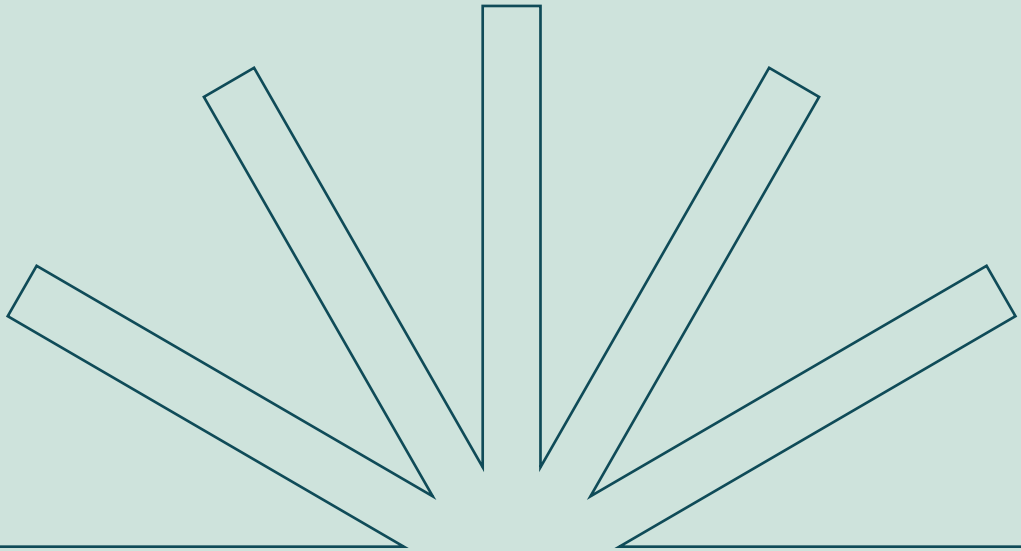


Green hydrogen: a key lever for decarbonizing industry in Spain



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1. Executive summary

This report analyses the role of green hydrogen in Spain's energy transition and industrial decarbonization, within the framework of European and national policies promoting climate neutrality and the electrification of the economy.

At European level, the REPowerEU Plan was established in 2022 as part of the European Union's objective to reduce net greenhouse gas emissions by at least 55 per cent by 2030 and achieve climate neutrality by 2050, in line with the European Green Deal. This plan recognizes renewable hydrogen as a key energy carrier for replacing fossil fuels in industry, heavy transport and energy storage. The plan proposes domestic production of 10 million tonnes of renewable hydrogen by 2030 and the import of a further 10 million tonnes, with financial and regulatory support mechanisms to drive its roll-out in Member States.

Within the context of the European plan, Spain offers unique and competitive conditions for hydrogen production: abundant solar and wind resources, competitive electricity costs, a gas network that is partially adaptable, and expertise in renewable energy. Furthermore, it has a robust strategic framework: The 2023–2030 Integrated National Energy and Climate Plan (PNIEC) sets a target of 12 GW of electrolyzers by 2030. There are currently around ten hydrogen valleys at various stages of development, many of which are supported by the Strategic Project for Economic Recovery and Transformation (PERTE) for Renewable Energy, Renewable Hydrogen and Storage (ERHA). In terms of infrastructure, the main routes of the future Spanish Hydrogen Backbone Network will be connected to the European H₂Med corridor, which forms part of the *European Hydrogen Backbone* (EHB) initiative, thereby linking the main industrial hubs of the Iberian Peninsula to the future European hydrogen transport network. In this context, Thanks to lower solar energy prices and one of the world's most mature markets for power purchase agreements (PPAs), the levelized cost of hydrogen production (LCOH) for green hydrogen in Spain could stand at between €4 and €5.5 per kilogram by 2030.

Through the PERTE ERHA program alone, planned public investment in Spain exceeds €1.5 billion, and the aim is to mobilize €2.8 billion in private funding.

The report examines how these factors enable Spain to move towards combined industrial electrification, using green hydrogen as a direct or indirect energy source or as a raw material, and analyses both the technical feasibility of the production processes and their energy and territorial impact. Direct electrification will be the predominant solution in low-temperature industrial processes, accounting for 60 per cent of national industrial energy demand, whilst indirect electrification using green hydrogen will be essential in sectors involving high-temperature processes or those that use hydrogen as a raw material, such as refining, fertilizer production, steelmaking, cement, glass and heavy goods transport.

The expert discussion in Spain is also summarized, identifying three areas of challenge:

- * the *regulatory sphere*, due to the lack of a standardized framework for certification, permits and grid access;
- * the *economic sphere*, the cost gap between gray and green hydrogen, the absence of long-term contracts and demand stimulation;
- * the *technological sphere*, linked to the manufacture of electrolyzers, efficient storage and transport; and
- * the *territorial sphere*, linked to the social acceptance of the renewable energy transition.

Overall, the study concludes that Spain is well placed to become a net exporter of green hydrogen and its derivatives (ammonia, e-methanol, sustainable aviation fuel) by 2050, provided it ensures consistency between industrial policy, energy planning and regulation. Its combination of renewable resources, existing infrastructure and emerging technological capabilities positions it as an energy hub for south-western Europe and a key player in the integration of the European hydrogen market.



2. Introduction

The far-reaching decarbonization of the European economy requires the gradual phasing out of fossil fuels across all productive sectors. In this context, green hydrogen—produced by electrolysis of water using electricity from renewable sources—has established itself as a strategic pillar of the new European energy policy. The European Union explicitly recognizes it as a key driver of the European Green Deal, having set a target of producing and consuming 10 million tonnes of renewable hydrogen per year by 2030—a figure that highlights the scale of its industrial roll-out and its potential to transform energy value chains.

Spain is in a privileged position in this energy transition. The availability of high-quality solar and wind resources, the existence of a robust gas infrastructure and the experience gained from large-scale energy projects place the country amongst those best positioned to lead the way in the production and use of green hydrogen in Europe. The Integrated National Energy and Climate Plan (PNIEC 2023–2030) sets a target of 12 GW of installed electrolysis capacity by 2030, reinforcing the commitments already set out in the Hydrogen Roadmap (2020). Added to this is the roll-out of the Strategic Project for the Recovery and Economic Transformation of Renewable Energy, Renewable Hydrogen and Storage (PERTE ERHA), which aims to mobilize more than 1.5 billion euros in public funding and 2.8 billion euros in private funding for renewable hydrogen projects.

The purpose of this report is to provide a comprehensive overview of the development of green hydrogen in Spain, analyzing its role in the electrification of industry, its regional roll-out, its infrastructure requirements, and the regulatory, economic and technological challenges that affect its scalability. The analysis draws on leading institutional and sectoral sources—the European Commission, MITECO, IDAE, AeH₂, Enagás, REE, EHB, the IEA and IRENA—which provide official information updated to 2025, supplemented by technical literature and relevant corporate positions.

The document is divided into **six main sections**:

- 01/** The electrification of industry in Spain and the role of green hydrogen.
- 02/** A global strategic framework that provides the context for international policies and targets.
- 03/** An analysis of the European situation, focusing on climate governance, industrial competitiveness and support mechanisms.
- 04/** A national analysis and the energy implications of green hydrogen in Spain.
- 05/** An overview of the current state of the expert debate, summarizing the regulatory, economic, technological and territorial discussions.
- 06/** Strategic conclusions, setting out the implications for Spanish energy and industrial policy.

Overall, the report aims to serve as a technical and strategic reference for public decision-makers, energy companies and industrial stakeholders, contributing to a coherent vision of Spain's role in the green hydrogen economy and its alignment with the objectives of climate neutrality and European reindustrialization.

3. Electrification of industry in Spain: the role of green hydrogen

3.1. Conceptual introduction: direct and indirect electrification in the Spanish context

The decarbonization of industry is based on a two-pronged strategy. On the one hand, the direct electrification of those processes where mature solutions with a good cost-benefit ratio already exist. Furthermore, indirect electrification using green hydrogen where no comparable alternative exists. Both options are based on harnessing Spain's abundant and competitively priced renewable electricity, although they differ in terms of their conversion processes and, consequently, their overall efficiency.

As we shall see below, this dual strategy of direct and indirect electrification will depend to a large extent on energy uses in industry (see **Figure 1**), in particular on the temperatures required in industrial processes.

Overall, the analysis in this report shows that more than 60 per cent of Spain's industrial energy consumption (IDAE, 2025a, p. 79) can be electrified directly using

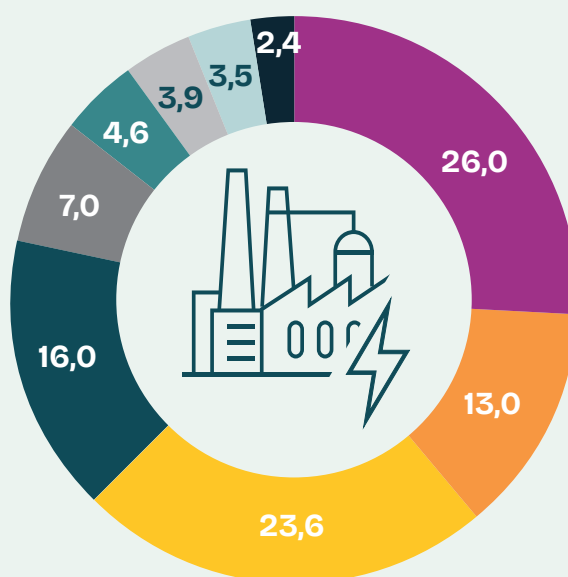
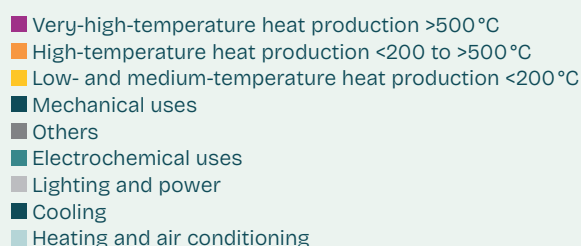
technologies already available on the market, whilst green hydrogen, on the other hand, should be reserved for high-temperature sectors or those involving reactive processes where direct electrification is technically or economically unfeasible. In this context, electrification and hydrogen should be viewed as complementary technologies within the same industrial decarbonization strategy, rather than as alternatives, so that their joint development can optimize both competitiveness and the effective reduction of emissions.

Consequently, public support policies, such as the Renewable Energy PERTE, Renewable Hydrogen and Storage (PERTE ERHA) and the Important Projects of Common European Interest (IPCEI), should prioritize hybrid projects and electricity-hydrogen integration projects in the most energy-intensive industrial clusters.

Figure 1.

Energy consumption
in industry

Note: Compiled by the author
based on data from the Institute
for Energy Diversification and
Saving (IDAE, 2025a).





3.1.1. Integration into the Spanish and European energy transition

The PNIEC 2023–2030 and the Hydrogen Roadmap (2020) set out this complementary approach: electrification is the main route to industrial decarbonization, whilst hydrogen is aimed specifically at hard-to-decarbonize sectors.

At the same time, at European level, the Net-Zero Industry Act (NZIA) and the Green Deal Industrial Plan are bolstering the roll-out of net-zero technologies—including electrification and renewable hydrogen—within a framework that prioritizes the direct replacement of fossil fuels with renewable electricity, whilst also promoting the use of hydrogen in those industrial and energy sectors where it offers greater technological or energy-related added value.

From this, as also projected by the International Energy Agency (IEA, 2021)¹, an operational hierarchy emerges:

- * Direct electrification in low- and medium-temperature processes (< 500 °C).
- * Green hydrogen in high-temperature or reactive processes.
- * CCU/CCS where the two previous methods are not technically feasible (e.g. cement)².

This order of priority guides public and private investment, prevents future demand for hydrogen from being overestimated, and aligns Spanish industrial policy with that of the EU.

3.1.2. Direct electrification

Spain is in a strong position: in 2024, 56 per cent of electricity generation came from renewable sources (Red Eléctrica, 2025, p. 2), with production costs among the lowest in Europe thanks to the roll-out of wind and solar power.

This advantage makes it feasible to replace natural gas with electric equipment (industrial heat pumps, electric resistance or induction furnaces, dryers, compressors, thermal fluid heaters), with the potential for substitution reaching 90 per cent of industrial thermal processes in Europe (Fraunhofer ISI, 2024).

Based on data from the IDAE and as shown in **Figure 1**, we can conclude that over 60 per cent of industrial energy demand occurs at temperatures < 200 °C (food, paper, textiles, light chemicals), making these sectors ideal candidates for direct electrification, with immediate reductions in emissions without the need for intermediate energy carriers or new infrastructure (IDAE, 2025a, p. 79).

3.1.3. Indirect electrification using green hydrogen

In processes involving temperatures above 500 °C or in those where hydrogen acts as a reactant—such as refining, steelmaking or fertilizer production—direct electrification is insufficient or unfeasible. In these cases, renewable electricity is first converted into hydrogen through electrolysis, and the hydrogen is then used as a fuel or as a raw material.

This approach offers versatility and storage capacity, but it also entails losses: the overall efficiency of the electricity→hydrogen→heat cycle is around 30–40 per cent (Sustainability Director, 2025), which is well below that achieved through direct use of electricity. For this reason, and taking into account all the existing storage options, renewable hydrogen should be reserved for applications that are difficult to electrify, particularly in large industrial centers.

¹ This is one of the assumptions underlying the IEA's decarbonization scenarios, specifically the net-zero emissions scenario for 2050.

² Considering mainly that in this process, beyond the energy aspect, the objective is to obtain lime from limestone.



3.2. Sectoral classification by temperature and technical feasibility

The feasibility of electrifying industrial processes depends primarily on two factors: the process temperature and the role played by the energy carrier, whether as a source of heat, mechanical energy or a chemical reactant. Based on these criteria, and according to the IDAE classification (2025a), industrial sectors can be grouped into three main categories.

3.2.1. Low-temperature processes (< 200 °C)

Low-temperature processes are typical in sectors such as the food and drink, textile, paper and board, light chemical and pharmaceutical industries, where operations such as pasteurization, drying, cleaning, washing or dyeing, evaporation and gentle distillation are common.

The main replacement technologies include high-temperature industrial heat pumps (HTHP), capable of reaching temperatures of up to around 160 °C with coefficients of performance (COP) ranging from 3 to 6, as well as electric heating elements, electric boilers for low-pressure steam generation, and electric or hybrid dryers with electronic humidity control.

Its feasibility is very high: according to an analysis by the IDAE (2025a), over 60 per cent of industrial thermal energy in Spain is consumed within this temperature range, making these sectors priorities for direct electrification.

It is for this reason that it must be understood that the need for green H₂ is either non-existent or marginal (limited to heavy goods transport or specific chemical applications) in industrial processes operating within these temperature ranges.

3.2.2. Medium-temperature processes (200–500 °C)

This second group includes sectors such as the basic chemical and petrochemical industries (endothermic reactions, partial reforming), the ceramics and tiles industry (intermediate firing), hollow glass and non-metallic materials, and non-ferrous metallurgy (aluminum and zinc smelting).

The technologies applicable to these include electric induction or resistance furnaces, cascade-cycle heat pumps (up to 200–250 °C), hybrid electricity + H₂ systems, where electricity covers the base load and hydrogen covers peak heat demand, and the recovery of waste heat using compressors and thermal energy storage (TES).

Spain has a very strong industrial base in ceramics (Castellón) and glass (Catalonia, Toledo), where electric kilns and mixtures containing H₂³ are already being tested. In chemistry, some processes (for example, the distillation of solvents or the generation of intermediate vapor) can be directly electrified. This is why the feasibility can be classified as medium to high.

The technical feasibility of electrification in this sector is medium to high, whilst the need for green hydrogen can be classified as medium, intended mainly for temperature ranges between 400 and 500 °C or for seasonal energy storage. However, technological and investment barriers remain, as does a significant cost gap between green and gray hydrogen.

The role of green hydrogen in this context is a complementary one, as it can cover the higher temperature ranges (~400–500 °C) and serve as seasonal energy storage in plants with a high degree of renewable intermittency.

³ The pilot project is H2togreenceramics—developed by the Institute of Ceramic Technology (ITC) and implemented by Técnicas Reunidas. Vidrala (2024). *Sustainability and Energy Transition Report*, pp. 24–27 (The use of electric furnaces and alternative fuels in the glass industry).



3.2.3 High-temperature processes (> 500 °C)

This third group includes sectors such as the steel industry (direct reduction of iron, electric arc furnaces), the cement industry (rotary kilns, clinker), refining (hydrotreatment, reforming, cracking), and others such as flat glass, heavy foundry, lime and refractory ceramics.

It is here that green hydrogen does indeed play a key role as a replacement technology, whether as a fuel or as a reducing agent, replacing natural gas, coke or coal; in the cement industry in particular, it makes sense to consider hybrid systems combining electricity, H₂ and CO₂ capture, as well as oxy-combustion calciners adapted for H₂.

In refining, green hydrogen comes into play as an immediate substitute for gray hydrogen, which is used as a reactant in hydrotreatment processes including desulphurization, denitrogenation, cracking and isomerization. In the medium term, it could be combined with captured CO₂ to produce synthetic fuels and even to generate advanced biofuels through the hydrogenation of biomass and used oils.

In the steel industry, the electrification of recycled steel production using electric arc furnaces (EAFs) makes sense as a means of mitigating GHG emissions, whilst for the production of high-purity steels, green hydrogen has a role to play as a substitute for coke or natural gas in the processes of reducing iron ore to metallic iron, which is then melted in an electric arc furnace to produce the final commercial product.



3.3. A comparison of energy efficiency and costs between electrification and the use of green hydrogen

The debate over electrification versus the use of green hydrogen requires us to take into account the energy and economic balances involved. Both options draw on the same source: renewable electricity; however, their performance and final costs differ significantly.

In the Spanish context, characterized by an electricity mix with over 50 per cent renewable generation and solar and wind generation costs that are among the most competitive in Europe, energy efficiency becomes an essential criterion for the rational allocation of resources (Red Eléctrica, 2024).

3.3.1. Energy efficiency of the direct electrical cycle

Using the mature technologies set out in **Table 1**, direct electrification converts electricity into heat or mechanical work without any intermediate carriers, achieving very high efficiencies:

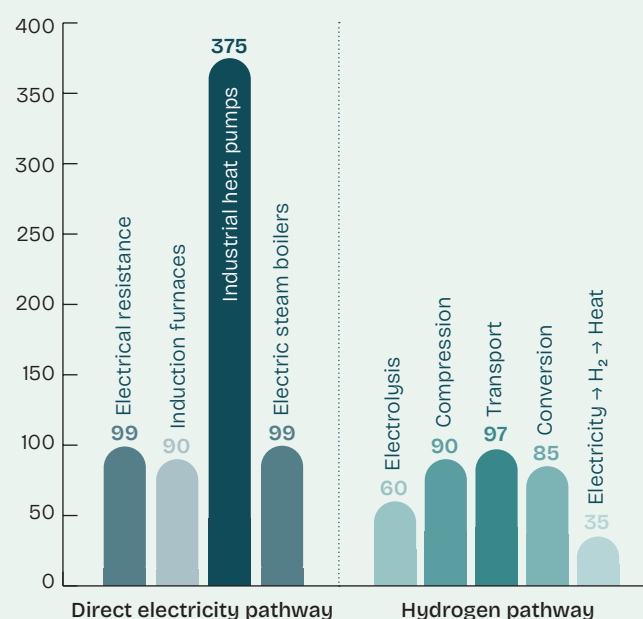
Table 1.
Thermal efficiency of process heat supply technologies

Technology	Electrical-thermal efficiency (η)	Notes
Electrical resistance	99 %	Direct low-temperature heat
Induction cookers	90 %	Light metalworking and foundry work
Industrial heat pumps	150–600 % (COP 3–6)	They recover waste heat and reduce net electricity demand
Electric steam boilers	99 %	Food and textile applications

Note: Compiled by the author based on data from the document "Direct electrification of industrial process heat: 'An assessment of technologies, potentials and future prospects for the EU' (Agora Industry, 2024, pp. 24–30).



Figure 2.
Typical process efficiencies, values in %



Source: Compiled by the author using data from Agora Industry (2024, pp. 24–30).

3.3.2. Energy efficiency of the green hydrogen cycle

Hydrogen involves a series of conversions, with cumulative losses at each stage:

Table 2.

Efficiency of the stages in the hydrogen value chain

Stage of the process	Efficiency typical	Description
Electrolysis (production)	55–65 % today Over 80 % feature SOEC technology ⁴	Conversion of electricity to H ₂
Compression and storage	80–99 %	Losses due to compression, leakage and pumping
Transport (gas pipeline or lorry)	95–98 %	By distance
Final conversion (combustion or fuel cell)	80–90 %	For heating or electricity

Source: Compiled by the author based on IEA (2025) and Sokil et al (2025). Horizon Europe. Hydrogen for Heating: Technologies, Challenges and Opportunities

The overall efficiency of the “electricity → hydrogen → heat” process is around 30–40 per cent (Sustainability Director, 2025).

In other words, almost three times as much renewable electricity is needed to produce the same amount of useful heat as in a direct-electricity system.

This difference translates into additional demand for renewable energy generation and greater infrastructure requirements: electrolyzers, storage, compression and transmission.

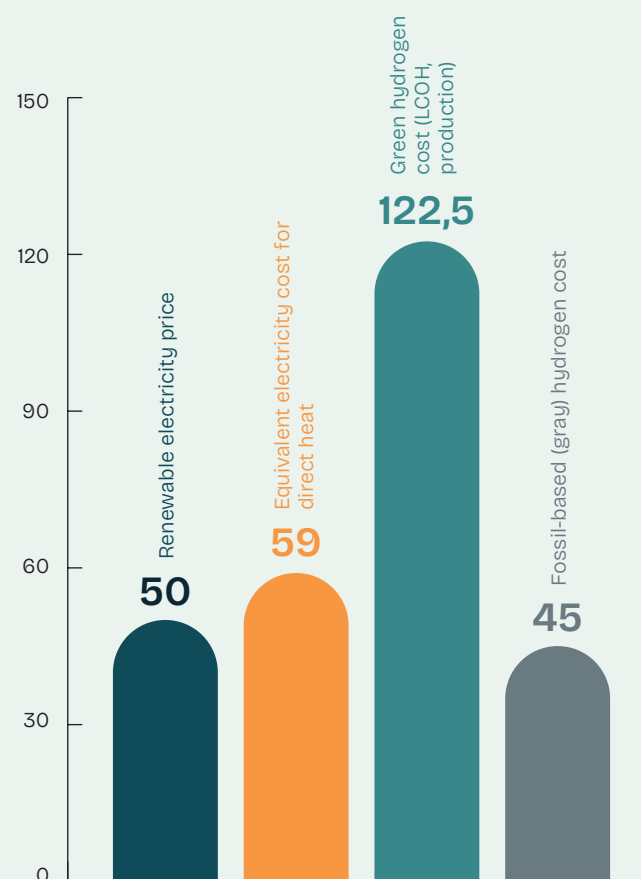
3.3.3. Economic comparison: levelized energy costs

Final energy costs reflect this difference in performance. Taking into account the average prices in Spain in 2024 (Red Eléctrica and IDAE), it is possible to establish orders of magnitude (**Figure 3**).

Although the cost of renewable energy generation in Spain is structurally low, these figures do not include the systemic costs associated with the large-scale integration of renewables into the electricity system.

Figure 3.

Comparison of average costs across different energy sources



Source: Compiled by the author using data from Pexapark (2025) and the World Bank (2024)

⁴ Solid Oxide Electrolysis (SOEC), see <https://www.iea.org/energy-system/low-emission-fuels/electrolyzers>



Various studies by the Economic and Social Council (CES) and the IEA warn that the costs of reserve capacity, storage and grid reinforcement can add between 10 and 25 €/MWh to the effective cost of energy in systems with high renewable penetration (CES, 2023, p. 84–89, 116–118) (IEA, 2024, p. (298–304).

However, the Spanish case offers certain advantages that mitigate this effect, such as the complementarity between solar and wind power, the availability of hydropower and manageable combined-cycle power, and the gradual roll-out of energy storage and demand response.

Therefore, although the marginal price of the system may rise in scenarios characterized by high intermittency, the competitiveness of renewables in Spain remains strong in the medium term.

3.3.4. Implications for Spain

Direct electrification should be the preferred option in all industrial processes operating below 200 °C, given that it is approximately three times as efficient as fossil fuel combustion and has a lower levelized cost of energy (LCOE). Green hydrogen, on the other hand, should be reserved for sectors that are difficult to electrify, particularly those in which the cost of fuel accounts for a smaller proportion of the total cost of the end product, such as steelmaking, cement production and oil refining.

Whilst the levelized cost of electricity (LCOE) for renewable energy in Spain is among the lowest in Europe, its actual competitiveness will depend on the electricity system's ability to integrate that energy effectively without incurring excessive back-up or storage costs. However, as the prices of electrolyzers and renewable electricity fall, the cost gap between electrification and hydrogen could narrow by 2030, according to projections by the International Energy Agency (IEA, 2025, p. 93).

In any case, national system efficiency requires prioritizing the direct use of renewable electricity wherever technically and economically feasible, in order to minimize the necessary expansion of renewable capacity and keep down the costs associated with the grid and the back-up of the electricity system.

3.4 Geographical scope and synergies with existing industrial clusters

The industrial energy transition in Spain is not uniform; rather, it reflects the country's geographical and sectoral diversity. Direct electrification is concentrated in areas where processes operate at low or medium temperatures and the electricity supply is stable, whilst green hydrogen projects are geared towards regions with high thermal demand and/or availability of renewable resources to produce it competitively.

3.4.1. Industrial distribution and electrification potential

Spain's industrial structure is centered around several energy and logistics corridors, each with its own distinct characteristics (**Table 3**).



**Table 3.** Industrial corridors in Spain

Region / Cluster	Key sectors	Average process temperature	Potential for direct electrification	Comments
Catalonia	Chemicals, pharmaceuticals, textiles, food	<150 °C (light chemical processing and steam)	Very high	A robust electricity grid, integrated industrial estates and expertise in energy efficiency; H2Cat's innovation network and scalability ⁵
Valencian Community (Castellón)	Ceramics, tiles, glazes	200–500 °C	Medium–high	Partial electrification is feasible; HyVal (Castellón Green Hydrogen) ⁶ , trials with electric furnaces and H ₂ –natural gas mixtures currently being tested ⁷
Andalusia (Huelva, Cádiz, Algeciras)	Refining, heavy chemicals, metallurgy, agri-industry	>500 °C	Low	High levels of emissions; potential green H ₂ hubs (Moeve, Iberdrola, Fertiberia, Enagás Renovable)
Basque Country	Steel industry, automotive industry, machinery	>500 °C	Medium	The secondary steel sector already uses electric arc furnaces; DRI and green H ₂ are under development (Sidenor) ⁸
Asturias	Integrated steel production, energy, cement	>1.000 °C	Low	It requires renewable hydrogen and carbon capture and utilization or storage (HyDeal ⁹)
Madrid and Corredor del Henares	Food, pharmaceuticals, paper	<200 °C	Very high	Cost-effective electrification and a dense electricity grid
Galicia and Castile and León	Paper, agri-food, wind power and biomass	<200 °C	High	Potential for direct electrification and industrial self-consumption using biomass and solar energy
Murcia / Cartagena	Refining, fertilizers, petrochemicals	>500 °C	Low	Key green H ₂ hub linked to Repsol and Fertiberia

Note: Compiled by the author using data from the INE¹⁰ and section 3.2 of this report.

⁵ <https://xarxah2cat.org>

⁶ Further information (March 2026): https://www.lasprovincias.es/economia/empresas/iberdrola-ultiman-construccion-mayor-planta-espanola-hidrogeno-20260305163634-nt.html#goog_rewarded

⁷ The pilot project is H2togreenceramics, developed by the Institute of Ceramic Technology (ITC) and implemented by Técnicas Reunidas

⁸ Basque Hydrogen Corridor (BH₂C) (2024)—projects listed on its website Projects | BH₂C

⁹ <https://www.hydeal.com/copie-de-hydeal-ambition>

¹⁰ The predominant sectors by region have been identified on the basis of data from the CNAE (National Classification of Economic Activities): https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736177032&menu=ultiDatos&idp=1254735976614



3.4.2. Factors influencing the siting of green hydrogen facilities

The development of green hydrogen in Spain is driven by three main factors:

* Availability of competitive renewable energy sources

- High levels of solar radiation in Andalusia, Castile-La Mancha, Murcia and Aragon.
- Steady winds in the Ebro Valley, Galicia and the north of Castile and León.

* Existence of concentrated industrial demand

- Refineries, heavy chemicals, steelmaking and cement.
- Around major industrial centers such as Western Andalusia (Huelva–Campo de Gibraltar), Catalonia (Tarragona), Murcia–Cartagena, Asturias, the Basque Country and the Valencian Community (Castellón)

* Logistics and port infrastructure

- The ports of Huelva, Cartagena, Valencia and Bilbao are establishing themselves as hubs for the export and import of H₂ and its derivatives (ammonia, methanol).
- These bring together the projects of the H₂Med corridor, which will connect Spain with France and the rest of Europe (Amber Grid et al., 2022, p. 44–52, 73–75).

3.4.3. Electrification and regional balance

Direct electrification, particularly through the use of industrial heat pumps and electric furnaces, is most viable in regions where heat consumption is at low or medium temperatures and the electricity grid is more developed. This includes much of Catalonia, Madrid, Valencia and the Ebro corridor, where industrial density facilitates shared solutions (*district heating*, collective self-consumption).

Conversely, the decarbonization of heavy industry in the north and south of the peninsula will depend to a large extent on the roll-out of green hydrogen as a fuel or chemical reducing agent, given that it is technically impossible to electrify furnaces operating at temperatures above 800°C in the short term.

The coexistence of both models—direct electrification and the use of renewable hydrogen—forms a dual energy landscape: on the one hand, along the Mediterranean corridor and in the center of the peninsula, electrification will be the priority, whilst along the Atlantic/Cantabrian

corridors, a combination of green hydrogen and CCUS will predominate.

3.4.4. Integration with national policies

The PNIEC 2023–2030 and the PERTE ERHA and Hy2Use programs set out an explicit territorial approach.

The funding prioritizes integrated projects that combine renewable generation, electrolysis and local industrial consumption (IDAE, 2024a): it promotes the creation of hydrogen clusters where supply and demand are physically close together, thereby reducing logistics costs.

Overall, direct electrification is emerging as a driver of competitiveness in regions with a diversified industrial base, whilst green hydrogen will be crucial to sustaining activity in energy-intensive industrial hubs. Both approaches are complementary and are in line with the NZIA principle: to strengthen energy sovereignty through local value chains for clean technologies (Regulation (EU) 2024/1735, 2024).

3.4.5. Regional conclusion

The regional pattern of industrial decarbonization in Spain combines electrification along the Mediterranean corridor and in the center of the peninsula with the use of green hydrogen in the industrial north and south. This distribution scheme makes use of both the existing electricity infrastructure and the geographical distribution of renewable resources, as well as the presence of strategic energy ports.

Industrial policy should therefore strengthen electricity and gas infrastructure suitable for hydrogen, thereby preventing bottlenecks from arising between generation and consumption points.

In the medium term, coordination between energy planning and land-use planning will be key to optimising public and private investment in both areas of decarbonization.

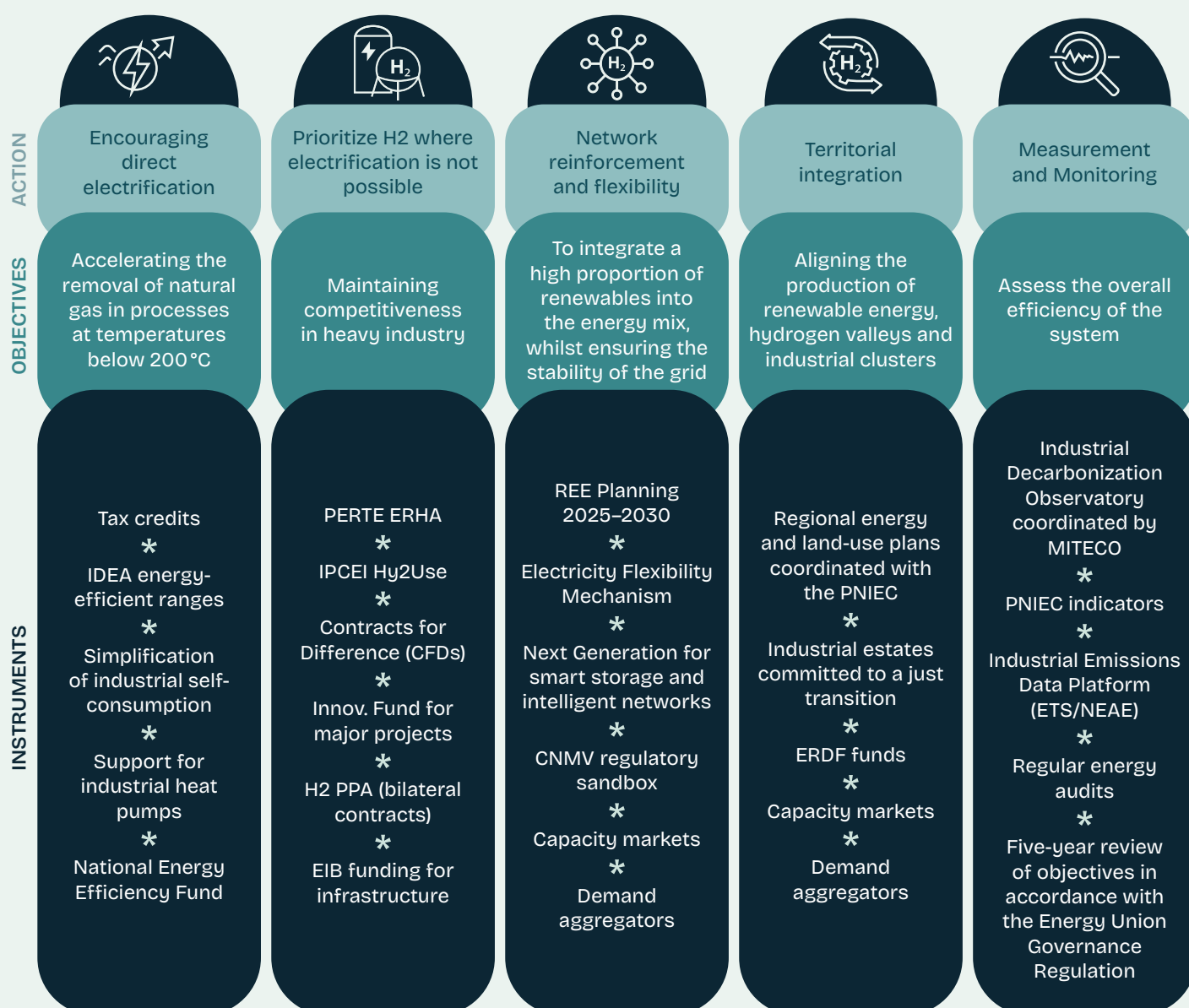
3.5 Recommended policies

In light of the above, it is recommended that action be taken across five areas of work, defining the objectives pursued in each and identifying some of the tools that support them—many of which still need to be developed. (Figure 4).

These measures must be based on electrifying processes where this is most efficient, using renewable hydrogen where technically necessary, and coordinating both approaches at a regional and regulatory level.

The consistent implementation of this combination will optimize the competitiveness of the domestic industry and strengthen Spain's role as Europe's clean energy hub—a leading position that will be consolidated through the development of future hydrogen valleys and cross-border corridors, which are discussed in the following chapter.

Figure 4: Recommended policies to promote hydrogen



4. Global strategic framework for green hydrogen production

4.1 International context

4.1.1 Demand

Global hydrogen production reached almost 100 million tonnes in 2023, showing a slight upward trend compared with previous years (IEA, 2024, p. 161). More than 90 per cent of this consumption is still linked to hydrogen produced from fossil fuels, which is used mainly in refining, ammonia production and steelmaking. Depending on climate ambition targets and the technologies employed, demand for hydrogen by 2050 could vary significantly, ranging from 150 to 600 Mt, potentially driven by its deployment in electrification, buildings, heavy industry and the chemical sector, as well as maritime and air transport (World Energy Council, 2021).

4.1.2 Production

Global production continues to be dominated by gray hydrogen. According to the IEA, around 70 per cent comes from natural gas reforming and a further 30 per cent from coal, with China being the leading producer. Low-carbon hydrogen—whether blue or green—accounts for just 1–2 per cent of the total (IEA, 2024). However, the International Energy Agency identifies more than 2,000 electrolysis projects that are either operational or announced globally, with Europe, North America, the Middle East and Australia leading the way¹¹. The acceleration in investment in electrolysis is linked to the expected fall in costs and the expansion of renewable capacity, although challenges remain in terms of scalability, certification and access to energy infrastructure (IRENA, 2024b).

4.1.3 Trade

International trade in hydrogen is still limited, as most of it is consumed close to the point of production. However, strategic corridors are being established to link regions with abundant renewable resources—such as Chile, Australia, the Middle East and North Africa—with the major consumption centers in Europe and Asia. IRENA (2022a) estimates that by 2050, up to 33 per cent of the world's hydrogen will be traded internationally, mainly in the form of derivatives such as ammonia, methanol or synthetic fuels. For this market to materialize, regulatory harmonization, technical standardization and certification schemes for renewable energy are critical factors (IRENA, 2024a, p. 6).



¹¹ See the IEA's tracking of these projects on its interactive map: [Hydrogen Production Projects Interactive Map—Data Tools—IEA](#)



4.2. Key strategic factors for the production of green hydrogen

4.2.1. Political and regulatory factors

The policy and regulatory framework is one of the key determinants of hydrogen development. The *Hydrogen Strategy for a Climate-Neutral Europe*, presented in 2020, set out a comprehensive plan to deploy 2×40 GW of electrolyzers by 2030 (40 GW in Europe and 40 GW in neighbouring countries that export to the EU) and to produce up to 10 million tonnes of renewable hydrogen in the EU by the same deadline (European Commission, 2020a). This framework was reinforced by the publication of the REPowerEU Plan (European Commission, 2022a), which, through the so-called *Hydrogen Accelerator*, sets an indicative target of 10 million tonnes per year of renewable hydrogen produced within the Union and a further 10 million tonnes imported by 2030.

On a global scale, the regulatory landscape is highly varied. Whilst some countries have already adopted national roadmaps with binding targets, others still lack a clear regulatory framework (EFI Foundation, 2022). According to IRENA (2022b), the geopolitics of hydrogen are taking shape around three main pillars: energy security, access to critical minerals and the establishment of sustainability standards. In this context, international cooperation and the development of common certification schemes are regarded as critical factors in preventing regulatory fragmentation and facilitating international trade (IRENA, 2024b).

4.2.2. Economic factors

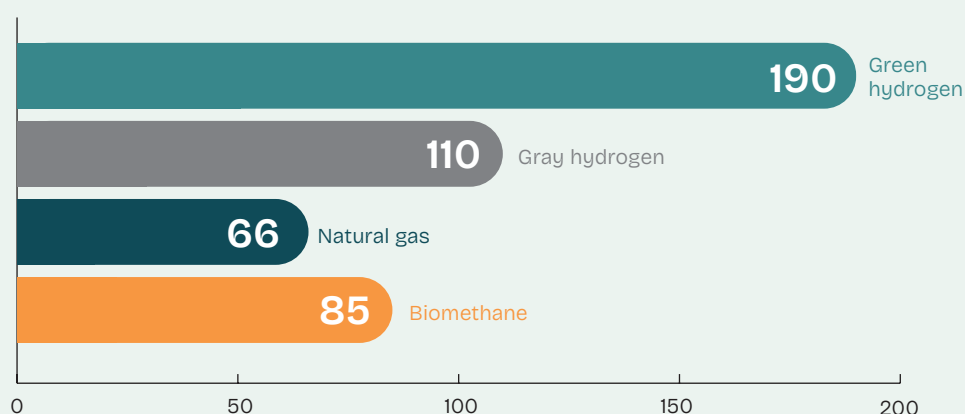
Cost remains the decisive economic factor for the take-off of renewable hydrogen, as illustrated in **Figure 5**.

At present, the average price of green hydrogen in Europe remains well above that of fossil hydrogen. However, looking ahead to 2030, a significant convergence is expected as the costs of electrolyzers and renewable energy fall. Major studies suggest that the cost of green hydrogen is likely to fall; however, due to geopolitical and market instability, projections are difficult to make and, depending on whether the assumptions are more or less optimistic, this cost could range from €1.6/kg to €5/kg¹³.

At the same time, other recent studies point to a gap between political ambition and the actual implementation of projects, which casts doubt on the ability to achieve the 2030 targets (Odenweller & Ueckerdt, 2024). Furthermore, robust global cost estimates show that, even under optimal deployment scenarios, green hydrogen will only be competitive in certain regions with abundant renewables and low financing risks (Ordóñez et al, 2023). Green hydrogen production therefore represents a competitive opportunity for Spain, as it meets the two criteria mentioned: high levels of renewable resources and production, and a low level of financing risk.

Figure 5.
Comparison of fuel gas costs
in 2025.€/MWh

Source: Produced in-house¹²



¹² Based on Eurostat data for natural gas and the European Hydrogen Observatory (Cost of Hydrogen Production <https://observatory.clean-hydrogen.europa.eu/index.php/hydrogen-landscape/production-trade-and-cost/cost-hydrogen-production>), excluding transport and storage costs for hydrogen. For biomethane, McKinsey & Company (2024b).

¹³ See this summary of the latest available studies on the cost of green hydrogen on the BNEF website: <https://about.bnef.com/insights/clean-energy/liebreich-clean-hydrogens-missing-trillions>.



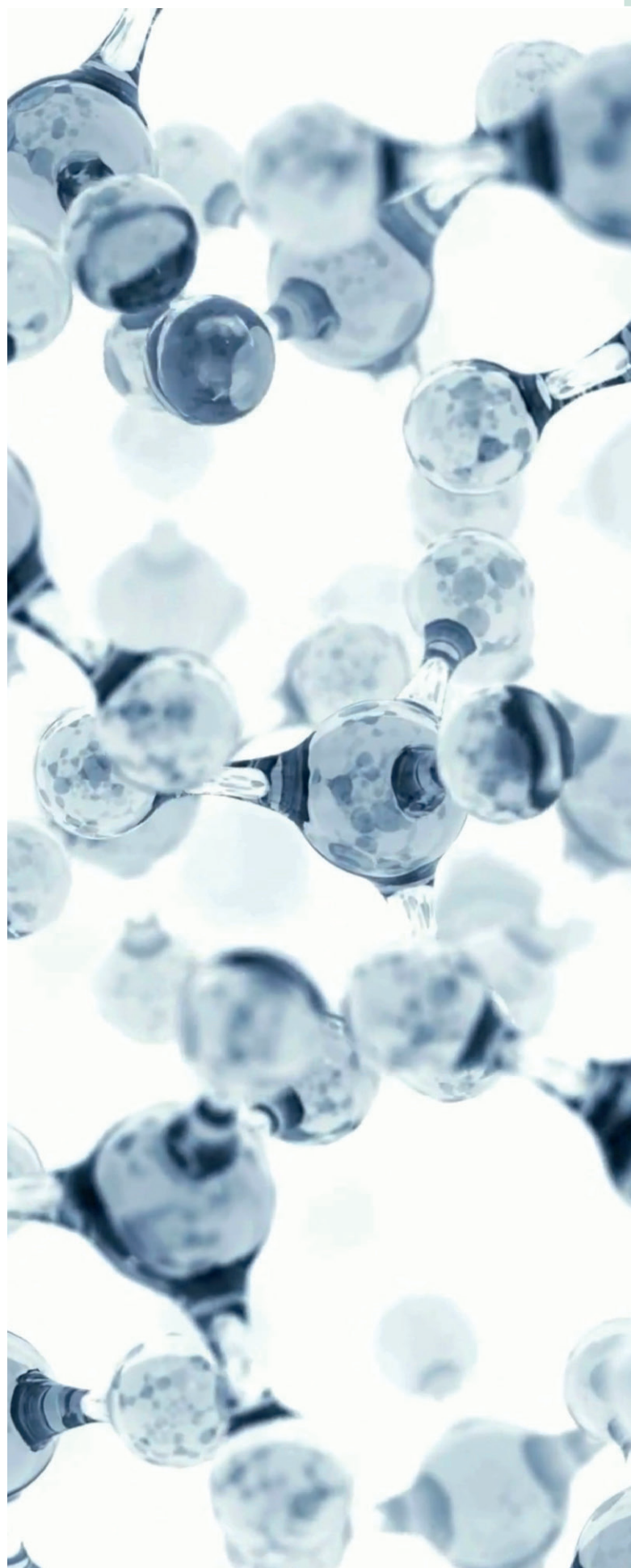
Nevertheless, according to the IEA, in the case of Europe—which developed its current production capacity at a time when demand could be met with low-cost imported natural gas—the combination of decarbonization targets and growing concern over the energy security risks posed by dependence on imported fossil gas is now leading the region to replace current production with domestic production based on renewable energy (IEA, p. 97).

4.2.3. Technological factors

Technological progress is key to scaling up production and enabling new applications. Alkaline and proton exchange membrane (PEM) electrolyzers have achieved significant improvements in efficiency and durability, whilst solid oxide electrolyzers (SOEC) show great potential in high-temperature industrial applications.

Furthermore, innovation extends across the entire value chain, from the transport of ammonia, methanol or organic liquid carriers, to storage in salt caverns or advanced materials for cryogenic tanks. Global trends in R&D point to an acceleration in technological innovation, with Europe, the United States, Japan and China playing a leading role, albeit with differing approaches in terms of sectoral specialization (Bal, 2025).

Technological standardization and cost reductions for electrolyzers are essential for the large-scale integration of renewable hydrogen into the energy system.





5. Analysis of European policy on green hydrogen

5.1. European policy

5.1.1. Strategic plans

The European Union's hydrogen policy forms part of the European Green Deal¹⁴, which sets the target of achieving climate neutrality by 2050. In this context, the European Hydrogen Strategy set a target of installing at least 40 GW of electrolysis capacity in the EU by 2030¹⁵. This plan was presented alongside the Energy System Integration Strategy (European Commission, 2020b) and led to the launch of the European Clean Hydrogen Alliance¹⁶, which acts as an industrial and investment coordination platform. Subsequently, the European Climate Law and the 'Fit for 55' legislative package reinforced these targets by linking them to a 55 per cent reduction in greenhouse gas emissions by 2030¹⁷.

The Russian invasion of Ukraine in 2022 marked a turning point: the REPowerEU¹⁸ plan identified renewable hydrogen as a key means of replacing Russian gas, increasing domestic production to 10 million tonnes and imports to 10 million tonnes. The 2023 update¹⁹ reaffirmed this commitment and introduced mechanisms to accelerate investment in industrial and infrastructure projects. In this context, Spain is emerging as one of the main beneficiaries, thanks to its potential in renewable energy and its strategic position as a *hub* for exports to the rest of Europe.

5.1.2. Regulation

The European regulatory framework has evolved rapidly to provide certainty regarding the production and use of hydrogen. The revisions to the Renewable Energy Directive of 2018 (RED II) and, in particular, 2023 (RED III) set binding targets for the use of hydrogen and renewable non-biological fuels (RFNBOs): at least 42 per cent of the hydrogen consumed in industry—rising to 60 per cent by 2035—and 1 per cent of energy consumption in transport by 2030 (European Parliament & Council of the European Union, 2023). To ensure sustainability, the Commission adopted two delegated acts in February 2023: Delegated Regulation (EU) 2023/1185 on the methodology for calculating greenhouse gas reductions from RFNBOs and recycled carbon fuels (RC Fuels), and Delegated Regulation (EU) 2023/1184 on the production conditions for RFNBOs.

The framework was strengthened in 2024 with the adoption of the new regulatory package on gas and hydrogen, Directive (EU) 2024/1788 (European Parliament & Council of the European Union, 2024a)²⁰ and Regulation (EU) 2024/1789 (European Parliament and Council of the European Union, 2024b)²¹, which lay down common rules for the internal markets and access to transport infrastructure.

14 European Commission. (2019). *The European Green Deal*. Publications Office of the European Union.

15 European Commission. (2020a). *A hydrogen strategy for a climate-neutral Europe (COM/2020/301 final)*, p. 2.

16 European Commission. (2020c). *European Clean Hydrogen Alliance*.

17 European Commission. (2021a). *'Fit for 55': Delivering the EU's 2030 climate target (COM/2021/550 final)*.

18 European Commission. (2022b). *REPowerEU plan (COM/2022/230 final)*.

19 European Commission. (2023a). *REPowerEU plan—Energy strategy*.

20 European Parliament & Council of the European Union (2024b). *Directive (EU) 2024/1787—Internal market for hydrogen*.

21 European Parliament & Council of the European Union (2024c). *Directive (EU) 2024/1788—Internal market for hydrogen*.



At the same time, the 2024 NZIA²² strengthens industrial policy instruments to support the manufacture of clean technologies in Europe, including electrolyzers and hydrogen value chains. Finally, in July 2025, a new delegated act was introduced setting out the methodology for calculating GHG emissions for different low-carbon hydrogen production pathways²³, thereby completing the regulatory framework.

5.1.3. Financial support

The European Union has mobilized a wide range of financial instruments to stimulate investment in renewable hydrogen. The *Hydrogen Public Funding Compass*²⁴ provides a comprehensive overview of the available programs, including the Innovation Fund and the European Commission's *Horizon Europe* funding streams.

Among the most notable mechanisms is the *European Hydrogen Bank*, which has been operating since 2023 as a mechanism to bridge the gap between production costs and market prices for renewable hydrogen through auctions. The first auction, which began in November 2023 and was concluded in April 2024, allocated 720 million euros to support 1.5 GW of electrolysis capacity, whilst the second²⁵, in February 2025, significantly increased the funding allocation. Furthermore, in March 2025, a specific mechanism was approved to support market development, aimed at long-term purchase and sale contract²⁶.

In addition to this, there are the Major Projects of Common European Interest (IPCEIs):

- * Hy2Tech, specializing in the development of hydrogen technologies
- * Hy2Use focuses on industrial applications
- * Hy2Infra focuses on infrastructure deployment
- * Hy2Move: a project focused on mobility.

According to the European Commission, these four IPCEI projects bring together 99 companies from 16 Member States and Norway, and receive state aid of up to 18,900 million euros, which is expected to mobilize more than 27,100 million euros in additional private investment²⁷.

Furthermore, the new Guidelines on State Aid for Climate, Environment and Energy (CEEAG) allow Member States to design national support schemes for hydrogen projects, subject to checks to ensure their compatibility with the internal market. Spain is already implementing these guidelines through programs that will be outlined in due course, thereby aligning its national strategies with the European framework.

²² European Parliament & Council of the European Union. (2024a). *Regulation (EU) 2024/1735 (Net-Zero Industry Act)*.

²³ European Commission. (2025a). *Delegated act—Methodology for low-carbon hydrogen*.

²⁴ European Commission. (2021b). *Hydrogen public funding compass*.

²⁵ European Commission. (2025b). *Second auction—European Hydrogen Bank*.

²⁶ European Commission. (2025c). *Market development mechanism—European Hydrogen Bank*.

²⁷ European Commission, *Approved IPCEIs in the Hydrogen value chain*.
https://competition-policy.ec.europa.eu/state-aid/ipcei/approved-ipceis/hydrogen-value-chain_en



5.2. Leading countries and best practices regarding green hydrogen in Europe

Germany

In 2020, Germany launched its National Hydrogen Strategy to set a clear course towards an import-based model with domestic production, prioritising supply to industry (steel, chemicals) and security of supply, and updated it in 2023²⁸.

Its key physical enabler is the *Hydrogen Core Network*: a backbone network regulated by *BNetzA* that will connect industrial hubs, storage facilities and import terminals, with commissioning scheduled to take place by 2032 and extensive reuse of existing gas pipelines (approved in 2024). The Ministry estimates that 9,700 km will be in service between 2025 and 2027 during the first phase, setting out a clear roadmap for investors. At the same time, Germany has established a mechanism to promote the hydrogen market, launching Carbon Contracts for Difference (*Klimaschutzverträge*) to create bankable industrial demand; the first round was launched in 2024.

To complete the 'supply-demand-logistics' triangle, Germany is rolling out *H₂Global*, a dual-auction mechanism for imports of *H₂* and its derivatives, with an increased budget for 2024–2025. In the maritime transport sector, the port of Wilhelmshaven is developing as a hydrogen hub with an ammonia terminal and 1GW of electrolysis capacity, whilst preparing for cracking and storage facilities linked to industrial corridors. All of this forms part of a target demand of 95–130 TWh of *H₂* by 2030, which guides the prioritization of uses and interconnections.

France

In 2020, France launched its *National Hydrogen Strategy* and updated it in April 2025²⁹ with realistic targets: up to 4.5 GW of electrolysis by 2030 and 8 GW by 2035 (recalibration of the pace of deployment and sectoral requirements).

The total public funding package for the hydrogen value chain (production, equipment, R&D) amounts to approximately €9,000 million, combining the new mechanism with France 2030 and the Important Projects of Common European Interest (IPCEI). The centerpiece is a mechanism to support buying and selling. This mechanism will guarantee a maximum purchase price for green *H₂* for

15 years, offsetting the difference with gray *H₂*, thereby removing any uncertainty for investors who may wish to finance long-term projects. It has a budget of €4,000 million, with the first calls for proposals launched in December 2024 for plants with a capacity of 5–100 MW. The policy is being implemented in industrial hubs (Fos-sur-Mer, Dunkirk, Le Havre–Seine Estuary, Vallée de la Chimie), prioritising the decarbonization of the refining, chemical and steel industries, whilst at the same time promoting local employment.

The French plan assumes a cautious growth in international trade: up to 2030, it envisages few import pilot schemes, focusing efforts on domestic supply and established industrial uses. In addition, transport and equipment (fuel-cell vans, fuel cells and tanks) are being bolstered with specific support measures.

In short, this plan combines quantified and credible targets, a long-term production contract backed by a robust budget, and a regional approach, linking aid, manufacturing and industrial demand in specific hubs.

Denmark

The Danish hydrogen³⁰ and Power-to-X strategy, set out in the *Danish Power-to-X Strategy* published by the Ministry of Climate, Energy and Supply, sets clear and quantified targets of between 4 and 6 GW of electrolysis capacity by 2030, fully in line with electricity planning and the development of offshore wind energy. In addition, it uses a targeted support mechanism, the Power-to-X (PtX) auction, with a budget of 1.25 billion Danish kroner, which facilitates investment in various green hydrogen technologies. This instrument is designed for industrial-scale production.

From the outset, the country has put in place the necessary infrastructure by mandating Energinet, the operator of Denmark's national electricity and natural gas transmission system, to develop hydrogen networks and storage systems. It also integrates the Power-to-X system using location criteria that optimize the electricity grid, operational flexibility and cross-sector integration between electricity, hydrogen, heat and *CO₂*.

²⁸ The German Government. BMWK (2023). *National hydrogen strategy—Update 2023*.

²⁹ French Government. (2020). *National Strategy for the Development of Low-Carbon Hydrogen in France*.

³⁰ Government of the Netherlands. (2022). *Hydrogen strategy—The Netherlands*.



Denmark maintains a dynamic governance framework, with annual updates (*Analyseforudsætningerne*) that guide public-private decisions. A national technology catalogue is also published, setting out the costs and specifications of electrolyzers, which is used as a reference for defining the criteria for financial support and *due diligence processes*.

Finally, the country coordinates the production of hydrogen and its derivatives, such as e-kerosene, ammonia and methanol, in synergy with offshore wind power generation, targeting sectors where decarbonization is particularly challenging. It also establishes the neutrality of the energy transmission network and prepares for European interconnections through the TEN-E and CEF programs, thereby paving the way for exports once the market matures

Netherlands

The Dutch hydrogen strategy, set out in the *Hydrogen Strategy for the Netherlands* (Ministry of Economic Affairs and Climate Policy, 2020)³¹ and regularly updated through letters to Parliament (*Kamerbrieven*), is characterized by a 'living' and transparent policy. The Government reports regularly on progress and adjustments relating to hydrogen quality, storage and regional infrastructure, reflecting remarkable regulatory agility and adaptability.

The approach is based on a "carrier-agnostic" strategy, which keeps various technological pathways open, such as ammonia, Liquid Organic Hydrogen Carriers (LOHC) and methanol, and applies a multi-criteria analysis to determine how to allocate public funding up to 2035, thereby avoiding premature technological lock-in.

From a technological perspective, the country has made substantial preparations for RFNBO certification, through pilot projects in cooperation with third countries, such as Australia, and the publication of practical guidelines for businesses, thereby strengthening its capacity to comply ahead of the entry into force of the European requirements. It also has a roadmap for offshore hydrogen, structured around phased demonstration projects: Demo-1 category (20–50 MW) and Demo-2 category (approximately 500 MW), accompanied by public consultations and environmental studies designed to mitigate risks prior to large-scale deployment.

The framework also provides for the reuse of the existing natural gas network, establishing a national backbone network of around 1,200 km, managed by HyNetwork/ Gasunie, with a phased roll-out and revisable plans to ensure an operational distribution system. At the same time, an import hub has been developed in Rotterdam, equipped to handle hydrogen derivatives such as ammonia, and their re-export to other Member States, using the logistics infrastructure as a lever for international competitiveness.

Regulatory alignment with the Renewable Energy Directive (RED III) and European standards on RFNBO is reinforced through a one-stop shop and European certification criteria, which provide traceability and financial certainty for investments. Finally, financial planning is underpinned by evidence-based analysis, including reviews by the International Energy Agency (IEA), to prioritize the most efficient uses of hydrogen, such as steel produced by direct reduction (DRI) or heavy goods transport, and to align demand with infrastructure development.

Table 4. Overview of H2 production projects in EU countries³²

Country	Projects in operation (>0.5 MW)	Projects under construction	2030 electrolyzer capacity target	Subsequent milestones	2050 target
Denmark	(>0.5 MW)	5	Subsequent milestones	2050 Target	Climate neutrality
Germany	5	19	10 GW / Demand 95–130 TWh H ₂		Climate neutrality
France	4–6 GW	9	4.5 GW	2035: 8 GW	Climate neutrality
Netherlands	5	5	4 GW		Climate neutrality
Spain	4	6	12 GW		Climate neutrality

³¹ Government of the Netherlands (2022). *Hydrogen strategy—The Netherlands*.

³² Compiled by the author based on data from the *European Hydrogen Observatory website*.



5.3. Cross-border projects

5.3.1. European Hydrogen Backbone

The European Hydrogen Backbone (EHB) is an initiative launched in 2020 by a consortium of European gas infrastructure operators (TSOs), whose aim is to design and develop a pan-European backbone network for the transport of hydrogen (Amber Grid et al., 2022, p. 3). The current vision envisages around 53,000 km across some 28 countries³³ by 2040, with approximately 60–70 per cent of the pipelines reused from the existing gas network (European Hydrogen Backbone, 2022).

The EHB's strategy is based on phases: first, regional corridors and bilateral projects, which will subsequently be interconnected to form a continental network. Among the most notable corridors are:

- * **Iberian–France–Northern Europe Corridor:** connects the Iberian Peninsula—which has significant export potential thanks to its renewable resources and future projects at ports such as Bilbao, Valencia and Huelva—with France and the rest of the continent. It includes projects such as **H₂Med/BarMar**, which envisages an undersea gas pipeline between Barcelona and Marseille and its extension into Central Europe.
- * **North Sea Corridor:** integrates hydrogen production in the Netherlands, Germany, Belgium and Denmark, making use of the large *offshore* wind farms. It is set to become one of the main hubs of the future network, as it is home to both power generation facilities and major industrial consumers.
- * **Baltic–Central Europe Corridor:** connects the Baltic states and Poland with Germany and the main centers of demand in Central Europe, strengthening security of supply in the region and facilitating the transmission of wind and renewable energy from the Baltic region.
- * **Nordic Corridor:** links transport from the Scandinavian countries, particularly Norway and Sweden (which have significant hydroelectric and wind power potential), to Central Europe, connecting with the major industrial valleys.
- * **Links to external imports:** These include links from strategic ports such as Rotterdam, Hamburg, Trieste and Taranto, as well as future connections with North Africa, which could be established via Spain or Italy,

in line with the Mediterranean corridors and import routes identified in REPowerEU.

5.3.2. Iberian corridors

The Iberian Peninsula is a strategic hub in the future pan-European hydrogen network, both because of its high potential for renewable energy generation—solar and wind, onshore and *offshore*—and because of its prime geographical location between Europe and North Africa. In this context, two key corridors stand out as they consolidate their role in the European and intercontinental hydrogen market.

The first is *H₂Med*³⁴, which is the first major green hydrogen interconnection project on a European scale. It comprises two main sections: *BarMar*, an underwater gas pipeline linking Barcelona with Marseille, and *CelZa*, the onshore interconnector between Celorico da Beira (Portugal) and Zamora (Spain). The project, spearheaded by the transmission system operators Enagás, NaTran, OGE, REN and Teréga, has been recognized by the European Commission as a Project of Common Interest (PCI) and is expected to be operational by 2032, with an estimated initial capacity of 2 million tonnes of hydrogen per year.

The second priority area is the connection *with North Africa*, which is envisaged in the EHB as a potential future extension of the backbone network. These branches could be developed using existing gas pipelines or through new subsea infrastructure, enabling the import of green hydrogen produced on a large scale in Morocco, Algeria or other Maghreb countries. This region enjoys a strong cost-competitive edge due to its high levels of solar radiation and wind potential, which is giving it an increasingly important role as a strategic supplier. Under this scheme, Spain, through its Mediterranean and Atlantic ports, is positioned as the natural gateway for African hydrogen into the rest of Europe.

Overall, the *H₂Med* project consolidates the Iberian Peninsula's position as an intra-European exporter, whilst the North African corridor reinforces Spain's role as an intercontinental hub for renewable hydrogen within the architecture of the *European Hydrogen Backbone*.

³³ 25 EU countries plus Norway, Switzerland and the United Kingdom.

³⁴ See the H2Med website: <https://h2medproject.com/es/el-proyecto-h2med>



6. National analysis and the energy dimension of green hydrogen in Spain

6.1. National Strategic Framework

The starting point for Spanish policy on renewable hydrogen is the *Hydrogen Roadmap: a commitment to renewable hydrogen* (MITECO, 2020b, p. (15–17), the first policy document to set quantified targets: to install 4 GW of electrolyzers by 2030 and to replace at least 25 per cent of the hydrogen used in industry, alongside complementary targets for transport and infrastructure. This roadmap forms part of the Long-Term Decarbonization Strategy (MITECO, 2020a)(ELP 2050), which sets out Spain's climate neutrality target for 2050.

The review of the *Integrated National Energy and Climate Plan* (PNIEC 2023–2030) (MITECO, 2024, p. (170.172), the initial version of which dates from 2021, was presented in 2023 and submitted to the European Commission in 2024; it raises the targets to 12 GW of electrolysis capacity by 2030. This increase places Spain amongst the most ambitious countries within the REPowerEU framework, aligning its strategy with the NZIA (2024), which promotes the domestic production of clean technologies.

Previously, the 2020 Roadmap had promoted the creation of regional hydrogen valleys and clusters, an initiative included in the PERTE ERHA programs and in Spain's participation in the Hy2Tech, Hy2Use and Hy2Move IPCEI projects³⁵. These instruments channel public-private investment and shape the regional roll-out of hydrogen in Spain.

Support from national bodies such as the IDAE and the ICO, together with regional incentives, is helping to foster the creation of specialized industrial clusters (Andalusia, Aragon, Catalonia, Castile and León, Castile-La Mancha, the Basque Country, amongst others).

In summary, the national strategic framework for hydrogen has four complementary objectives:

- 01** Replace existing gray hydrogen, thereby reducing emissions in energy-intensive sectors.
- 02** To develop a national industrial value chain in hydrogen technologies and electrolyzers.
- 03** To position Spain as a net exporter of renewable energy and green hydrogen within the European market.
- 04** To drive innovation, knowledge and technological capacity-building by promoting R&D&I, specialized training and pilot projects that will reduce costs, improve efficiency and consolidate a national innovation ecosystem for renewable hydrogen.

This framework lays the foundations for the quantitative and territorial analysis that follows, focusing on the regional distribution of demand, production capacity and the integration of hydrogen into the Spanish energy system.

³⁵ See all the information on the IDAE website:

Hy2Tech: <https://sede.idae.gob.es/tramites-servicios/proyectos-es-hy2tech-concesion-directa-de-subsuenciones-los-proyectos-espanoles>

Hy2Use: <https://www.idae.es/ayudas-y-financiacion/programa-ipcei-hy2/programa-piice-hy2use>

Hy2Move: <https://www.idae.es/ayudas-y-financiacion/programa-ipcei-hy2/programa-piice-hy2move>



6.2. National regulatory framework

The Climate Change and Energy Transition Act, passed in 2021, provides the legal framework for achieving climate neutrality in Spain by 2050 and for guiding decarbonization policies across all economic sectors. Although the law does not set specific targets for renewable hydrogen, it does lay the foundations for its development and provides the necessary legal framework to support sectoral initiatives such as the Hydrogen Roadmap.

Its impact on the roll-out of hydrogen is therefore indirect but crucial.

The Act establishes the electrification of the energy system as the main route to decarbonization and mandates the Government to promote hydrogen. Furthermore, by incorporating the principles of European climate policy, the legislation ensures consistency with the EU framework, thereby strengthening Spain's position in the transition to a low-carbon economy.

Royal Decree 376/2022 of 17 May partially transposes Directive (EU) 2018/2001 (RED II) with regard to the promotion of energy from renewable sources in the transport sector and the establishment of a system of guarantees of origin for renewable gases, including biomethane and hydrogen. The regulation sets out the sustainability and greenhouse gas emission reduction criteria that biofuels, biogas and other renewable fuels must meet, and establishes the national certification and traceability framework for their accreditation by the European Union. The Royal Decree thus contributes to the recognition of renewable hydrogen as a sustainable energy carrier, complementing the financial support mechanisms established through the PERTE ERHA and the funding schemes managed by the IDAE.

The European framework, centered on Directive (EU) 2023/2413—which revises Directive 2018/2001 and is known as RED III—reinforces the treatment of hydrogen as a renewable non-biological fuel (RFNBO) and, for the first time, sets binding targets for these fuels, requiring Member States to ensure minimum shares of RFNBO in energy consumption in transport and in the use of hydrogen in industry.

Spain has transposed RED II, on which the current regulations governing renewable hydrogen are based, and is actively working on the implementation and legislative development of RED III. In particular, the national system of guarantees of origin for renewable gases was established by Royal Decree 376/2022 and set out in Order TED/1026/2022, the management of which falls to the Technical Manager of the gas system. These instruments are in line with the regulations on self-consumption set out in Royal Decree 244/2019, which allows for the direct supply of renewable electricity to facilities such as electrolysis plants. Furthermore, Royal Decree-Law 18/2022 introduces measures to streamline administrative procedures and promote renewable gases which, although not aimed exclusively at hydrogen, help to speed up the processing of projects relating to its production and use.

At present, the transposition in Spain of the European gas and hydrogen package is at an early stage. Regulation 2024/1789, which is directly applicable, already establishes the new common framework for the internal markets in natural gas and hydrogen, whilst Directive 2024/1788—which requires its transposition into national law by 5 August 2026—has not yet been transposed. The Government has begun preparatory work to amend Spanish legislation, in particular Law 34/1998 on the Hydrocarbons Sector and other related regulations, with a view to incorporating aspects such as access to networks, the regulation of specific hydrogen infrastructure and the definition of system operators.

Between September and October 2024, the Ministry for Ecological Transition and the Demographic Challenge conducted a preliminary public consultation on the transposition of the new European framework on gas and hydrogen into Spanish law. Once this phase is complete, the Government will have to submit a preliminary draft for public consultation.

Furthermore, the National Commission for Markets and Competition (CNMC) plays a central role in the economic and regulatory aspects of hydrogen deployment, by setting the methodologies for tolls and remuneration for gas infrastructure and overseeing access to the networks. The national system of guarantees of origin for renewable gases, including hydrogen, is governed by Royal Decree 376/2022 and Order TED/1026/2022, which designate the Technical Manager of the Gas System as the body responsible for the system of guarantees of origin for gas



from renewable sources, whilst the CNMC retains its powers over guarantees of origin for renewable electricity. Furthermore, under Royal Decree-Law 8/2023, Enagás has been appointed provisional operator of the Hydrogen Backbone Network (*Spanish Hydrogen Backbone*).

With regard to tariffs, the methodologies for tolls and charges relating to the transmission, distribution, regasification and storage of natural gas are set out in Circular 6/2020 and other circulars issued by the CNMC, and subsequent resolutions apply these methodologies to determine the specific toll rates. This economic framework will form the basis for future adjustments to the regulation of access to and pricing of hydrogen infrastructure, within the context of the European decarbonized gas and hydrogen package.

6.3. A regional framework for green hydrogen

At regional level, the autonomous communities exercise key powers in the areas of spatial planning, energy, industry and the environment, which makes their legislation and planning a crucial component of the regulatory framework.

For example, several autonomous communities have adopted their own green hydrogen strategies or regional energy transition plans:

- * Andalusia, with its *Hydrogen Roadmap* (2024), drawn up within the framework of the Andalusian Green Hydrogen Alliance.
- * Aragón, a pioneer through the Aragón Hydrogen Foundation (since 2003), serves as a national benchmark in testing, standardization and technical support (Government of Aragón, 2023).
- * The Basque Country, through its *Basque Hydrogen Strategy* (EVE, 2022), brings together industrial, port and mobility projects.
- * Castilla-La Mancha and Extremadura have incorporated hydrogen into their sustainable mobility plans and provide financial support for hydrogen projects (Regional Government of Castilla-La Mancha, 2022; Regional Ministry for Ecological Transition and Sustainability of Extremadura, 2023).

These regional initiatives, which complement national legislation, define industrial land zones, fast-track licensing procedures and specific grants, creating a regulatory patchwork that determines where and how projects are rolled out.

Broadly speaking, hydrogen governance in Spain is based on the principles of subsidiarity and multi-level coordination: the EU sets out the framework legislation; the central government establishes the basic rules and traceability requirements and coordinates the system; and the autonomous communities carry out industrial planning and promotion, with support from local councils on licensing and land use. This multi-level balance has enabled Spain to bring together hundreds of hydrogen initiatives: at least 361 projects identified in the 2024 AeH₂ Census (TRL≥3) and more than 500 initiatives linked to the H₂Med corridor reported by around 170 companies in 2025, in addition to the seven hydrogen clusters awarded by MITECO (≈2.3 GW of electrolysis capacity).





6.4. Funding and public support schemes

Funding for renewable hydrogen in Spain is based on a combination of European, national and regional program, which mobilize public-private investment across the entire value chain: production, storage, transport and end use.

The European Union channels its support primarily through the Recovery and Resilience Facility (Next Generation EU) and the Important Projects of Common European Interest (IPCEI) in hydrogen, which act as framework instruments for State aid authorized by the Commission (IDAE, 2024a, p.6). Spain is participating in both programs through the IPCEI Hy2Tech (electrolyzer technologies and components) and the IPCEI Hy2Use (industrial applications)³⁶.

At national level, the Recovery, Transformation and Resilience Plan (PRTR) includes a specific component, Component 9, 'Roadmap for Renewable Hydrogen and its Integration into Different Sectors', aimed at promoting the production and use of green hydrogen. This priority is being implemented through the Strategic Project for the Economic Recovery and Transformation of Renewable Energy, Renewable Hydrogen and Energy Storage (PERTE ERHA), approved by the Council of Ministers in December 2021 (MITECO, n.d.-a). Under the PERTE ERHA program, which provides for a total investment of over 16,300 M€ (6,900 M€ in public investment and around 9,500 M€ in private investment), the renewable hydrogen program has a public budget of €1,555 million and is set to mobilize around €2,800 million in private investment (MITECO, 2020a).

At the regional level, several regions have launched additional calls for proposals for hydrogen projects, financed by ERDF or regional funds:

- * Andalusia (Andalusian Energy Agency, 2023): €70 million for production and mobility projects (IDAE, 2022 & IDAE, 2023).
- * Aragón (Aragonese Institute for Economic Development): guarantee schemes and soft loans administered by Sodiar.
- * Basque Country → *Hazitek* program for industrial R&D³⁷.

6.5. An overview of the sector: capabilities and resources

Spain boasts a unique combination of natural resources, industrial capabilities and technological infrastructure, which places it amongst the European countries best positioned to develop a green hydrogen economy.

From an energy perspective, the 2023–2030 Integrated National Energy and Climate Plan (PNIEC) aims to reach 160 GW of installed renewable electricity capacity by 2030, of which 76 GW will come from solar photovoltaics, 62 GW from wind power, and 22.5 GW from energy storage (MITECO, 2024).

This availability, combined with one of the highest levels of solar radiation in Europe (1,800–2,200 hours per year) and a wind capacity factor of over 25 per cent across large areas of the north and the Ebro Valley, guarantees a competitive and continuous supply of renewable electricity to power, among other things, electrolysis³⁸.

In the industrial sector, Spain has companies that assemble electrolysis systems and manufacture essential balance-of-plant (BoP) components—such as valves, compressors, pressure vessels, heat exchangers and power electronics—which are part of IPCEI projects *Hy2Tech* and *PERTE ERHA*. Although the full-scale manufacture of stacks for electrolyzers is still limited, there are projects underway aimed at developing industrial assembly and production capacity by 2030. The National Hydrogen Centre (CNH₂) and the Aragón Hydrogen Foundation are coordinating several R&D programs to validate PEM and AEM technologies at laboratory and pilot scale (AeH2, 2024) (MITECO, n.d.-a).

Spain also has a versatile and partially adaptable energy infrastructure. The national gas network, comprising more than 11,000 km of gas pipelines and six regasification terminals (Amber Grid et al., 2022), can be partially converted to transport gas blends or pure hydrogen, according to studies by the EHB (2024). Furthermore, the ports of Huelva, Bilbao, Cartagena and Valencia have begun construction of infrastructure for the bunkering and export of hydrogen and its derivatives, thereby becoming part of the H₂Med project's logistics network (Enagás, n.d.).

³⁶ Beyond the industrial sector, Spain is also participating in the Hy2Move IPCEI (mobility).

³⁷ See <https://www.spri.eus/es/ayudas/hazitek>

³⁸ Factor de capacidad eólico basado en <https://wemakeconsultores.com/eolica-y-solar-en-espana-resumen-del-2025>



In the field of science and technology, Spain has a well-established network of research and demonstration centers, such as the National Hydrogen Centre (CNH₂), a national leader in applied R&D and safety, Tecnalia and the *Aragón Hydrogen Foundation*, which specialize in system validation, and *research groups at the CSIC, CIEMAT, the University of Zaragoza and the University of Cantabria, which focus on materials, catalysts and energy management.*

These technical capabilities and areas of expertise are underpinned by a rapidly expanding business ecosystem: the Spanish Hydrogen Association (AeH₂) now brings together more than 370 companies and organizations³⁹.

Overall, Spain combines abundant renewable resources, a diversified industry, an adaptable energy infrastructure and a solid scientific base, placing it in a structurally advantageous position to scale up the production, consumption and export of green hydrogen.



6.6. The territorial and energy dimensions of industrial decarbonization in Spain

6.6.1. National outlook for industrial hydrogen demand by 2030

Domestic hydrogen consumption in Spain currently stands at almost 0.5 million tonnes per year, almost all of which is gray hydrogen, produced by reforming natural gas and used mainly in the refining, fertilizer and basic chemicals sectors (Cossent et al., 2025, p.12).

The 2023–2030 Integrated National Energy and Climate Plan (PNIEC) envisages a structural shift in this trend: the installation of 12 GW of electrolysis capacity by 2030 (MITECO, 2024, p. 172–174)⁴⁰. This volume would make it possible to replace virtually all the fossil hydrogen currently consumed and to meet a new, emerging industrial demand arising from the decarbonization of sectors such as steel, synthetic fuels and heavy transport.

By adding together the production figures for all the projects awarded under the H₂ Valles plan, and having thus exceeded the minimum feasibility criteria⁴¹ for receiving public funding, a total production capacity of almost 270,000 tonnes of H₂ per year is achieved by 2030, as shown in **Table 5**. In addition, it adds around 2,292.8 MW of electrolysis capacity, ensures that at least 60 per cent of the H₂ produced is consumed locally, and integrates associated renewables, storage and the synthesis of derivatives (e-fuels, ammonia, SAF), thereby consolidating complete industrial ecosystems.

³⁹ This information can be found on the AEH website: <https://aeh2.org/en/the-aeh2>

⁴⁰ Although there are international estimates for 2050 (for example, IEA, 2024a), Spain does not have official projections broken down by industrial sector or clear long-term estimates. Consequently, no quantitative projections are presented for 2050, and the analysis is limited to current figures and regulatory targets up to 2030.

⁴¹ The criteria set out in the call for proposals established minimum requirements regarding the maturity of the project, availability of land, a power purchase agreement (PPA) or an identified buyer, environmental authorization procedures already underway, direct industrial impact, or the degree of integration into the value chain.

**Table 5.** Hydrogen production from the projects awarded under the H2 Valles scheme⁴²

Region / territorial area	Expected production (thousands of Ton H ₂ / year, 2030)	Key sectors
Andalusia (Onuba)	53.8	Refining, ammonia and synthetic fuels (Moeve, Fertiberia, EDP, Yara)
Galicia (A Coruña–Ferrol)	29.9	Refining, methanol and port fuels (Reganosa, EDP, Forestal del Atlántico)
The Ebro Corridor (Aragon and Catalonia)	95.5	Petrochemicals, fertilizers and exports (Catalina, HyBERUS, T-HYNET)
Castile and León (Compostilla Green, Valle Leonés)	89.9	Logistics, transport, e-fuels

6.6.2. Replacing fossil fuels in industry: gray hydrogen and natural gas

Industrial decarbonization in Spain requires not only replacing the gray hydrogen currently used in chemical processes, but also reducing the overall reliance on natural gas and other fossil fuels in industrial thermal processes. Green hydrogen, together with direct electrification, forms the cornerstone of this energy transition, covering temperature ranges and applications where electric technologies are not competitive.

Current structure of industrial energy consumption

According to figures from Enagás, total natural gas consumption in Spain in 2024 reached 311.9 TWh, of which 237.1 TWh was conventional consumption (households, commerce and industry). Within this group, industrial use of natural gas accounts for approximately 70 per cent of the total, that is, 176.8 TWh/year (Enagás, 2024, p. 7).

Furthermore, Spanish industry continues to use around 29 TWh of coal and fuel oil annually (IDAE, 2024a, p.77), and nearly 0.5 million tonnes of gray hydrogen (≈17 TWh)⁴³, used mainly in refining, fertilizer production and basic chemicals.

Taken together, these fossil fuel sources (gas, fuel oil, coal and gray H₂) generate more than 80 Mt of CO₂ annually, equivalent to around 30 per cent of the country's total emissions (MITECO, 2025).

Levels of technological substitution

The potential for substitution depends on the process temperature and the type of technology available (see Chapter 3). The following table summarizes the technological options by temperature range and provides comments on their economic viability.

⁴² These figures exclude other projects mentioned above, as they had not yet met the minimum criteria for institutional financial support at the time of the call for proposals, and are based on the projected annual hydrogen production figures officially stated in Annex II of the ministerial resolution via the IDAE (2025b). It cannot be ruled out that additional projects may be added to this capacity in future calls for proposals, once they meet the requirements, or if they are funded from purely private sources. For the purposes of this forecast, it is assumed that all these projects will be fully operational by 2030, operating at their design production levels. These figures therefore represent potential supply capacity, rather than an estimate of actual demand, which will depend on other factors, chief among them economic competitiveness compared with fossil hydrogen.

⁴³ Source: <https://www.miteco.gob.es/es/energia/hidrocarburos-nuevos-combustibles/hidrogeno.html>

**Table 6.** Temperature range and efficiency of process heat supply processes

Temperature range	Typical process	Principal substitution vector	Expected efficiency	Technical commentary / barriers
<200 °C (low temperature)	Drying, fermentation, pasteurization, industrial climate control	Direct electrification (heat pumps, heating elements)	150–600 % (COP 3–6)	Cost-effective to replace; does not require hydrogen.
200–500 °C (average temperature)	Textiles, food, paper, light chemicals	Direct electrification or H ₂ /gas blend	90–120 %	The cost of electricity may limit its roll-out; H ₂ is useful as a backup.
>500 °C (high temperature)	Metallurgy, cement, glass, ceramics	Green hydrogen or an H ₂ /methane blend	50–70 %	Few electric alternatives; ovens and burners need to be adapted.

Note: Compiled by the author based on IDAE (2025a) and Agora Industry (2024).

Stages in the timeline of technological replacement

In light of the points set out in the previous chapters, the following scenarios can be envisaged for the integration of green hydrogen into the market up to 2050:

* Phase I (2025–2030): Replacing gray hydrogen.

The gradual replacement of fossil hydrogen with green hydrogen in refining, basic chemicals, fertilizers and heavy goods transport, through the projects awarded under the PERTE ERHA and the Renewable Hydrogen Valleys program.

* Phase II (2030–2040): Partial substitution of natural gas in thermal processes.

Introduction of hydrogen in cement works, ceramics, light metallurgy and as a blend in gas networks (H₂ ≤ 20%). It requires the replacement of burners, valves and control systems.

* Phase III (2040–2050): Structural substitution of fossil fuels.

Widespread use of H₂ in steel production (DRI steel), clinkerization and high-temperature processes, complementing electrification and seasonal storage. Export of surplus production, such as e-fuels and green ammonia.

Growth in demand will depend on the cost parity between domestically produced renewable hydrogen and imported hydrogen. With falling electricity costs and high renewable energy penetration, Spain could allocate part of its electricity production for export by 2050, acting as an energy *hub* for south-western Europe.

6.6.3 Domestic production and renewable energy requirements

The development of a green hydrogen economy in Spain depends directly on the availability of competitive and abundant renewable electricity. The PNIEC 2023–2030 sets a target of installing 12 GW of electrolyzers by 2030 (MITECO, 2024, p. (522–523), with a potential output of 1.7 million tonnes of renewable hydrogen per year (≈56.6 TWh)⁴⁴.

Alignment with the national renewable energy expansion

Spain's electrolysis strategy is underpinned by the rapid expansion of renewable energy, which by 2024 had already exceeded 80 GW of installed capacity (Red Eléctrica de España, 2024, p. 6), with the PNIEC forecasting a total of 165 GW by 2030 (103 GW from solar and 62 GW from wind) (MITECO, 2024, p. 29). This will make it possible to simultaneously drive the growth of direct electrification and the development of hydrogen production without compromising security of supply.

44 Converted to TWh using an energy equivalence value of 33.3 kWh/kg of H₂ (Hydrogen Technology Observatory, 2025).



Although European legislation requires hydrogen projects to be accompanied by their own renewable energy, green hydrogen could act as a flexibility mechanism for the electricity system, absorbing surplus renewable energy during periods of low demand and reducing curtailment. In its forward-looking studies, Red Eléctrica Española warns that solar and wind power output will be significant by that time, and may well be sufficient to maintain the stable operation of that electrolysis capacity.

Renewable sources and technological breakdown

Table 7. Contribution of different technologies to renewable energy generation (MITECO, 2024, p. 511)

Associated renewable source	Estimated participation in 2030	Comments
Solar photovoltaic	51 %	Primary source in terms of cost and geographical availability.
Onshore and offshore wind power	39 %	Base load and night-time generation; floating offshore wind expanding.
Hydropower and biomass	10 %	Supplementary contribution and grid support.

Overall energy balance

Spain has the most competitive solar and wind resources in Europe, putting it in an advantageous position to produce green hydrogen at costs competitive with gray hydrogen by 2030. The coordinated growth of renewables, storage and electrolysis would make it possible to maintain grid stability, reduce curtailment and establish the country as a net exporter of hydrogen and synthetic derivatives.

6.6.4. Hydrogen corridors and export capacity

Spain is establishing itself as the main southern hub of the European hydrogen system, thanks to its high renewable energy capacity, its geographical location and its gas network, which can be partially repurposed.

The national strategy combines three complementary levels: internal industrial integration corridors, cross-border transport infrastructure and export capacity to Central Europe, organized around the H₂Med project and the European Hydrogen Backbone (EHB) framework (MITECO, 2024, p. 172–175) (Amber Grid et al., 2022, p. 9–13).

National corridors: territorial integration

Taking into account the projects funded under the PERTE ERHA and other initiatives (European, regional, private)⁴⁵, a coherent territorial network is being established in Spain, centered on three main axes of territorial coordination and featuring strong export-oriented and integration components within the H₂Med network:

01 Northern Atlantic Corridor—Connecting Galicia, Asturias, Castile and León and the Basque Country, bringing together the projects of the *A Coruña Hydrogen Valley*, *Asturias H₂ Valley*, *Compostilla Green*, *Valle Leonés* and the *Basque BH₂C Corridor*

- * Main uses: green steel, refining, methanol and bunkering at ports.
- * Potential link with France (Bayonne–Lacq) via the future northern interconnector.

02 Southern-Mediterranean Corridor—It links Andalusia, Murcia, the Valencian Community and Catalonia, and forms the country's export hub.

- * It includes the valleys of Huelva, Algeciras, Escombreras, Castellón and Tarragona.
- * Directly linked to the H₂Med (BarMar) gas pipeline.

⁴⁵ See the map below: <https://app.powerbi.com/view?r=eyJrIjoib2QwOGZmOTAtNzRhYS00NmQ0LTlkMDItNjlmZD-NmZjZhMDU3IiwidCI6ImJjZDI3MDFjLWFiOWItNGQxMitiYTiwLWYzZTNIODMwNzBjMSIsImMiOjh9>



03 Central / Ebro Corridor—It encompasses Aragon, Navarre and Castile-La Mancha, acting as the backbone linking the North Atlantic and South-Mediterranean corridors.

- * Links to the Catalina, HyBERUS and GetHyGA projects, and the H₂Med link with BarMar (Spain–France) and CelZa (Portugal–Spain).

Overall, and according to various scenarios (McKinsey & Company, 2024a, p. (6) These national corridors would ensure a meshed network for local transport and consumption, with a volume of green hydrogen of 1.1 million tonnes per year by 2030, of which at least 200,000 tonnes could be destined for export⁴⁶. These industrial valleys and clusters form a balanced regional infrastructure, with projects present in all the country's major industrial regions, thereby reinforcing Spain's role as a future European *hub* for the production and export of green hydrogen.

Transport and storage infrastructure

Spain has a mature gas network which, although the extent to which it can be adapted is a matter of debate, is partially reusable for hydrogen⁴⁷. According to Enagás, existing gas pipelines could be adapted to transport H₂, with an estimated investment of €4,000–6,000 million and a phased roll-out between 2028 and 2040 (Enagás, 2025). In addition, plans are in place to construct a further 1,000 km of new track, intended for the Atlantic and Mediterranean corridors⁴⁸.

The main supporting elements are:

- * Underground storage facilities: Serrablo (Huesca), Yela (Guadalajara) and the Yela II project, adapted for hydrogen and ammonia.
- * Port terminals: Algeciras, Huelva, Cartagena, Castellón, Tarragona and Bilbao, with the capacity to export liquid H₂, ammonia and e-methanol.
- * Compression plants and logistics *hubs*: Getafe, Zaragoza, Puertollano and Tarragona, connected to the electricity and rail networks (Mediterranean Corridor).

Integration with the energy system

Interconnecting the gas and electricity networks would make it possible to synchronize hydrogen production with renewable energy generation, making use of surplus solar and wind energy during off-peak hours and contributing to the flexibility of the national electricity system. Hydrogen would thus serve as a means of seasonal storage and as a mechanism for balancing renewable supply and demand across the Iberian Peninsula.

With the projects currently planned, Spain could have a fully integrated hydrogen infrastructure in place by 2032, capable of meeting domestic industrial demand, supplying the H₂Med and EHB transnational corridors, and, based on the latest updates, to export around 2 million tonnes per year of green hydrogen to the rest of Europe⁴⁹.

The combination of competitive renewable energy sources, a partially reusable gas network and its geostrategic position therefore positions the country as an energy *hub* for south-western Europe and a key player in the European Union's security of supply.

46 Under the 'current trajectory' scenario, 0.6 million tonnes of gray H₂ are produced per year in Spain, and this figure rises to 1.5 million under the aspirational scenario.

47 Some stakeholders believe that the Spanish gas network, which was designed for natural gas, does not meet the technological requirements of hydrogen, and that if *blending* is carried out using gases that are, by definition, non-renewable, the resulting mixture will not be renewable, which would not facilitate the energy transition. Like the Fundación Renovables, they are committed to prioritizing on-site hydrogen production.

48 Further information: <https://www.infraestructurasdehidrogeno.es/infraestructura-interior-de-hidrogeno>

49 See: <https://h2medproject.com/es/el-proyecto-h2med>



7. The state of the expert debate on hydrogen in Spain

7.1. Regulatory challenges

Despite strong industrial and financial momentum, the regulatory framework for renewable hydrogen in Spain remains incomplete and fragmented, which creates uncertainty and holds back investment. Experts agree that the main challenges are not technological, but rather legal, administrative and related to coordination between administrations and levels of government (MITECO, 2024 & Comillas Pontifical University, 2025).

Definition and traceability

The entry into force of Delegated Regulation (EU) 2023/1184 established the criteria of *additionality*, *temporal correlation* and *geographical correlation* for renewable hydrogen, but Spain has not yet completed the adaptation of its legal framework. Until then, the lack of an operational certification and traceability scheme had hampered PPAs and public support mechanisms, resulting in a high level of regulatory risk for developers (European Commission, 2023a, p. 17). However, this problem is being resolved, for example through the development of the national system of guarantees of origin (GO-H₂) and its integration into *CertifHy*.

Permits and licenses

The administrative procedure for electrolysis plants remains a bottleneck. Each installation requires multiple permits (relating to energy, industry, the environment and water), which may involve more than ten different bodies.

In line with the European Commission, the *Spanish Hydrogen Association* (AeH₂) is proposing a 'one-stop shop for hydrogen' and maximum processing times of 12 months for projects < 50 MW. Some regions (Aragón, Andalusia, Castile-La Mancha) have already put fast-track mechanisms in place, but the lack of a unified national framework continues to slow down the roll-out (MITECO, n.d.).

Network integration and access to infrastructure

On the one hand, although Spain achieved 56.8 per cent renewable energy generation in 2024 and this is becoming increasingly important for industry, today the electricity system is facing congestion in grid access, which could pose a problem for the PNIEC targets or the H₂ Valleys. To this end, for example by reviewing and speeding up the processing of industrial access and connection permits through a one-stop shop and by setting maximum time limits, greater grid connection capacity and planning would be required to make the most of this renewable resource (Alinnea, 2025).

Meanwhile, Spain is introducing specific regulations governing the transport and blending of hydrogen in the gas network⁵⁰. There is heated debate on this issue, with environmental groups arguing, for example, that blending would jeopardize the achievement of European climate targets⁵¹.

For their part, industry experts are calling for the establishment of access tariffs, rules on unbundling, third-party access rules (Sedigas, 2023) and injection conditions consistent with the European H₂Med/EHB network, currently being designed (Enagás, 2025, p. 11). The forthcoming transposition of Directive 2024/1788 of the hydrogen and gas package is expected to address these issues.

Multi-level coordination

The devolution of powers leads to significant differences between the autonomous communities. Whilst some have their own strategies and dedicated channels, others lack regulatory instruments. There are calls for a basic national framework that establishes common principles and guarantees legal certainty, whilst allowing for regional flexibility in its implementation.

50 See the CNMC's Resolution of 13 June 2025: <https://www.cnmc.es/expedientes/rdcde00625>

51 See the press release from the "Gas is not the solution" network dated November 2024: <https://fundacionrenovables.org/notas/riesgos-transposicion-paquete-gas-hidrogeno-ue>



A European perspective

The new Gas-H₂ package (2024) will harmonize the European internal market by laying down rules on certification, dedicated transport and non-discriminatory access. Spain will need to amend its legislation by August 2026; if it manages to do so without delaying investment, it could become one of the first fully regulated European markets for green hydrogen.

In short, the regulatory challenge in Spain is one of timing: infrastructure and projects are progressing faster than the regulations. Completing the certification process, streamlining permits and defining the grid connection are essential conditions for consolidating the country's role as a European *hub* for green hydrogen.





7.2. Economic challenges

Spanish renewable hydrogen is competitive in terms of structural costs thanks to the low price of solar and wind power, but it requires regulatory and financial certainty. The reduction in the *green premium*, the introduction of CfDs and full traceability will be crucial to transforming a sector that is still dependent on public subsidies into a self-sustaining, export-oriented market by 2030.

The development of renewable hydrogen in Spain faces a structural economic gap between the cost of producing green hydrogen and the price of fossil (gray) hydrogen. Despite technological advances, the *green premium* remains the main barrier to commercial competitiveness. Experts from the Hydrogen Chair (Comillas) agree that the challenge lies not in technical feasibility, but in creating a stable and predictable financial framework that enables projects to secure long-term contracts and attract private capital (AeH2, 2024, p. 10-13).

Current costs and the break-even point

In 2024, the levelized cost of hydrogen (LCOH) for green hydrogen in Spain is estimated to be between €3 and €10 per kilogram, according to the World Bank (2024). According to IBHYX, the first Iberian renewable hydrogen price index, the price has ranged between 6.15 and €6.25/kg since early 2026⁵². The factors that have the greatest impact on cost are the price of electricity (65–80 per cent of the total), the electrolyzer utilization factor and the cost of capital (CAPEX).

At the same time, within the European context, Spain enjoys unique and competitive conditions for hydrogen production: abundant solar and wind resources, competitive electricity costs, a gas network that is partially adaptable, and expertise in renewable energy.

In this regard, thanks to lower solar energy prices and one of the world's most mature markets for power purchase agreements (PPAs)—between 10 per cent and 20 per cent below the projected production cost in Central Europe—the levelized cost of hydrogen production (LCOH) for green hydrogen in Spain could stand at between €4 and €5.5 per kg by 2030 (McKinsey, 2024a).

Public support instruments

Beyond the PERTE ERHA, the IPCEI schemes and the H₂ Pioneers program, the sector is calling for operational support mechanisms similar to the *Contracts for Difference (CfD) that the European Commission introduced in 2024 to stabilize producers' revenues (European Commission, 2024)*.

In addition, other tools are also considered key, such as renewable hydrogen auctions⁵³, tax rebates and regional incentives (Andalusia, Aragon, Castile-La Mancha), 'soft' financing from the ICO, the EIB and *Innovation Fund*, and Energy Saving Certificates (CAE) as potential additional sources of revenue.

An emerging market and stable demand

The domestic market for green hydrogen remains limited to integrated projects where the producer and the consumer are part of the same consortium (refining, fertilizers, steel). There is still a need for a transparent wholesale market, with reference prices and trading mechanisms (hydrogen PPAs). Approved in Spain by Royal Decree 376/2022, the national system of guarantees of origin (GO-H₂) is, in this respect, crucial for establishing traceability and added value, thereby facilitating domestic and cross-border trade.

Financing and investor risk

The main obstacle identified by banks and investment funds is the lack of long-term contracts (*offtake agreements*) and the volatility of gas prices. Regulatory and demand risk drive up the cost of capital (WACC > 10 per cent). Regulatory stability and the setting of a CO₂ shadow price above €100/t are considered necessary conditions for mobilizing private investment and achieving commercial scale (Curcio, 2025).

⁵² See: <https://greenenergy.mibgas.es>

⁵³ See, for example, the February 2026 notice from MITECO: <https://www.miteco.gob.es/es/prensa/ultimas-noticias/2026/febrero/el-gobierno-adapta-las-bases-reguladoras-de-las-ayudas-al-hidrog.html>



7.3 Technological challenges

Renewable hydrogen is at an intermediate stage of technological maturity. Whilst some green hydrogen options do not yet appear to be available on an industrial scale under competitive conditions, such as in the ceramics sector (Sedigas-PwC, 2024), other solutions for production, storage and use are already viable. However, given that they still lack sufficient scale, standardization and cost reduction, experts agree that Spain's technological priority is not invention, but industrialization: manufacturing equipment, integrating value chains and ensuring operational reliability (AeH2, 2024 & MITECO, n.d.-b).

The technological challenge facing the hydrogen sector in Spain does not lie in technical feasibility, but in making the transition from demonstration to mass production. Reducing costs, scaling up the manufacture of electrolyzers, developing safe storage solutions and establishing common standards will be key to consolidating a competitive, export-oriented industrial ecosystem by 2030.

Electrolysis and industrial manufacturing

The projected increase in capacity (from the current 1.5 GW to 12 GW by 2030) will require a tenfold increase in the production of electrolyzers. In Spain, there are already production and assembly lines for PEM, alkaline and SOEC technologies at companies such as H₂B2, Iberdrola-Cummins, Fusion Fuel and Siemens Gamesa, but the volume remains low. The main challenges are:

- * To scale up domestic production of *stacks* and critical components (membranes, electrodes).
- * To reduce average CAPEX from €900–1,200/kW to less than €700/kW by 2030.
- * To increase service life (from 50,000 to 80,000 hours) and efficiency (>75 per cent).

The PERTE ERHA and the IPCEI Hy2Tech programs are funding innovation centers in Puertollano, Zaragoza and Bizkaia, but the industry experts consulted are calling for a coherent industrial policy that links R&D, manufacturing and domestic demand.

Storage and transport

Large-scale storage remains the weakest link. Spain relies on geological storage facilities (Serrablo, Yela) and pressurized tanks for industrial uses.

The most significant technological challenges are:

- * Adapt underground storage facilities to the permeability of hydrogen.
- * To develop cryogenic and chemical carrier systems (ammonia, methanol, LOHC).
- * Improve safety and standards relating to materials (hydrogen embrittlement, valves, welds).

In the transport sector, the priority is to convert part of the existing gas network (11,000 km) and complete the new H₂Med gas pipelines, which will require steel compatibility tests and leak detection systems (Enagás, 2025b).

Sectoral integration and standardization

Electrolyzers and industrial applications must be integrated into a highly renewable electricity system, operating flexibly to absorb surplus wind and solar power. This requires:

- * Control systems and advanced digitalization (SCADA, AI for timetable management).
- * Technical standardization and common European certification of equipment.
- * Training of qualified staff in design, operation and maintenance.



7.4. Social and regional challenges

The production of green hydrogen relies on a high capacity for generating renewable energy. Given that other technologies and sectors will also require a greater contribution from renewable energy, it is highly likely that, as with other countries, Spain will face two key challenges:

- * Social acceptance of the roll-out of renewable energy;
- * Conflicts of use regarding renewable energy.

Firstly, the roll-out of renewable energy is structurally linked not only to technological changes, but also to cultural, economic and regional changes. Whether through changes in land use, coexistence with other economic activities (agriculture, tourism, etc.) or impacts on the landscape or biodiversity, the roll-out of renewable energy opens the door to social and territorial conflicts that must be understood as intrinsic to a complex and pluralistic society where many legitimate and conflicting interests are represented in the face of the ecological and energy transition. In the face of these territorial tensions, which may delay, hinder or, in some cases, even halt this transition, it is important to anticipate socio-territorial conflicts by setting in motion processes of just, participatory and transparent transition that broadly include all sectors of the population in this process (Muñiz San Martín, Moya, 2023). Furthermore, it is essential to consider the economic, social or cultural returns and benefits that may accrue to the regions where energy transition projects are carried out (Rodríguez, D., 2026).

On the other hand, with regard to the second point, given that the green transition relies primarily on replacing fossil fuels with renewable energy, and that there are technological or socio-territorial constraints on the production and storage of green electricity, there may well be conflicts of use between different sectors (industry, transport, energy, agriculture, data centers, etc.).

Specifically, within this global framework, it would be necessary to correctly assess and prioritize the needs for renewable energy and green electricity in general, and for domestic and industrial consumption of green hydrogen in particular, as well as its export capacity, taking into account, amongst other things, the development of strategic autonomy at European level.





8. Strategic conclusions

The development of green hydrogen in Spain represents a structural opportunity to make progress towards industrial decarbonization and to consolidate a fully renewable energy system. The country has comparative advantages within Europe: an abundance of solar and wind resources, competitive electricity costs, reusable gas infrastructure and an industrial network capable of integrating new electrolysis and storage technologies.

The analysis carried out shows that green hydrogen is not a universal substitute for natural gas, but rather an essential complement to high-temperature processes and to the production of synthetic fuels and chemical feedstocks. Direct electrification will cover most low-temperature thermal applications, whilst indirect electrification using hydrogen will enable the decarbonization of refining, steelmaking, cement production, glass manufacturing and fertilizer production.

Spain's industrial geography gives rise to a dual model: along the Mediterranean and central peninsular corridors, priority will be given to direct electrification (low-temperature industries), whilst along the Atlantic and Cantabrian corridors, green hydrogen will be promoted for high-temperature processes and chemical reduction. This model makes it possible to capitalize on both the abundant solar and wind energy resources in the south and center, and the port and energy infrastructure in the industrial north and south. It will be essential for the PERTE ERHA and Hy2Use programs to coordinate these two pathways within a single territorial framework based on efficiency and specialization.

Spain has succeeded in aligning its national strategy with the European framework through documents such as the Hydrogen Roadmap and the inclusion of ambitious targets in the strategic framework document on climate and energy: the PNIEC. In line with this strategic approach, numerous initiatives have been approved, such as the roll-out of funding schemes through the PERTE ERHA. The target of 12 GW of electrolyzers by 2030 would place the country amongst the EU's leading producers of renewable hydrogen, contributing to the objectives of REPowerEU and the EHB.

In the medium term, the challenge will be to consolidate the domestic value chain, ensure the availability of electrolyzers, components and storage systems, and roll out a transmission and export network that is fully interoperable with the European one. The H₂Med project and the Atlantic, Mediterranean and Ebro corridors will enable the integration of production and consumption within the Iberian energy system, thereby strengthening regional security of supply. The challenges remain *regulatory*, due to the need for a consistent and predictable framework; *economic*, to reduce the cost gap compared with fossil hydrogen and mobilize private investment; *technological*, to scale up production and improve the efficiency of the systems; and *regional*, regarding social acceptance of the roll-out of renewables.

Spain has abundant renewable resources, a robust electricity grid and a diversified industrial base—conditions that place it in a privileged position to lead European industrial decarbonization, provided that a rational energy allocation strategy is adopted, based on electrifying processes where this is most efficient, using renewable hydrogen where technically necessary, and coordinating both approaches at regional and regulatory levels.

The consistent implementation of this combination would boost the competitiveness of domestic industry and strengthen Spain's position as a leading European clean energy hub, a leadership that would be consolidated through the development of future hydrogen valleys within the framework of the cross-border corridors that are crucial to the configuration of the EU hydrogen network.

In conclusion, Spain has the technical and industrial capacity to become a European leader in green hydrogen. Its role will not be to compete globally on price, but to lead the way in European energy integration, export value-added products, create skilled jobs and demonstrate that a green and just transition is compatible with a competitive industry.

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Acronyms

AeH₂	Spanish Hydrogen Association
AEM	Anion Exchange Membrane—Electrolyzer using anion exchange membrane technology
BoP	Balance of Plant—Balance de Planta
BNetzA	German State Network Agency (Electricity, Gas, Telecommunications, Postal Services and Railways)
CAE	Energy-Saving Certificates
CaPex	Capital expenditure—capital investment
CfDs	Contracts for Difference—Contracts for Difference
CCUS	Carbon Capture, Utilization and Storage
CCfD	Carbon Contracts for Difference
CEEAG	Climate, Energy and Environmental Aid Guidelines—Climate, Energy and Environmental Aid Guidelines
CH₄	Methane
CNH₂	National Hydrogen Centre
CNMC	National Commission for Markets and Competition
DIN	Deutsches Institut für Normung- German Institute for Standardization
DRI	Direct Reduction Iron—Direct reduction of iron
EAF	Electric Arc Furnace—Electric arc furnace
EHB	European Hydrogen Backbone—European H2 backbone network
EHBK	European Hydrogen Bank—European H2 Bank
ELP	Long-Term Decarbonization Strategy
ERM	Regulation and Metering Station
GdO	Guarantee of Origin
HTSO	Hydrogen Transport System Operator—Hydrogen network manager
ICO	Official Credit Institute
IDAE	Institute for Energy Diversification and Saving
IEA	International Energy Agency—Agencia Internacional de Energía
IPCEI	Important Project of Common European Interest—Joint projects of European interest
IRC	Common Reception Facility
IRENA	International Renewable Energy Agency—Agencia Internacional de Energía Renovable
IRI	Individual Receiving Facility
LCOH	Levelized Cost of Hydrogen—Levelized cost of hydrogen
LOHC	Liquid Organic Hydrogen Carrier—Carriers
LULUCF	Land Use, Land Use Change and Forestry—Land use, land-use change and forestry
NGTS	Technical Management Standards for the System
NHS	Germany's National Hydrogen Strategy
NOx	Nitrogen oxides
NZIA	Net Zero Industry Act
PEM	Proton Exchange Membrane—Electrolyzers using proton exchange membrane technology
PCI	Project of Common Interest
PERTE ERHA	Strategic Project for Economic Recovery and Transformation in Renewable Energy, Renewable Hydrogen and Energy Storage
PNIEC	Integrated National Energy and Climate Plan
PPA	Power Purchase Agreement—Electricity purchase agreement
PRTR	Recovery, Transformation and Resilience Plan
PtX	Power-to-X—Energy-to-X
RC Fuels	Renewable Carbon Fuels
REE	Red Eléctrica de España
RFNBO	Renewable Fuels of Non-Biological Origin
RITE	Regulations on Heating Systems in Buildings
SAF	Sustainable Aviation Fuel—sustainable aviation fuel
SOEC	Solid Oxide Electrolyzer Cell—Solid Oxide Electrolysis
TRL	Technology Readiness Level—Technology readiness level
WACC	Weighted Average Cost of Capital—Weighted average cost of capital
WB	World Bank—Banco Mundial
WTO	World Trade Organization—Organización Mundial del Comercio

The study concludes that Spain is well positioned to become a net exporter of green hydrogen and its derivatives—such as ammonia, e-methanol and sustainable aviation fuel—before 2050, provided it ensures alignment between industrial policy, energy planning and regulation.

Its combination of renewable resources, existing infrastructure and emerging technological capabilities positions Spain as an energy hub for south-western Europe and a key player in the integration of the European hydrogen market.

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