has a significant impact on the project's carbon intensity, which the company can monetize or use as a guarantee to secure public subsidies.

Table 6: Examples of an integrated setup helping improve energy efficiency along the value chain

Name of the project	Project setup
Port of Rotterdam	Well-connected large industrial area involving 3,000 companies and including hydrogen grids (2 private and soon 1 additional with open access) operating at local and international levels (via a port facility)
Teesside	Compact industrial area reducing transport and distribution distances
AquaVentus	Development of offshore wind-powered electrolyzer plants and transport of gaseous green hydrogen by pipeline to overcome electricity transport losses
H2Sines	Compact industrial cluster with hydrogen offtakers
Yuri project	Green hydrogen to ammonia project developed close to a port and a pipeline
Puertollano	Large green hydrogen plant to supply a nearby fertilizer plant

Minimize transport and distribution losses – Teesside, UK (bp)

In March 2022, bp announced plans for a clean hydrogen facility in Teesside (H2Teesside) that would aim to produce up to 1 GW of blue hydrogen, 20% of the UK's hydrogen target by 2030. In parallel, the company is developing a green hydrogen project – HyGreen Teesside – targeting production by 2025 with an initial planned phase of 80 MWe of installed hydrogen production capacity. The project will play an important role in delivering the UK's net-zero emissions targets and aims to deliver up to 5% of the country's hydrogen target of 10 GW by 2030 upon reaching its planned expansion of up to 500 MW. Bp is developing the site in a packed area with a radius of several square kilometers: facilities such as pipelines, CO_2 storage and offtake sites are located within walking distance. This setup minimizes methane leaks thanks to limited distances to transport and distribute hydrogen. In addition to the benefits related to energy efficiency, the site's configuration makes it possible to reduce the project's carbon intensity and thus receive financial support from the UK government for the development of low-carbon-intensity hydrogen projects.

Maximize the energy converted via offshore wind-based electrolysis – AquaPrimus, Germany (RWE)

The AquaVentus initiative in Germany comprises numerous sub-projects along the value chain, from hydrogen production in the North Sea to transport to customers on Heligoland Island and Germany onshore.[6] The AquaPrimus sub-project relies on innovative technologies with the development of one 15-MW offshore wind-powered electrolyzer plant located in the 12-mile zone off the island and connected via pipeline to Heligoland. Its main ambition is to reduce the energy loss associated with the export of electricity through cable by converting it to hydrogen directly offshore (a dedicated pipeline then transports the energy in the form of hydrogen). Additionally, the project reduces costs through modularization and upscaling to improve the project's economic competitiveness. Heligoland will use green hydrogen as a renewable heating source. AquaPrimus will deliver technical lessons learned and cost reduction possibilities that companies can use for their own large-scale offshore wind/electrolysis projects along the German coast (AquaSector) and for other offshore wind/hydrogen projects in the North Sea.

3. Diversify revenue sources by securing offtake from a variety of hydrogen consumers

A critical barrier that hydrogen projects face today is a lack of demand visibility: many are awaiting decisions on enabling regulatory frameworks and funding that will incentivize offtakers to enter long-term hydrogen supply contracts.[7]

Successful project developers de-risk their business model by securing a minimum number of engaged offtakers and hence revenue sources from the start. In some cases, companies diversify their revenues by selling by-products, enlarge their market thanks to open-access infrastructure or develop tools to attest to the low-carbon intensity of hydrogen production. These solutions make their projects more valuable and help attract investors. We give concrete examples in the section below.

Table 7: Project end-users

Name of the project	Project end-users
Port of Rotterdam	Industrial area with 3,000 companies, including hydrogen end-users
Teesside	H2Teesside: fuel and feedstock for industrial offtakers HyGreen: fuel for mobility, industrial and home heating
H2Sines	Refinery, local industry, natural gas network, mobility, decentralized customers, international export
Power to Green	Hotels, vehicle rental, domestic/industrial users, Lloseta city council, port of Palma de Mallorca, public transport (bus)
AquaVentus	Hard-to-abate sectors (steal production, chemistry, maritime transport, aviation), energy storage, hydrogen trade
Refhyne	Industry (incl. refinery), power generation, heat for buildings and transport
Boden	Pre-sold steel production (1.5 Mt sold over the expected 2.5 Mt of steel production) to multiple steel users

Develop additional sources of revenue from the sell of by-products – Power to Green (Acciona), AquaVentus, Germany (consortium)

Acciona's business model bridges the cost gap by selling surplus photovoltaic production and, eventually, oxygen to hospitals and fish farms (to enrich oxygen in water).

In Germany, the AquaPortus sub-project from AquaVentus plans to switch the domestic heating of Heligoland Island from fuel oil to the waste heat generated by the dehydrogenation of a liquid organic hydrogen carrier (LOHC). The ambition is also to distribute the LOHC safely, efficiently and flexibly through existing infrastructure to industrial or mobility customers who would receive LOHC directly and convert it to hydrogen on-site.

Monetize the green premium through traceability systems – Power to Green (Acciona)

Acciona has developed a blockchain-based software platform to manage the traceability of the entire hydrogen value chain. The software tokenizes the whole hydrogen value chain by assigning a unique token to each kilogram of green hydrogen produced for customers. Thanks to this system, the company can certify every kilogram of low-carbon hydrogen consumed by its customers. From an investor or project developer perspective, it can help efficiently track the carbon intensity, monetize a green premium for decarbonized hydrogen and increase the value of the project.

Grow the market by taking advantage of open access to hydrogen infrastructure to supply hydrogen to distant consumers – AquaVentus, Germany and Port of Rotterdam, Netherlands (consortiums)

Every energy market relies on physical infrastructures. Open access to hydrogen transport infrastructure is at the core of national and internal market development.

While private hydrogen pipelines have existed for decades (for instance, Western Europe has a 1,600-km network of hydrogen gas pipelines to deliver large quantities of hydrogen to chemical, petrochemical and gas industries), a non-discriminatory open-access infrastructure such as the one existing for natural gas is required to boost hydrogen market development.

- The AquaVentus pipeline connecting offshore wind electrolyzer plants is due to transport 1 million tons of green hydrogen per year. The project plans non-discriminatory third-party access for all successful developers at tenders for hydrogen areas and foresees low transportation costs at the final stage.
- The Port of Rotterdam is developing a future-proof open-access infrastructure with a connection to hydrogen networks. The hydrogen pipeline will connect a conversion park with electrolyzers and offshore wind turbines to an endpoint at the Pernis refinery. The pipeline is 32-km long, will be laid underground, and will connect to national and international hydrogen networks, helping develop the European Hydrogen Backbone.[8]

4. Build a heterogeneous financing structure

Diversification of funding sources is a key factor in derisking projects. Public funds provide insurance for private investors to engage in innovative projects. In most case studies, a blend of public and private capital exists. Opening the capital of projects allows stakeholders playing a crucial role in the project to be directly incentivized. Because of the nascent hydrogen market and the need to scale the hydrogen sector rapidly, all financial efforts are needed. Financial structures are diverse due to the nature of the investors and origin of funds, from local support to national or even international investments.

Table 8: Project financing structure

Name of the project	Investors
Boden	Industry (automotive, manufacturers), technology services, private equity, public lenders
Zero Emission Valley (ZEV)	Industry (Michelin, Engie), Public authorities (Auvergne-Rhône-Alpes region), Public investment body (Banque des territoires)

Involving project partners in the shareholding structure – Boden, Sweden (H2GreenSteel)

Not only has the H2GreenSteel project already pre-sold 60% of its future production, but the company has also enabled the involvement of some of its future clients (from the automotive, industrial, and manufacturing sectors) and technology providers in the shareholding structure. This innovative partnership provides direct financial and industrial incentives for partners to boost the project while helping project developers align the new facility characteristics with client needs.

Multi-level financing structure, ZEV, France (Michelin, ENGIE)

The Zero Emission Valley (ZEV) project developed by Michelin and Engie in France has received financing from different levels of investors:

- At the European level, the 2017 Connecting Europe Facility (CEF) blending call awarded the project €10.1 million, enabling the project to start. CEF is a key EU funding instrument to accelerate investments in Europe's transport, energy and digital infrastructure networks.
- At the national level, as part of the national hydrogen plan launched in 2018 by the Minister for Ecological Transition and Territorial Cohesion, the French Agency for Ecological Transition (ADEME) has approved €14.4 million in aid on behalf of the French State.
- At the regional level, the project has received strong political and financial (€15 million) support from the Auvergne-Rhone-Alpes region, which aims to be a pioneer in hydrogen mobility in France and one of the first carbon-neutral territories at the European level. The region intends to accelerate the deployment of fuel cell vehicles and hydrogen stations throughout the region while helping create a profitable model that is replicable on a European scale.

5. Develop cooperation and partnerships with the entire project value chain

Collaboration across the value chain is a vital issue, especially for cross-border projects. As there are no global standards, markets or certifications in the hydrogen sector, project developers must cooperate to unify low-carbon hydrogen terminology and criteria across regions. Even for projects at the national level, there is still a need for strong partnerships between the various stakeholders. A few examples of such follow below.

*Unlike the previous sections, in this section we do not provide an overview of the partnerships for the different projects. This is because the list of stakeholders for each project is not always disclosed or exhaustive considering **the extensive number of partners involved**. Therefore, to avoid inconsistencies due to the data available from the different projects, we suggest contacting the individual project developers for precise information.*

Build strong public-private cooperation, ZEV, France (Michelin, ENGIE)

The ZEV project is a perfect example of the benefits of solid cooperation in the hydrogen sector. The industry, public authorities and academia have initiated regional public and private sector coordination to implement the hydrogen strategy, ensure adequate skilled workforce training, and support research for the hydrogen sector's development and industrialization. The project is firmly connected at the local, regional, national and European levels for funding.

Key success factors of these public-private partnerships

- The presence of a local network of hydrogen players, which encourages public authorities to intervene in the hydrogen economy to develop employment and the economic attractiveness of the territory;
- The existence of a hydrogen strategy and development planning (electrolyzers, transport infrastructure, refueling stations);
- Choosing to form a strategic alliance, going so far as to create a commercial structure – HYmpulsion – that will install and operate the hydrogen stations;
- A collective willingness to replicate the project and connect to other valleys to build regional or cross-border corridors in Europe.

Foster a multi-stakeholder dialogue for cross-border trade – From Brunei to Japan (AHEAD)

The need for cooperation is particularly critical for the cross-border transport of hydrogen derivatives in Asia. No market can develop without holding a multi-stakeholder dialogue in the region, as the projects are developed on different continents to service various regional markets. In 2020, the Advanced Hydrogen Energy Chain Association for Technology Development (AHEAD) developed a demonstration project focusing on a hydrogen energy supply chain using an organic chemical hydride method. The project is a significant milestone for the hydrogen sector as it has realized the world's first international hydrogen supply chain by connecting Brunei Darussalam (Indonesia) and Japan through a series of processes, including MCH[9] production in Brunei, maritime MCH transport, and the dehydrogenation of MCH in Japan. The number of processes and technologies involved, in addition to the international setup of the project, required a significant focus on cooperation and alignment between the various stakeholders.

Align standards across the supply chain – Refhyne, Germany (Shell)

The alignment of operating and safety standards between Shell, ITM Power (electrolyzer manufacturer) and the industry has been a key enabler of Refhyne's success. The development of 100-MW+ electrolyzers at scale requires new knowledge about mass manufacturing, designs and techniques for their integration into industrial locations. It needs new norms and standards to ensure safe production and it requires the definition of strategies for operating the electrolyzers effectively and efficiently.

Shell is implementing the project with a highly integrated cross-functional team and an intensively managed interface to ensure the operability of the whole supply chain. The project has benefited from using subcontractors preapproved by both ITM and Shell.

In addition to technological standards, it is interesting to observe that the project has required the alignment of business cultures. ITM began the Refhyne project with a limited staff, reflecting the need for early technological innovation and contrasting with the mature culture of Shell. It was necessary to combine the approaches of a mature organization and a small enterprise culture to build a cross-functional team.

6. Ensure social acceptance from local project stakeholders

Social acceptance of hydrogen production is crucial to scaling up the hydrogen sector. Water stress, safety and land use are examples of the concerns to discuss with communities while promoting the benefits of hydrogen, such as the number of jobs created thanks to project implementation.

Table 9: Initiatives fostering social acceptance

Name of the project	Initiatives fostering social acceptance
Boden	Create a sustainable lifestyle and living with the local economy
Power to Green	Optimize local resources
Teesside	Revive and develop local employment

Create a sustainable lifestyle and living with the local economy, Boden, Sweden (H2GreenSteel)

In Sweden, H2GreenSteel has developed a value chain closely associating local businesses and communities with the project. The company works with the city of Boden to create local employment, build infrastructure and deploy concrete actions for the economic development of a sustainable value chain in the area.

Optimize local resources, Power to Green (Acciona)

The Power to Green project in Mallorca is a chance to keep communities active and use existing resources that might otherwise be discarded. Cemex, a key stakeholder in this project alongside Acciona, has enabled the reuse of existing industrial land where it was closing a cement plant. The project has provided jobs to the workforce that would have otherwise disappeared, offering to develop green jobs and ensuring a just energy transition for local communities. It is also an opportunity to improve water use – Cemex's activities needed 10 times more – in a water-stressed area, despite water demand for green hydrogen.

Support and develop local employment, Teesside, UK (bp)

Teesside is built in a former steel manufacturing area and thus benefits from the local acceptance of stakeholders who are used to living close to industrial activities. Teesside will play a huge role in decarbonizing UK industry and will provide economic opportunities for the community and the region by preserving and creating thousands of jobs in the area. Local political support for the transformation of an existing industrial site is helping foster the development of the project in the best conditions.

Conclusion

The examples in this report show how various early-stage hydrogen projects have overcome well-known barriers to the scaling up of hydrogen. Based on our in-depth webinars and analysis of the 14 projects, we identify six success factors and provide examples for each, highlighting how companies have overcome the main barriers. These cover the three project archetypes – industrial cluster, long distances between export and import facilities, and valleys – and the various production pathways and benefits for many end-use sectors.

As only 10% of current hydrogen projects have obtained a final investment decision, we believe these detailed descriptions will contribute to building robust business models and accelerating the development of the hydrogen sector in the coming years.

A recipe for success

1. Reduce exposure to electricity and natural gas prices by relying on the best market and regulatory mechanisms to access affordable energy sources;
2. Improve the efficiency of hydrogen projects by reducing transport and storage losses;
3. Diversify revenue sources by securing offtake from a variety of hydrogen consumers;
4. Build a heterogeneous financing structure involving public and private investors;
5. Develop cooperation and partnerships with the entire project value chain to align standards, interests and business culture;
6. Ensure social acceptance from local project stakeholders.

The unprecedented momentum for investing in low-carbon hydrogen projects is enormous. We invite project developers, business partners and policymakers to dive into the concrete examples detailed in this document to increase robust investments and develop appropriate incentives for hydrogen.

In addition to the key findings highlighted in this document and with regards to the ambition of scaling the hydrogen economy, WBCSD has produced key outcomes for hydrogen, including 7 policy recommendations to accelerate the deployment of hydrogen for a 1.5°C scenario and investment guidelines describing practical steps to integrate 1.5°C criteria into investment decisions for the main hydrogen production pathways.

Endnotes

[1] International Energy Agency (IEA) (2021). *Global Hydrogen Review*. Retrieved from: https://iea.blob.core.windows.net/assets/5bd46d7b-906a-4429-abda-e9c507a62341/GlobalHydrogenReview2021.pdf.

[2] Hydrogen Council (2022). *Hydrogen Insights 2022*. Retrieved from: https://hydrogencouncil.com/wp-content/uploads/2022/09/Hydrogen-Insights-2022-2.pdf.

[3] The consortium includes Equinor, Fluxys, Gascade, Gasunie, Heligoland, RWE and Siemens.

[4] Norwegian and Swedish balancing zones are likely the only regions in Europe with 90% or more of the renewable energies required for the RED II additionality exemption.

[5] In Europe, deploying renewable hydrogen-DRI (direct reduced iron) to decarbonize steelmaking could require over 350 TWh of low-CO_2 electricity per year. This is a substantial amount of renewable electricity, representing over 35% of the EU's total renewable electricity production in 2019.

[6] The projects include the development of offshore wind farms with integrated hydrogen generation (AquaPrimus), a large-scale offshore hydrogen park (AquaSector), a central supply pipeline (AquaDuctus), hydrogen offtake on Heligoland Island (AquaCore), a research platform (AquaCampus) and hydrogen-based maritime applications (AquaNavis).

[7] Hydrogen Council (2022). *Hydrogen Insights 2022*. Retrieved from: https://hydrogencouncil.com/wp-content/uploads/2022/09/Hydrogen-Insights-2022-2.pdf.

[8] More details about the European Hydrogen Backbone can be found at https://ehb.eu/.

[9] Methylcyclohexane (MCH) is a hydrogen carrier composed of liquid from the chemical reaction of hydrogen to toluene. MCH contains over 500 times more hydrogen per volume than hydrogen gas, so it can carry hydrogen more efficiently.

Disclaimer

This publication is the result of a collaborative effort to share key practices and learnings about hydrogen projects. Members and non-member companies have contributed and reviewed drafts, thereby ensuring the document reflects the actual development of their projects

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