Challenges and Solutions of Green Hydrogen Storage and Transportation

BOSLAN

ENGINEERING AND CONSULTING

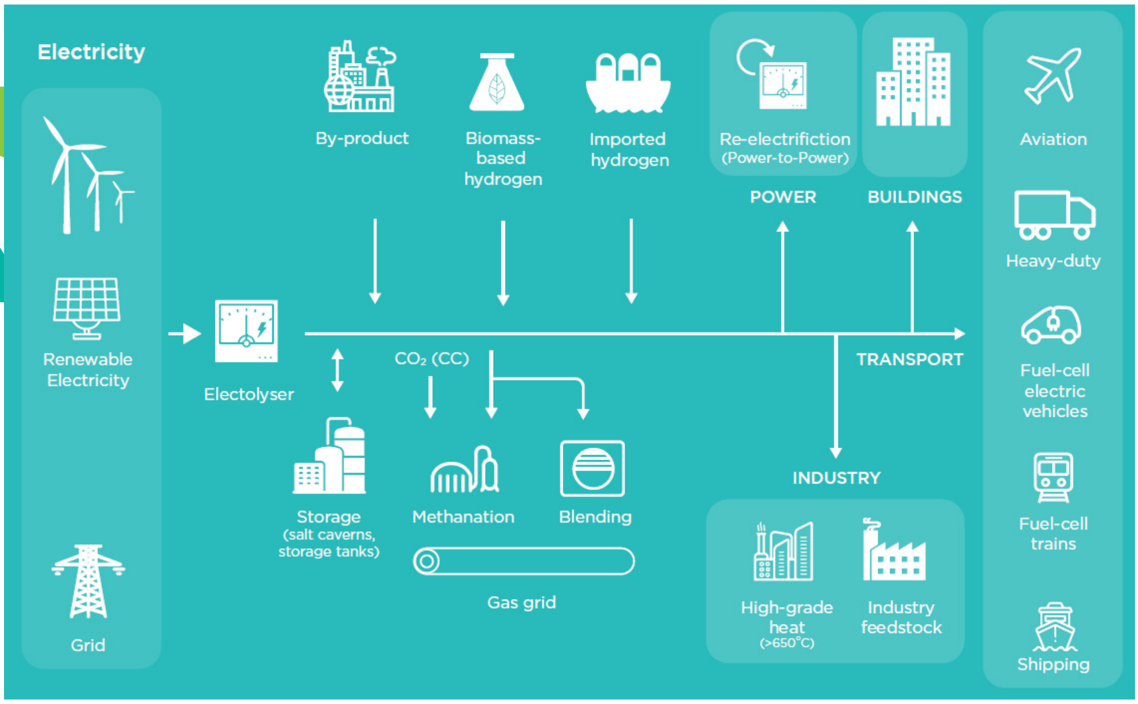
Advancing together towards climate neutrality

EXECUTIVE SUMMARY

With electricity prices hitting historic records and the climate emergency manifesting itself more and more evidently, today there is a more pressing need than ever to multiply the current capacity of clean energy production.

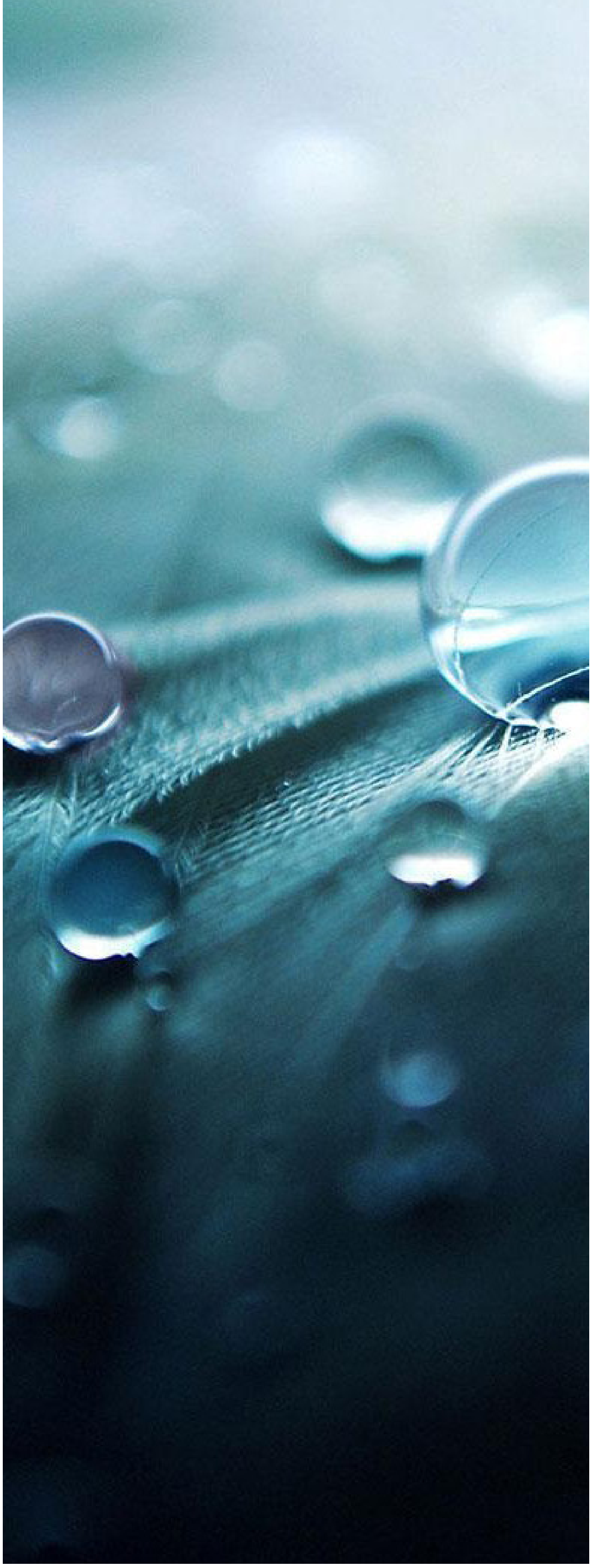
However, large-scale renewable energy generation will be even more efficient if it has a storage system for the energy produced when there is no consumption. The transformation of renewable energy into hydrogen allows for a product that can be stored, transported, and burned without emitting pollutant gases.

Green hydrogen has become a key element in achieving the decarbonization objective in a climate-neutral Europe by 2050, [1] **and public administrations will play a fundamental role in the development of this technology.** This will involve the promotion of policies that encourage R&D, investment in distribution networks, the development of ecosystems that coordinate all the companies in the hydrogen value chain, and the consolidation of policies that ensure the future market demand for hydrogen.



Renewable Energy Cycle. Source: Global Wind Energy Council[3]

Today, there is a more urgent need than ever to multiply the current capacity for clean energy production.



Within the hydrogen chain, one of the main challenges in scaling up its use will be to address storage, transportation, and distribution, which can currently account for more than 50% of the total cost.[2] Blending alleviates the issue of transportation and distribution but does not serve as a long-term solution in the face of large-scale production. On the other hand, reusing the existing gas network is feasible under certain circumstances - such as terrestrial transport in high-pressure pipelines - but maritime transport presents more serious difficulties.

The leadership of the HYSHORE project allows BOSLAN to develop its own know-how about the best solutions for marine hydrogen transport. This project analyzes the technical viability of bunkering green hydrogen on offshore generation platforms. Alternatively, the feasibility of connecting green hydrogen platforms to the mainland through umbilical conduits on the seabed for onshore storage is being analyzed, as well as the viability of loading hydrogen onto carrier ships as a short-term solution.

BOSLAN is a pioneer in Spain in the comprehensive management and development of hydrogen projects, as well as other renewable gases such as biomethane. The technical and operational difficulties of storing and transporting both gases are similar, and the solutions developed for the latter are largely extrapolatable to hydrogen, which allows for shortening R&D times.

PART 1

The decisive role of green hydrogen in the decarbonization process

The urgency to scale up clean energy production

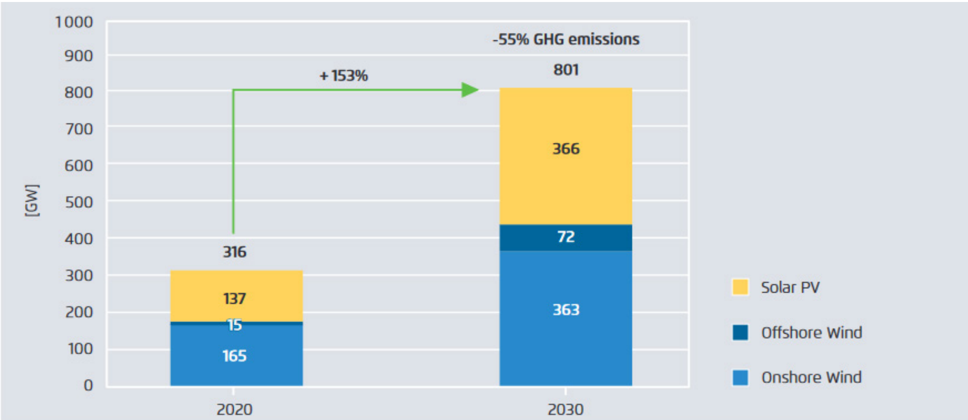
The third quarter of 2021 in Spain is experiencing historic highs in electricity prices.[4] It is estimated that 20% of the price increase is due to the costs of CO2 emission rights.[5] This tax, which discourages generation from fossil fuels, is falling on the consumer because there is not yet a green generation network that can replace traditional generation. Without widespread renewable or green energy, CO2 fees will continue to impact end consumers.

Given that energy is a primary necessity, it is mandatory that it not only be clean but also accessible to all of society. In the global energy context in which traditional fuels have a high environmental cost, are concentrated in a few territories, and are traded based on geopolitical strategies, the commitment to renewable energies is increasingly necessary. These are energies with very reduced impact on the environment and are available, in different forms, around the planet.

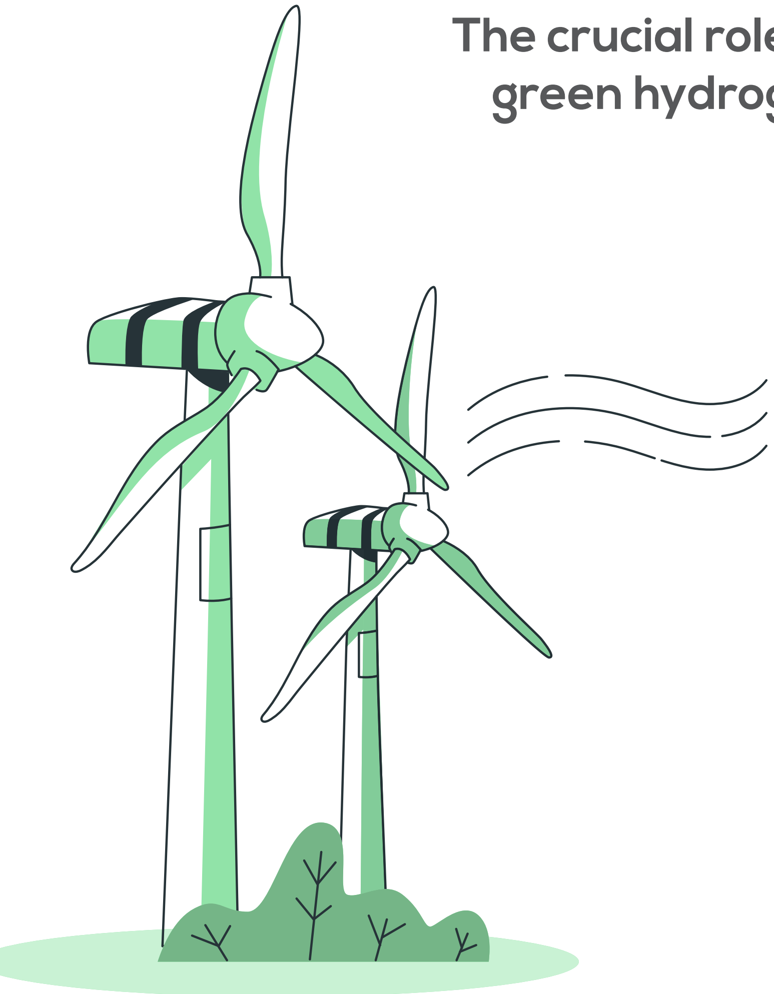
The generation of renewable energy in Europe needs to almost triple the current capacity in the next decade.[6] The partial decarbonization objectives established by the EU for the period 2021-2030, as well as the UN's Millennium Development Goals, require redirecting the European energy generation strategy towards more efficient technologies and primary sources with less environmental impact.[7]

Such primary sources must be generated on a large scale in order to replace the increasingly high global energy demand.

And finally, it must be obtainable in proximity to minimize the fees derived from transportation that make energy consumed at the destination more expensive. The European Commission's proposal to reduce greenhouse gas emissions by at least 55% by 2030 puts Europe on the path to achieving the goal of being climate neutral by 2050,[8] but to reach these milestones the capacity of solar and wind generation has to increase from just over 300 GW in 2020 to more than 800 GW in 2030.[9]



Renewable energy generation capacity to achieve a 55% reduction in greenhouse gas emissions by 2030. Source: Agora Energiewende[10]



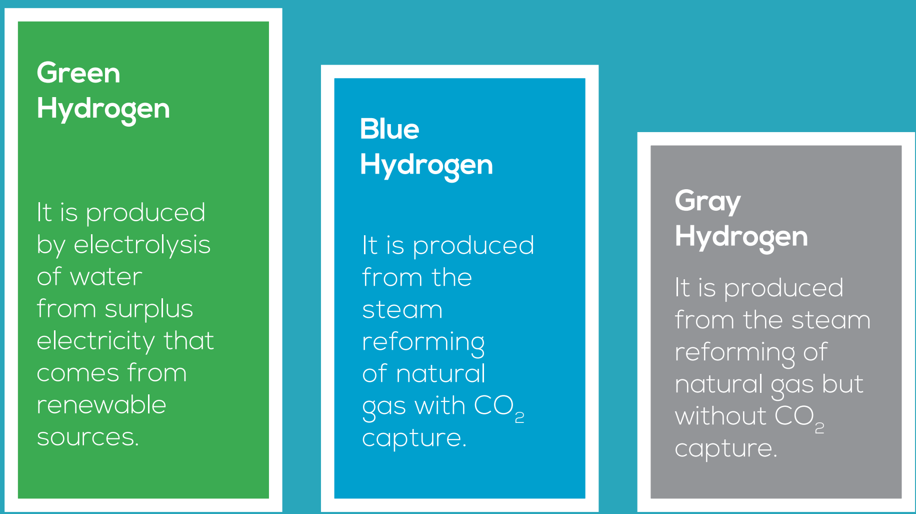
The crucial role of green hydrogen

Large-scale renewable energy generation will be even more efficient if it has a storage system for that energy when there is no consumption. Renewable energies have production windows that may not coincide with consumption times, so their storage is very important for production efficiency factors to be maximized. Green hydrogen storage (hydrogen generated 100% from renewable energies) can be located at solar parks, wind farms or any other point of renewable electric generation, forming a high-performance installation. Among all the infrastructures under study, green hydrogen generation from offshore wind energy is considered to have the greatest generating potential due to the large area it can cover and the favorable conditions of the wind resource.

Different types of hydrogen: green, blue, and gray

The energy transition involves implementing the use of hydrogen in energy generation processes as it is a climatically neutral gas that does not generate polluting emissions either in its production or consumption. But for this, the generated hydrogen must be green, with a zero carbon footprint.

Types of hydrogen are classified according to their method of production:



Types of Hydrogen according to their production method. Source: BOSLAN

Large-scale green hydrogen production is a key element in the EU's action for climate and the European Green Deal.[11] The transformation of renewable energy into hydrogen through the electrolysis process allows for a product that is storable, transportable, and combustible without emitting pollutants. These hydrogen characteristics are fundamental for a true conversion of the energy business, as it has become the only real alternative for decarbonizing sectors that are not easily electrifiable such as heavy industry, air and land transportation, or construction. Its zero environmental impact, its abundance in the atmosphere, and the simplicity of the means to produce it will offset the still high electricity costs of renewable energy to make this gas a real alternative in the current Environmental Sustainability Framework.[12]

For this reason, in 2020, the European Commission set the goal in its strategy for a climate-neutral Europe to multiply hydrogen production by 40 in the next ten years[13]

The role of public administrations

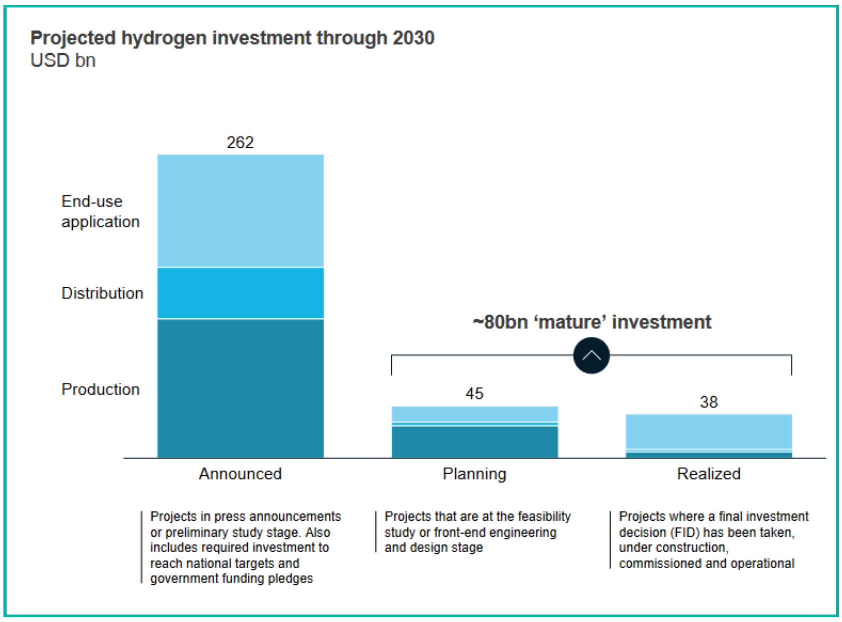
The comparative advantage of traditional fossil fuels over green hydrogen today is the economic cost of production. While the CO2 tax has somewhat balanced the scale in favor of hydrogen, the promotion of policies that encourage its development and invest in distribution networks is essential so that comparable prices to other fuels can be achieved through economies of scale.

The development of ecosystems that coordinate all the companies in the hydrogen value chain will be key to promoting innovation and agreements between different public and private entities. This, along with generating regulations updated to the current and future context, can introduce hydrogen in applications so far exclusive to the industrial sector. In this context in Spain, different initiatives are framed at the national and regional level, such as:

- **The 'Basque Y of green hydrogen' initiative promoted by Iberdrola. This is a corridor that includes the construction of three hydrogen stations in the logistics centers of Vitoria, Bilbao, and Pasajes (San Sebastián) as well as 10 MW of electrolyzers, for a total production of 4,000 kg/day of green hydrogen. This initiative, which has already been subscribed by 30 companies, will lead to the creation of 1,700 jobs.**

- **The development of a unit dedicated to hydrogen in the Energy Intelligence Center (EIC) in the Abanto Technology Park. This will involve the construction of a demonstration and development center for the possibilities offered by hydrogen for different sectors, called the "Hydrogen Living Lab".**

- **The creation of the Basque Hydrogen Corridor in 2020, BCH2. This is a Petronor-Repsol initiative in which the Basque Energy Agency and the Public University of the Basque Country are collaborating. It has the participation of 78 organizations: 8 institutions, 12 knowledge centers and business associations, and 58 companies.**



Investments in hydrogen projected from now until 2030. Source: Hydrogen Council[14]

The consolidation of policies that ensure the future market demand for hydrogen is another fundamental aspect to encourage private investment. The development and scaling up of hydrogen require projects with long-term return, and to meet the objectives set by Brussels, close alignment will be needed between European, national, and regional administrations.

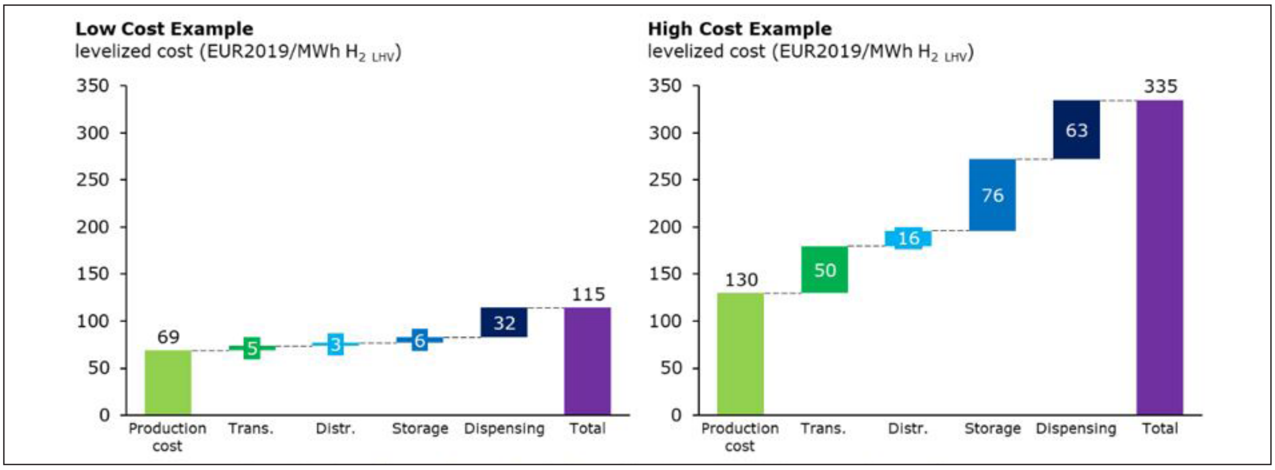
PART 2

Challenges of hydrogen storage and transport

Hydrogen has the ability to be stored as compressed gas or in a liquid state, and it allows large amounts of energy to be stored for long periods of time. Its energy management capacity based on consumption gives it high added value.

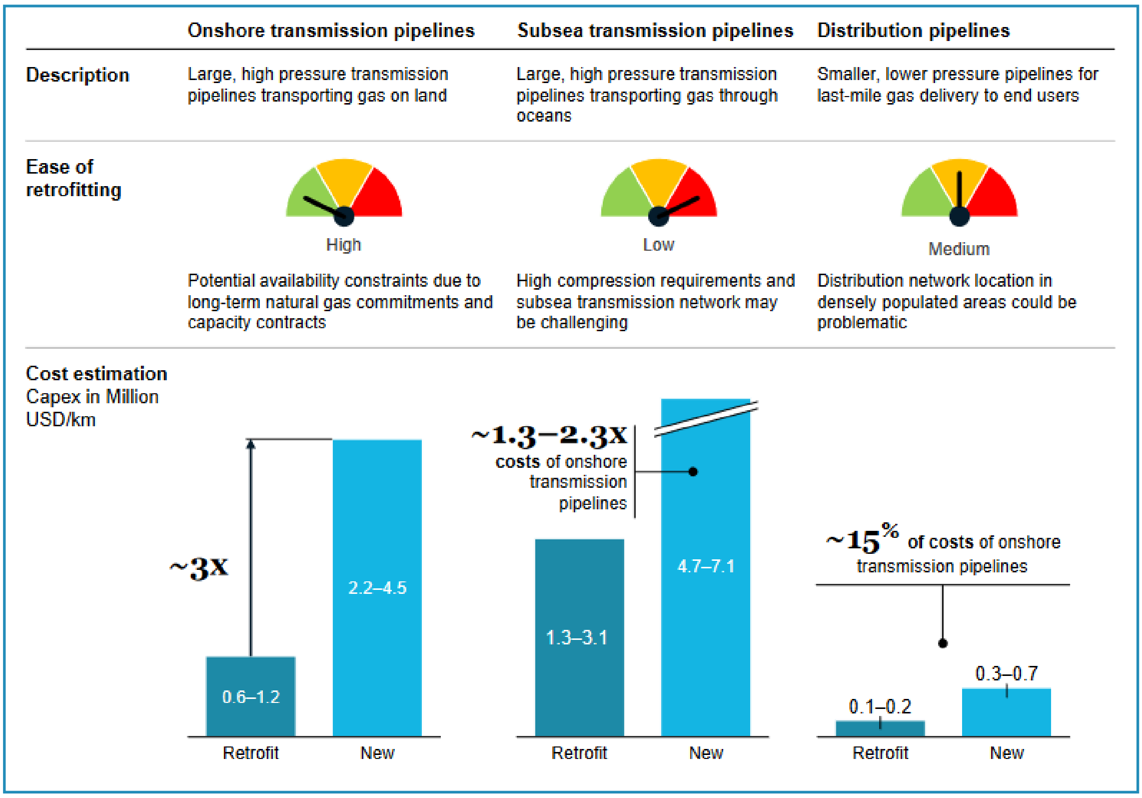
However, one of the main challenges in scaling the use and generation of hydrogen will be solving storage and transport from a technical, regulatory, and cost-reduction standpoint.

Transport, distribution, storage, and dispensing of hydrogen can currently account for more than 50% of the total cost,[15] Hence the sector's interest in developing economically viable alternatives.



Breakdown of costs of the hydrogen production and distribution chain in 2020 – example cases. Source: European Union[16]

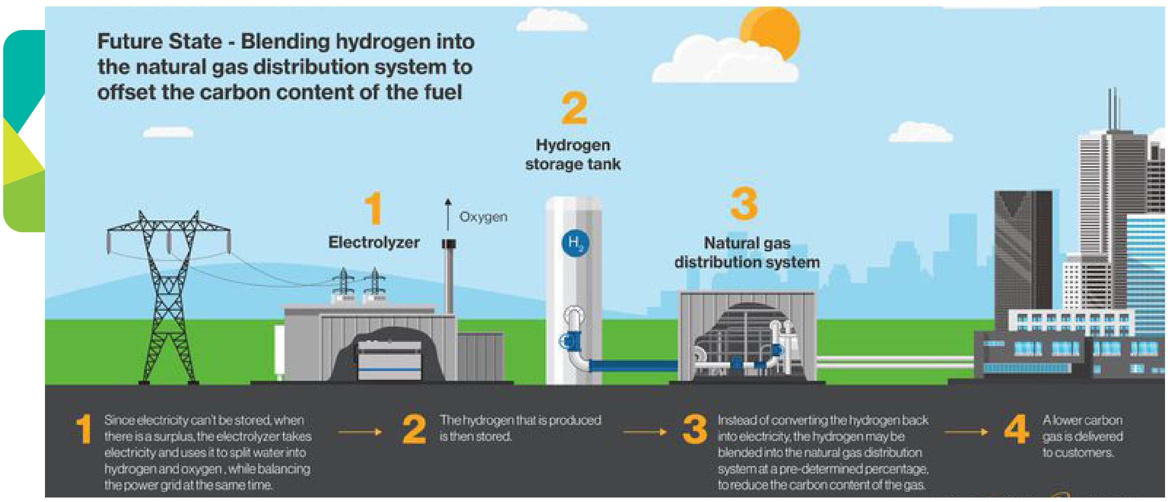
Reusing the gas network is a viable solution for high-pressure land pipelines, but reusing low-pressure pipelines and maritime conduits presents serious difficulties, both from a technical standpoint –development and maintenance– as well as regulatory and safety issues.



Comparative of hydrogen transport and distribution networks. Source: Hydrogen Council[17]

Development of Hydrogen Blending

Among the main uses of hydrogen, blending is gaining weight: *Blending* refers to the injection of hydrogen in small percentages into existing natural gas networks in coexistence with natural gas, after hydrogen methanation, to reduce its CO_2 emissions. A significant advantage of blending is that it solves the transport of hydrogen throughout the geography to private homes.



Hydrogen blending. Source: Enbridge[18]

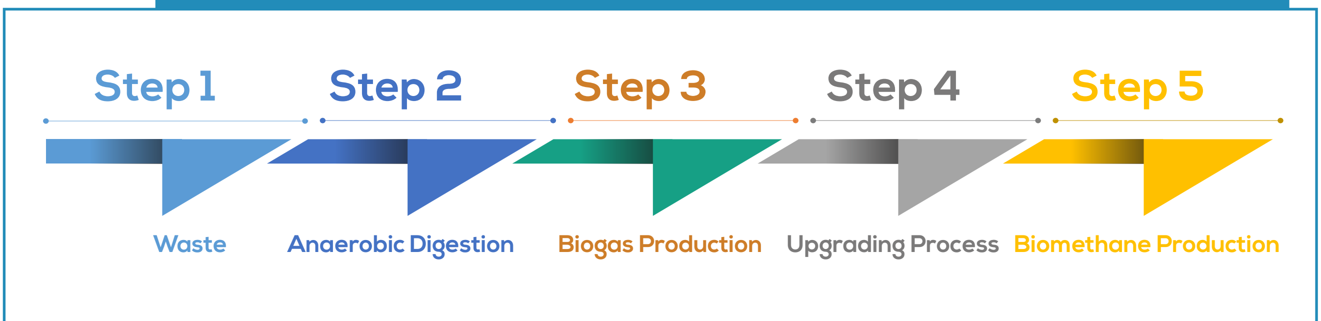
The use of existing natural gas infrastructures to transport both biomethane and hydrogen implies a substantial reduction of the costs associated with these renewable gases. However, due to restrictions on the amount of hydrogen that can be added, its capacity to absorb the generated hydrogen is limited. Hydrogen blending is allowed in a concentration of between 0.1-10% by volume (a maximum of 5% in Spain) because it is still under study how the transport and distribution network and the equipment using the gas would behave with higher concentrations of hydrogen.

The experience accumulated with biomethane in recent years is particularly relevant to addressing the technical problems presented by hydrogen blending.

BOSLAN'S EXPERIENCE WITH BIOMETHANE

The decarbonization policy of the energy sectors has driven the search for alternatives to conventional gases or fuels through renewable gases, where not only hydrogen but also biomethane plays a critical role.

To understand where biomethane comes from, it is necessary to introduce the concept of biogas. This is obtained from the degradation of organic matter (such as waste from landfills or from the livestock, agricultural and/or industrial industry), thanks to the action of different microorganisms in an anaerobic fermentation process. The biogas obtained in this process contains a concentration of between 45-70% methane, 35-40% CO_2, and other compounds such as water, hydrogen, nitrogen, hydrogen sulfide, and oxygen. In order to increase the calorific value of this biogas and make it similar to the conditions of natural gas, it is subjected to an upgrading process, which consists of increasing the methane concentration in it through absorption techniques that manage to separate the CO2 and the rest of the compounds, thus obtaining biomethane.



BOSLAN in its philosophy of providing comprehensive service to the client, has in its team specialists capable of developing everything from waste digestion engineering for biogas generation, through the development of the upgrading process, to the connection of the production plant with the basic network of gas pipelines of the Technical System Manager through a gas pipeline and an injection point.

Biomethane has different uses today, very similar to those that hydrogen can have, such as injection into existing natural gas infrastructures in coexistence with natural gas, fuel in vehicles, fuel for boilers and electricity generation. The technical and operational difficulties that we must face to efficiently manage the storage and transport of both gases are also very similar, and the experience accumulated in recent years with biomethane is proving very valuable in new hydrogen projects led by **BOSLAN**.

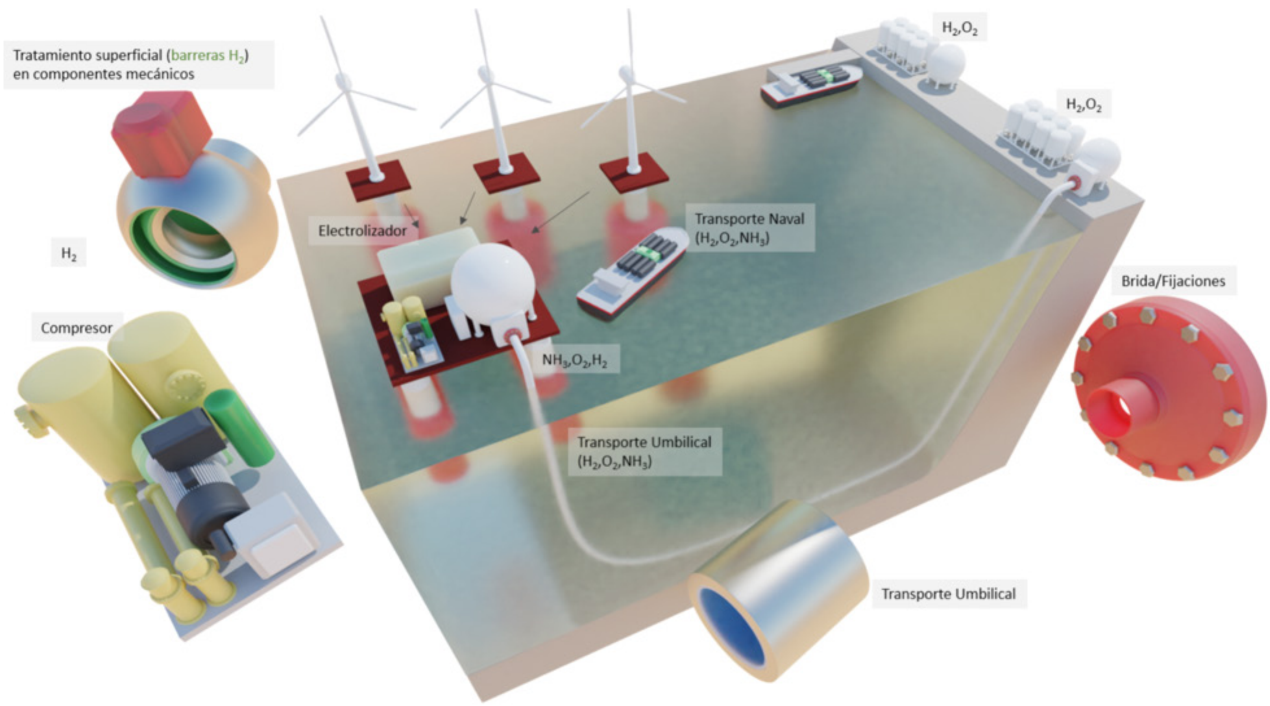
Generation of Offshore Green Hydrogen: the challenge of Storage and Distribution in the Marine Environment

BOSLAN leads the HYSHORE Project "Experimental Development for the Transport and Logistics of Hydrogen generated in Offshore Wind Parks". It is a pioneering project in the context of hydrogen distribution in the marine environment.

HYSHORE analyzes the technical feasibility of hydrogen bunkering in offshore green hydrogen generation platforms. This work is being carried out by BOSLAN together with the Basque Maritime Forum, the Basque Network of Technological Centers, and leading companies in the marine sector.

Floating offshore wind turbine. Source: Flagship Project[19]

Alternatively, we analyze the feasibility of connecting the green hydrogen platforms to land by means of umbilical conduits on the seabed for onshore storage of this energy resource. These are conduits for pressures of 1000 bar, with new welded joints and special surface barrier treatments for hydrogen.



Hyshore Project. Source: BOSLAN

Finally, HYSHORE analyzes the technical feasibility of loading hydrogen onto carrier ships as a short-term solution to the still limited development of exclusive hydrogen freighters. Once all the aforementioned transport options have been analyzed, HYSHORE will estimate the costs of the different solutions to carry out a comparative study.

PART 3

BOSLAN, a pioneer in hydrogen projects

BOSLAN is a pioneer in Spain in the management of hydrogen projects, and has experience in the comprehensive management of renewable gas projects from their initial phase carrying out feasibility studies (technical-economic), the project phase, developing the engineering and processing of permits and licenses, as well as in the construction phase carrying out the functions of contract engineering and technical assistance in the purchase of equipment, in addition to the management and supervision of the work.

The leadership of the HYSHORE project allows BOSLAN to develop its own know-how of the best solutions for the transport of hydrogen in marine environments from offshore platforms for the generation of green hydrogen.

Besides, **BOSLAN exercises the Facultative Management of the Puertollano hydrogen project for IBERDROLA**, as well as the tasks of contract engineering and supervision of the work on site, quality and environment. This is one of the hydrogen technology projects developed by IBERDROLA, and in which it has trusted BOSLAN to provide services from the contracting phase to commissioning. This project, developed in the facilities of Fertiberia, involves the construction of a hydrogen and oxygen production plant by electrolysis from renewable sources, integrating both products in the Fertiberia production process and is part of the agreement signed by both companies for the development of this technology.

This collaboration has recently been reinforced by BOSLAN being chosen by IBERDROLA as one of the companies included within the alliance for the development of **the Basque Y of Green Hydrogen**, along with other companies in the region.

BOSLAN is also providing services in another hydrogen project that IBERDROLA is developing for TMB in Barcelona. This project consists of the construction and commissioning of a hydrogen generation plant through water hydrolysis (green hydrogen), with storage capacity and that will supply hydrogen to adjacent facilities (hydrogen refuelling stations) for the supply of the bus fleet of Metropolitan Transport of Barcelona (TMB).

BOSLAN, AN ENGINEERING AND CONSULTING COMPANY WITH A MULTIDISCIPLINARY SPIRIT

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BOSLAN is a company with over 20 years of experience offering specialized engineering and consulting services. It has offices in 9 countries and employs 750 people, who participate in projects in 30 countries.

BOSLAN has an organization divided into activity areas from where all the engineering work, technical direction, tests, and commissioning are coordinated and executed in the energy sector, in oil & gas, in various industrial sectors and infrastructures.

Thanks to the multidisciplinary nature of the different departments and the experience acquired in multiple projects, BOSLAN is configured as an integrative engineering and project development company.

With the capacity to accompany its collaborators and clients throughout the entire business cycle: feasibility studies, project submission for funding, conceptual designs, detailed engineering development, project direction and coordination, construction supervision, and commissioning.

As part of its strategy, BOSLAN is committed to R&D investment, to equip itself with knowledge, advanced design tools, and BIM development methodologies, to approach each project comprehensively, as well as guaranteeing a agile, personalized, and reliable response with the required quality levels. Always seeking to exceed our clients' expectations and become their trusted partners.

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