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Spain's Hydrogen Ambition

Between reindustrialisation and export-led energy integration with the EU

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Part of a series edited by Yana Zabanova and Rainer Quitzow

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Summary

This paper examines the recent evolution of the domestic and external dimension of hydrogen in Spain. When published in 2020, the Spanish Hydrogen Strategy was focused on the creation of hydrogen clusters that could concentrate production and consumption, attracting economic activity associated with the molecule. For this reason, the external dimension of Spain's hydrogen strategy was relatively modest in its nascent state. The Russian invasion of Ukraine and the EU Commission's call in the REPowerEU to increase the level of ambition for renewable hydrogen has led to a change in Spain's hydrogen policy, reinforcing its external and energy security dimensions and contributing to a more geopolitically resilient Europe. This new approach to hydrogen development creates a complex tension between the promises of industrial development and the potential for integrating Spain in the European energy system.

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1. Introduction

In Spain, green hydrogen has been embraced with great enthusiasm by the national government, regional administrations, the private setor, and, to some extent, civil society. The development of hydrogen is mainly perceived as a tool for industrial development and economic diversification. When the Spanish Hydrogen Strategy was published in 2020, it focused on the creation of hydrogen valleys or clusters that could concentrate production and consumption, attracting economic activity associated with the molecule. For this reason, the external dimension of Spain's hydrogen strategy was relatively modest in its nascent state. The Russian invasion of Ukraine and the EU Commission's call in the REPowerEU to increase the level of ambition for renewable hydrogen has led to a change in Spain's hydrogen policy, reinforcing its external and energy security dimensions for a more geopolitically resilient Europe. This strategic shift exposes a trade-off between hydrogen production for domestic consumption as a driver of green reindustrialisation, versus an export model that improves the Iberian Peninsula's energy integration with Europe.

Spain is an active player in the development of sustainability criteria at the European level that could allow Spanish renewable hydrogen to benefit from its competitive advantages. With a relatively large installed renewable power capacity (30 GW of onshore wind, 19GW of solar PV, 17GW of hydropower and 2.3GW of concentrated solar) and significant additional potential, Spain's government has advocated for strict greenhouse gas emissions criteria in the EU. Like Portugal, Spain is also concerned that the obstacles to Iberian gas and electricity interconnections with European markets posed by the French government will remain in place for hydrogen, especially given the self-sufficient nuclear-based hydrogen pathway followed by France and despite recent French commitments for a trans-Mediterranean hydrogen-ready pipeline labelled H2Med. Until now, Spain has focused its hydrogen diplomacy exclusively on the European policy space, with the international dimension less of a priority.

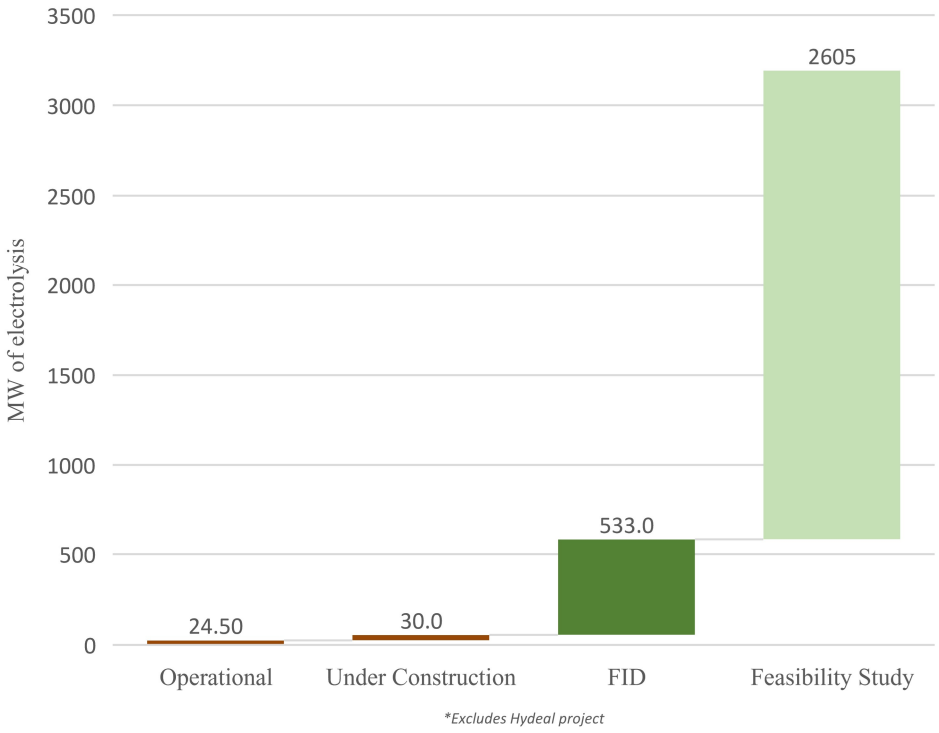
The main documents setting the Spanish hydrogen strategy are the Hydrogen Roadmap published in 2020, the Integrated National Energy and Climate Plan (NECP) 2021-2030, the Climate Change and Energy Transition Law adopted in 2021, the Long-Term Decarbonisation Strategy 2050, the Just Transition Strategy, and the Energy Storage Strategy. Spain has set the target of reaching between 400MW to 600MW of electrolysis capacity by 2024 and 4GW by 2030. These targets were published in October 2020 and will have to become more ambitious in line with the Fit-for-55 and the REPowerEU packages in the upcoming review of Spain’s NECP.

2. Domestic Hydrogen Development in Spain

The Spanish government has focused its strategy on green hydrogen, prioritizing it over other ways of producing decarbonized hydrogen in the Spanish Hydrogen Roadmap. Except for some specific projects associated with the production of blue hydrogen in refineries, all other projects are aligned with this preference for green hydrogen. The absence of upstream activities has taken blue hydrogen out of the equation, while the planned nuclear phase-out programme planned for 2027-2035 excludes its use for hydrogen production. According to the Spanish Hydrogen Roadmap, early hydrogen development will focus on industrial uses, centered around hydrogen clusters or valleys. Sectors that already use hydrogen as a feedstock, mainly refining and fertilizers, are expected to be the early movers. At present, Spain consumes approximately 500,000 tons of fossil hydrogen a year, almost exclusively for industrial uses (70% in refineries and 25% in chemical industries) with on-site captive hydrogen production.

Added to this are the tailwinds generated by unusually high natural gas prices with no expectations of a decrease in the short (and even medium) term (IEA, 2022), the good image of green hydrogen in Spain, and the possibility of obtaining over €1.5 billion in support from the EU Recovery Plan through the temporary recovery mechanism (Next Generation EU, NGEU), all of which have generated an extremely favourable context among the Spanish private industrial actors. The development of relatively cheap green hydrogen is also seen as a unique chance to attract investment in downstream industries in the metallurgic and petrochemical sectors in which hydrogen feedstock represents a significant share in overall final costs (Van der Graaf et al, 2020). Renewable hydrogen could also serve as a backup for the Iberian electricity system in the absence of new interconnections, which will need surplus management and seasonal storage as the penetration of renewables advances with expected surplus low carbon generation during autumn and spring against deficits in many days of winter and summer. According to the IEA 2022 Hydrogen Projects Database, in Spain there are 25MW of operational electrolysis, with 30MW under construction and 533MW in the Final Investment Decision stage. Another 2.5 GW are under feasibility study, which would deliver a total of 3.2 GW by the end of the decade, more than 80% of the Spanish Hydrogen Roadmap target.

(Figure 1) Capacity of announced green hydrogen projects in Spain by status in 2022-2030 (MW)



Source: Based on IEA data, Hydrogen Projects Database, October 2022. Modified by the authors.

Hydrogen is also part of the Just Transition Strategy (MITECO, 2022), and it is expected to support regional industrial development and restructuring. As part of the Just Transition Agreements, the grid access points available after the closure of the coal power plants are being auctioned, incorporating elements of local employment, reindustrialisation, and territorial cohesion (Cuesta et al, 2022). For example, Iberdrola has begun constructing a green hydrogen plant for industrial use in the former coal-mining town of Puertollano (IRENA, 2022). This is not an isolated case, and there is growing optimism about the role of hydrogen in reindustrializing regions in economic decline after several decades of loss of competitiveness partly due to high energy costs. This is the case of Asturias, a coal mining and metallurgical region, which has suffered years of deindustrialization and demographic decline, and now sees green hydrogen as an opportunity to break this inertia.

2.1 A hydrogen strategy with a decentralized component

In Spain, hydrogen development is also attracting interest from devolved administrations. As of March 2023, four of the seventeen Autonomous Communities have presented a hydrogen plan with combined targets of 1GW of electrolysis by 2030, while many others are in the drafting process. One of the key elements in this regional development is the formation of transregional alliances and partnerships for the creation of hydrogen corridors. This is particularly promising in the case of the Ebro Hydrogen corridor, a public-private initiative with a target of 1.5GW of electrolysers and 6GW of renewables by 2030 comprising the Basque Country, Navarre, Aragon, and Catalunya that would establish a hydrogen supply chain from renewable abundant regions such as Aragon to industrial clusters in Bilbao and Tarragona.

These types of trans-regional initiatives are essential to avoid regulatory fragmentation and foster the

development of a national hydrogen market. They may also drive regional development focusing on its areas of greatest competitive advantage. This is the case of the Basque Country, which seeks to strengthen and revitalize its local industry with a clear component of technological development. Neighbouring Castile and Leon perceive hydrogen as a channel to accelerate investment in renewable deployment and its associated value chain. Moreover, the involvement of the Autonomous Communities in the development of renewable hydrogen is key to ensure that administrative processes are simplified. According to EU legislation, the installation of an electrolyser is currently considered an industrial application and requires a complex administrative process that falls under a regional authorisation procedure. One of the key elements of these regional plans is their potential integration with other industrial or renewable clusters in France and Portugal, creating sub-national transboundary cooperation that may help to unlock transnational hydrogen integration.

It must be noted that in Spain there is growing concern about the phenomena of rural depopulation (Junquera, 2021) and recent evidence suggests that renewables, especially onshore wind, are not creating long-term jobs at the local level (Fabra et al, 2022). These trans-regional initiatives involving the renewable resources from such regions for use elsewhere have already generated scepticism among regional political forces (Herrero, 2021). Understanding this phenomenon and knowing how to address it will be a key element in ensuring social support for the development of green hydrogen in Spain, in particular if there is a long-term export ambition.

2.2 Spanish frontrunners: refining, fertilizers, steel, and high calorific processes

The refining sector in Spain has positioned itself as global early mover in the production and use of renewable hydrogen. By 2030, all operators in the sector (Repsol, BP and Cepsa) expect to have decarbonised all their hydrogen consumption. Spain has one of the most modern refining fleets in Europe following countercyclical investments of € 6.5 billion by the main players in the sector between 2012-2015 (AOP, 2018). In fact, Spain is a net exporter of refined products, which in 2022 reached a combined value of € 29 billion, the equivalent to 7.5% of the total exports (Comex, 2023). The adoption of green hydrogen would allow a significant reduction in Scope 1 carbon emissions in the short term, a priority for the three companies involved in the refining activity in Spain that have ambitious decarbonization strategies. Following the 2012-2015 investments, many of the Spanish refineries adopted a last man standing strategy in Europe, modernizing their facilities to be able to process more types of crude oils at a higher efficiency. The use of green hydrogen would also be favoured by high natural gas prices, the end of EU ETS free allowances in 2034 as the CBAM is phased in, the existence of know-how in the development of renewables by Spanish refinery operators and the excellent financial results of 2021-2022, with refining margins at record highs.

In Spain, electric utilities are following a cooperative model for the development of industrial hydrogen projects. This cooperative approach involves technical companies with industrial experience serving as hydrogen offtakers and financial partners, physically connected to hydrogen production. This development involves regional public bodies and is instrumental for the breakthrough of green hydrogen in sectors such as fertilisers, methanol, or metallurgy.

In the fertilizer sector, Fertiberia, a national champion with a dominant market position in Spain and Portugal, is moving fast in the integration of green hydrogen for ammonia production with a pipeline of projects of 860MW of electrolytic capacity. Together with Iberdrola, Fertiberia is operating the biggest green hydrogen-to-ammonia plant in Europe with a 20MW electrolyser at its Puertollano plant and plans to build another one in Huelva of 200MW together with Cepsa by 2026. The alliance between Fertiberia, Cepsa and Iberdrola comes at a key moment for the fertilizer sector, with gradual phase out of the EU ETS free allowances up to 2034, the entry into force of CBAM in 2023 (in its pilot and reporting phase and fully in 2026) and feedstock prices at record highs. In addition, Fertiberia

had to sell its Algerian subsidiary under political pressures from Algiers in 2019, losing a key supplier of cost-competitive ammonia. Fertiberia has announced plans to reach carbon neutrality by 2035, hoping to become a frontrunner in the production of low carbon fertilizers and compete in the EU market (Fertiberia, 2019). Although there were no domestic production of methanol in Spain, low carbon methanol production projects associated with renewable hydrogen have emerged involving petrochemical companies (traditionally importers), and utilities[1].

In recent decades the Spanish steel industry has undergone deep industrial restructuring towards electric arc furnace (EAF) steel production, leaving only ArcelorMittal as an integrated blast furnace steel producer at its Asturias (Gijon) site. This ArcelorMittal plant, with a production of around five million tons of primary steel is at the core of the HyDeal Ambition, one of the world's largest integrated renewable and hydrogen hub projects. This project aims to produce electricity in Castile and Leon, taking advantage of renewable resource and land availability, and produce green hydrogen that would be used for the direct reduction of iron (DRI) and EAF technique. In February 2023, the European Commission approved a grant of €460 million to Spain's ArcelorMittal's HyDeal project, paving the way for the rapid ramp-up of the project which is scheduled for completion in 2025.

In addition, Spain ranks third in the EU in terms of high temperature industrial consumption[2] with 33TWh of natural gas in sectors such as ceramics, glass, and cement (Agora Energiewende, 2021). Despite the multiple technical challenges, these sectors are developing initiatives such as the Orange.Bat program and the Spanish Cement Decarbonization Roadmap, in which the use of low carbon hydrogen is included (Oficemen, 2020).

2.3 Technology developments, R+D and capacity-building

Spain lacked the know-how associated with renewable hydrogen when the Hydrogen Roadmap was published, having to develop its entire industrial and innovation complex from the ground. This technological situation mirrors the initiative shown by the private sector to launch green hydrogen projects, which has been forced to seek electrolytic technology abroad for the development of the first green hydrogen pilot projects. So far, the announced projects are expected to use technology from Nel, John Cockerill, Siemens, and Cummins with no Chinese electrolyser so far due to bankability and reliability issues. Yet in the field of power electronics, which makes up a considerable share of the investment costs in hardware for large-scale electrolysis plants, Spain's leading companies such as Ingeteam or Sener are increasing their global presence.

In the future, Spain is expected to develop an important local assembly and electrolyser industry to supply the domestic market without necessarily relying on Spanish innovation. This situation could replicate that of the car or onshore wind industry, in which Spain is one of the European leaders by volume of output without a major national champion. The expected development of green hydrogen in Morocco, Tunisia, and Portugal would offer a potential market for Spanish world-leading companies in technical project development and infrastructure construction. The first major project underway is Cummins' Guadalajara plant which will have the capacity to manufacture 500 MW of electrolysers per year by 2024, and a planned future production capacity of 1 GW per year.

In December 2021, the Ministry for Ecological Transition and the Demographic Challenge (MITECO) within the Hydrogen line of the Recovery and Resilience Plan (NRRP) opened a line of support for innovation projects for large electrolysers of 100 million euros; the demonstration and validation of vehicles of 80 million euros; industrial and experimental research of 40 million euros, and the

[1] Maersk, Triskelion, Foresa, Viridi Energías Renovables España and Green Enesys Group are developing projects along utilities such as Iberdrola and Repsol

[2] (>500 ºC)

promotion of capacities and technological advances in testing and manufacturing lines of another 30 million euros. The MITECO has also launched the Incentive Programme for pioneering and unique renewable hydrogen projects (H2 PIONEROS Programme). It includes a funding line of 150 million euros for pioneering renewable hydrogen projects with commercial viability for local production and consumption in sectors that are difficult to decarbonise, such as industry or heavy transport. The total budget allocated to hydrogen in the Recovery Plan is 1,555 million euros (Feás and Steinberg, 2021), being considered one of the 30 key components of the Spanish NRRP (Lázaro et al, 2022). In another public initiative, the state-owned company Navantia, which specializes in the construction of military ships and submarines, has announced its intention to develop a renewable energy business line. This field of operation would include the manufacture of electrolysers with know-how from the assembly of the latest generation of submarines in partnership with Repsol.

Spain's hydrogen-related innovation strategy has also followed a process of increasing internationalisation. Spain joined the Mission Innovation 2.0 project in September 2022, and four Spanish projects were selected in the €5.4 billion Commission Hydrogen IPCEI[3] to support first deployment and innovation in the hydrogen technology value chain in July 2022. The selected companies in the area of hydrogen generation were Nordex; with a project of building an electrolyser factory, H2B2; the single Spanish SME included in the project with their own PEM electrolyser technology; and SENER, with a long history of engineering innovation. The Spanish branch of the Italian Iveco has been selected in the area of heavy-duty mobility. In the second IPCEI in September which focused on the development of industrial projects, Spanish companies obtained 20% of the selected projects. These developments demonstrate Spanish leadership in both hydrogen production and applications.

Spain is experiencing two bottlenecks associated with the lack of skilled human capital. On the one hand, many companies, in particular SMEs, are unable to take advantage of generous Recovery and Resilience Facility funds because of the lack of qualified personnel in the public and private sector to carry out the administrative procedures (Olcese, 2022). This lack of qualified staff not only affects the development of projects in the short term but may also slow project development in the future when the demand for qualified labour will be higher. For this reason, the Spanish Government included professional training and reskilling as one of the five strategic objectives in the Recovery and Resilience Plan (NRRP). To this end, knowledge creation criteria have been incorporated into the different tenders for funds, with special emphasis on projects targeted at developing hydrogen clusters or hubs.

2.4 Overview of green hydrogen development in Spain: risks and trade-offs

Although renewable hydrogen is expected to emerge as the most competitive option across Europe in the long term (Agora Energiewende, 2021), the investment window for fossil-based hydrogen with carbon capture will likely remain open until the 2030s (IRENA, 2022). The Russian invasion of Ukraine and the natural gas crisis seem to have closed this window of opportunity for blue hydrogen production within the EU, but not for imports. Spain risks losing its green hydrogen momentum if other EU countries support blue hydrogen as a transition fuel despite its proven lower environmental standards (Howarth and Jacobson, 2021). This backing for blue hydrogen could make more low carbon hydrogen available at a lower cost for a quicker uptake in demand in the short term, creating an uneven playing field for green hydrogen industrial consumers. This could lock in blue hydrogen infrastructure in the EU for the coming 30 years, furthering fossil fuel path dependence (Van de Graaf et al, 2021) and increasing entry barriers to green hydrogen production located outside of this existing network (Lambert, 2021). Spain’s peripheral situation in the European natural gas system could be further exacerbated if blue hydrogen is developed in parallel to green hydrogen during the next decade (Agora

[3] Important Projects Of Common European Interest (IPCEI).

Energiewende, 2021b).

Water availability can be a limiting factor for green hydrogen production. The irregular rainfall pattern of the Mediterranean climate means that water consumption for hydrogen projects may be in direct competition with agricultural consumption in certain regions of Spain during specific times of drought, expected to intensify in a +2°C global warming scenario (Roudier et al, 2016). Many of the regions with the best solar resources are also producers of irrigation-intensive agriculture, sometimes with unsustainable water consumption patterns. In coastal areas, water desalination can be a viable solution, considering its low impact on the hydrogen production costs: $0.02 of hydrogen per kg (Khan et al, 2021), while in the interior it can become a real barrier for new renewable electrolytic projects in the absence of a wastewater treatment plant nearby (Simoes et al, 2021).

The development of hydrogen will have to be implemented under strict environmental and social sustainability criteria. Large projects and infrastructure such as H2Med are already facing opposition by relevant civil-society actors which doubt their environmental, economic, and social benefits (Fundación Renovables, 2023). Spain does not have socio-environmental contracts for the phase-in of renewables and hydrogen, in contrast with the institutionalized Just Transition Agreements for the phase-out of coal and nuclear energy in the affected communities. In a scenario of rapid deployment of renewables for hydrogen production, it is necessary to articulate a comprehensive institutional framework to ensure its long-term environmental and social sustainability. Otherwise, the broad social support in Spain for the energy transition (Lázaro and Escribano, 2019) could be undermined.

3. External dimension of hydrogen in Spain

The external dimension of hydrogen in Spain has evolved since the publication of the Hydrogen Roadmap in 2020, shifting from a focus on domestic development to greater integration through exports as a response to the Russian invasion of Ukraine. Spain assumed the mandate established in the REPowerEU to frame hydrogen strategies not only in terms of decarbonisation but also in terms of energy security (Zabanova, 2022). For the time being, Spain has signed bilateral hydrogen cooperation agreements with Italy in 2020 and Portugal in 2021, emphasizing the need to share information and integrate technology supply chains. With Germany, there is a broad understanding on energy transition and climate ambition that extends to hydrogen. However, there are some elements of antagonism, notably on hydrogen imports from outside Europe and possible conflicts over state aid and industrial policy. With France, the announcement of the construction of the H2Med pipeline in December 2022 marked the beginning of a new phase of cooperation. Nevertheless, the rapprochement between Madrid and Paris on energy integration seems fragile. For Spain, a high priority is securing France's commitment to building new infrastructure that integrates Spain into the EU energy (and hydrogen) market. The construction of the H2Med pipeline connecting the Iberian Peninsula to Europe via France will be crucial to determine whether the hydrogen strategy in Spain targets domestic consumption or also ambitions exports.

Spain has remained outside the development of bilateral and multilateral agreements with non-European actors on hydrogen and it is not a member of multilateral institutions such as the IEA-led Hydrogen Initiative. The absence of a cooperation agreement with Morocco is noteworthy considering the significance that the North African country is giving to the external dimension of green hydrogen with the signing of agreements with Germany and Portugal. The Spanish private sector is also involved in the external dimension of hydrogen. In October 2022, Cepsa and the Port of Rotterdam announced the establishment of the first green hydrogen (ammonia-based) shipping corridor in Europe from the Port of Algeciras, the largest in Spain.

3.1 Hydrogen exports, imports, and the Iberian Peninsula as a transit hub

Concerning connectivity, Spain and Portugal aspire to help develop a European hydrogen market that generates an Iberia-Central Europe hydrogen corridor, potentially later extended to North Africa. In this sense, the historical French reticence to facilitate Spanish energy integration beyond the Pyrenees raises fears that the current lack of natural gas and electricity interconnections could be replicated: Spain has excess LNG regasification and generation capacity (both gas and renewables) that it cannot export because of this missing infrastructure (Escribano, 2021). In the absence of an integrated Western European network of hydrogen pipelines, Spain's exports would risk losing the competitive advantage generated by its abundant renewable resources, geographical proximity to European import markets, and stable European institutional and geopolitical situation. Considering the possibilities of hydrogen transport from Spain to Europe, the distance of 1,500-3,000 km seems to be on the verge of an estimated break-even point for exports to northern European consumption clusters between pipeline and ammonia-methanol shipping transport (Nuñez-Jimenez et al, 2022). If the international hydrogen market is focused around the transport of ammonia by ship, the main costs would be in the

transformation of the molecule and not in the additional cost per kilometre. This situation could affect Spanish export ambitions in the long term, as producers with low renewable costs but in the European geographical periphery such as Morocco, Chile or the United States could compete and offer hydrogen at a similar or lower price.

Another key element in the external dimension of green hydrogen is the possibility of integrating the North African and the European markets in the Mediterranean import corridor already identified in the REPowerEU package. Morocco's ambitions to become a green hydrogen exporter would be coupled with Algeria's pressing need to replace its hydrocarbon exports and the existence of natural gas pipelines. Both countries, with excellent geographical conditions for the development of green hydrogen, and blue hydrogen in the case of Algeria, would offer the possibility of establishing a trans-Mediterranean corridor through Spain. In addition, Spain and Morocco are increasing energy integration in the areas of electricity, natural gas, and refined products that could further extend to the green hydrogen sector (Urbasos, 2023). Although the costs of hydrogen pipeline retrofitting would be significant, the GME pipeline connecting Algeria and Spain through Morocco would have favourable characteristics for trans-Mediterranean hydrogen transport with an underwater route of only 45 km, considerably reducing the compression problems that these infrastructures have in their conversion to hydrogen (Amore-Domenech et al., 2023). However, the Algeria-Morocco section of the pipeline ceased operations in October 2021 in the context of increasing geopolitical polarization between Algiers and Rabat, exposing a key barrier for future Mediterranean energy integration.

Hydrogen exports from North Africa would face the same obstacles as the Iberian Peninsula in reaching Northern European markets, unless alternative transit pipelines are built, such as the proposed H2Med, or transportation by sea becomes competitive, in this case bypassing the Peninsula as a transit hub (Escribano, 2021). LNG terminal retrofitting could be a long-term solution if an EU wide hydrogen pipeline network is not fully developed. However, the main operator of LNG plants in Spain, Enagás, is prioritizing the development of hydrogen pipeline transport infrastructure within the framework of the European Hydrogen Backbone, leaving operational LNG plants for natural gas and biomethane imports as well as bunkering of maritime and heavy transport in the long term (Enagás, 2022). Given that the new LNG regasification plants in Germany must be prepared for a transition to hydrogen, whether in the form of ammonia, methane, or liquid hydrogen, these infrastructures could be decisive in the flow of renewable hydrogen from the Iberian Peninsula if LNG to ammonia repurposing is techno-economically viable.

In a scenario of isolation from the rest of Europe, Spain could alternatively focus on generating a low carbon hydrogen ecosystem in the Western Mediterranean based on local industrial consumption rather than exports. The Spanish industry would benefit from relatively lower hydrogen production costs than the rest of the EU, which could be a driver for the competitiveness of the low carbon hydrogen associated industry: ammonia, methanol, steel, and synthetic fuels. This industrial development could have a greater or lesser level of complexity and added value: from the simple production of ammonia, methanol, or direct reduced iron to the production of green steel or more advanced petrochemicals. The supply of green hydrogen from North Africa would allow for scale and enhance industrial competitiveness. It would also enable economic engagement in the Western Mediterranean at a time of rapid transformations, such as the entry into force of the CBAM and the Green Deal Industrial Plan, offering attractive transition prospects and increased interconnections in the Spanish Southern Neighbourhood.

3.2 Infrastructure: hydrogen as a driver for greater energy integration

Intensifying interconnections with the rest of Europe has been a traditional priority of Spanish energy policy since its accession into the EU (Escribano et al, 2019). Given Spain's ambitions of being a key

hydrogen transit country and exporter, a strategic element is the development of infrastructures that enable the achievement of an Iberian Peninsula to Central Europe green corridor. So far hydrogen infrastructure is limited due to the industrially concentrated and sparsely distributed use of hydrogen in Spain. For this reason, interconnections should be developed simultaneously at the domestic and international level connecting renewable resource, hydrogen production, and industrial centres.

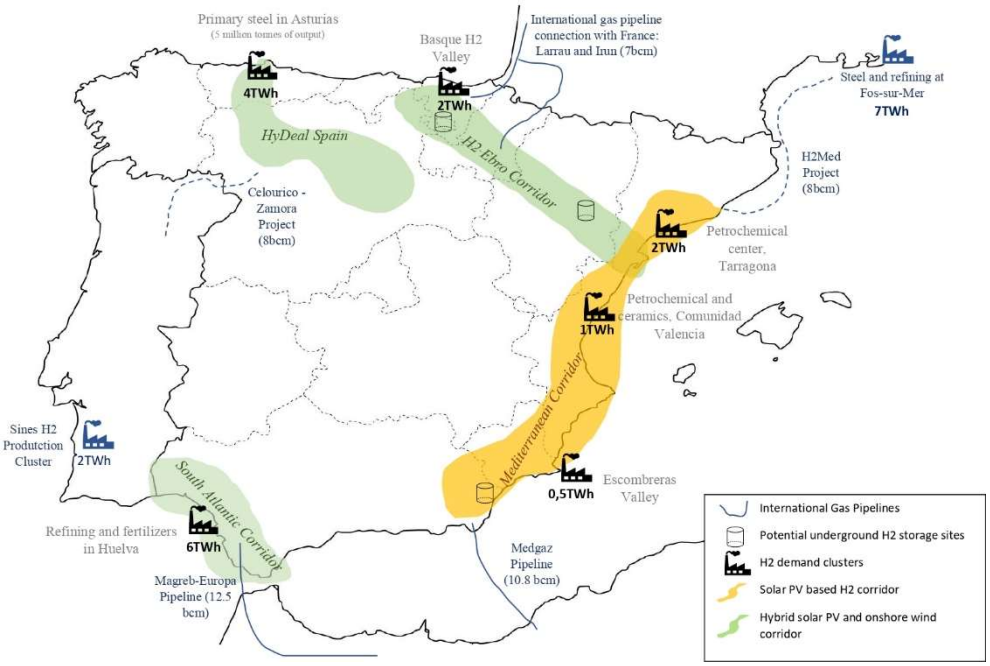
Spain and Portugal have progressively integrated the electricity (MIBEL) and, to a lesser extent, gas markets (MIBGAS). This has provided a well-developed market structure for energy trade that would facilitate further coordination between the electricity and gas sectors in the future creation of a hydrogen value chain at the Iberian level. Portugal´s Hydrogen Strategy aims to install 2GW of electrolysis capacity by 2030, targeting export markets. The role of Spain for the transit of Portuguese hydrogen will depend on the integration of the Iberian Peninsula in the European hydrogen market. The development of interconnected hydrogen valleys could emerge on the Northern Atlantic coast while Sines, the main green hydrogen cluster in Southern Portugal, lacks an existing direct gas connection with the closest Spanish hydrogen hub in Huelva. In December 2022, Spain and Portugal signed an agreement for the construction of a hydrogen interconnection between Zelorico and Zamora. This 350-million-euro IPCEI candidate pipeline will substantially improve hydrogen integration between Portugal and northern Spain, with work scheduled to start in 2025 if 50% of the project is successfully financed with EU funds. The pipeline is designed to deliver hydrogen produced in Portugal to the new green industrial cluster in Asturias, thus functioning as an element of Iberian integration and industrialisation, rather than as an export-oriented project.

In the case of Italy, Spain signed a cooperation agreement that would have less to do with infrastructure cooperation than with its technological competence and vast diplomatic-corporate networks across the Mediterranean region and the African continent (Giulli, 2022). This agreement came in a context of high-level bilateral energy understanding with the creation of a virtual LNG pipeline between Barcelona and Livorno, and shared interests in pressing France to open to greater energy interconnections. However, since the victory of Giorgia Meloni and the change of government in Italy, communication between Rome and Madrid has been substantially reduced and bilateral initiatives including hydrogen have been frozen.

France represents a somewhat paradoxical case. While there are clear bilateral synergies for energy, and hydrogen in particular, the lack of collaboration for infrastructure development in recent decades has generated some suspicion south of the Pyrenees. In Spain, both the Basque hydrogen valley and the Ebro Hydrogen Corridor are clusters close to the French border and with existing natural gas interconnections that could be integrated into the French gas grid and consumption centres. However, the Mediterranean corridor has a greater potential to be extended into the hydrogen hub that France aims to develop in the Provence-Alpes-Côte d'Azur region, with an expected demand of more than 7TWh of hydrogen by 2030 in the Fos-sur-Mer refining and metallurgic cluster (Agora Energiewende, 2021).

The construction of the offshore H2Med pipeline would offer a higher incentive for cooperation between Portugal, Spain, and France. This would couple the Ebro-Mediterranean hydrogen corridors with a potential exchange capacity of two million tons, equivalent to 20% of the REPowerEU target for domestic production in the EU by 2030 (Urbasos, 2022). However, France has shown itself to be inconsistent in its position on the pipeline. Firstly, French domestic preferences for an offshore route make the pipeline project substantially more expensive and technically more challenging. Second, France has attempted to exert pressure on Spain with its support to the H2Med pipeline to garner Madrid's support in the European negotiations on low carbon hydrogen from nuclear origin. Meanwhile, the other major bilateral energy infrastructure, the Spanish-French electricity interconnection in the Bay of Biscay, has not yet begun its construction and accumulates delays due to cost overruns caused by inflation in materials costs.

(Figure 2) Regional development of hydrogen in Spain and its international implications



Source: own elaboration. Estimates for hydrogen consumption from (Agora Energiewende, 2021) and potential underground saline storage from (Crotogno et al. 2010).

In a long-term cooperative and well-governed scenario, Morocco and other North African countries could be key Spanish allies in the creation of a European pipeline-based hydrogen market, giving Spain a relevant role in this regional supply flow as consumer and re-exporter. The existing geo-economic drivers support Mediterranean hydrogen market development due to its abundant renewable resources, existing infrastructures, and relatively low transport costs, which are expected to make green hydrogen competitive during the present decade at the Mediterranean basin level (Escribano, 2021). Green hydrogen is understood as an additional element in the trans-Mediterranean functional integration on energy and decarbonization, another key area of Spanish foreign policy. The Iberian Peninsula-Central Europe hydrogen route has the potential to position Spain as a logistical bridge to North African abundant renewable resources, giving the Peninsula a central position in the new European decarbonised energy trade.

Although electricity interconnections with France are progressing slowly and are unlikely to meet the objectives established in the Spanish NECP of reaching 8,000MW of interconnection by 2030, renewable hydrogen could be a complementary option to connect the renewable resources of the Peninsula with the rest of continental Europe. This double connection of electricity and hydrogen would increase the robustness and resilience of the decarbonised European and Iberian energy systems, while providing Spain with an opportunity to capitalise on its renewable resources and land availability.

3.3 Regulatory diplomacy

Spain aspires to contribute to the development of a European hydrogen market with guaranteed low emissions. With a strong commitment to green hydrogen, the international efforts of the Spanish government are to ensure that there are strict sustainability standards at the European level. Strict sustainability and governance criteria on hydrogen trade benefit European strategic autonomy, prioritising

European hydrogen production, which partially helps to explain the active role of the Spanish authorities in the development of EU-wide legislation.

Spain welcomed the EU Regulation 2022/869 on internal markets for renewable gases and hydrogen, seeing the measure as enabling EU-wide cross-border hydrogen trade and developing a truly low carbon gas market. During the revision of the regulation on trans-European energy infrastructure (TEN-E), Spain positioned itself against EU financial support for fossil gas infrastructure and blending hydrogen into the natural gas network, favouring a stricter sustainability criterion to avoid any lock-in effect in fossil assets (Taylor, 2021). The Spanish Government has been a vocal supporter of separating nuclear hydrogen, labelled as low carbon, from renewable hydrogen. Despite pressure from Paris for a change of position, Spain has made clear its preference for favouring renewable hydrogen at both the national and European level against other low carbon alternatives (nuclear and SMR with CCS).

Regarding the February 2023 Hydrogen Delegated Acts, Spain welcomed their main outcomes. The Government supports a transitional period in which temporal correlation and additionality are extended towards a monthly period instead of an immediate implementation of the stricter hourly correlation. This flexibility is expected to allow the development of the first projects at a competitive cost, allowing its integration into industrial processes, fertilizers, and refineries, that need a continued supply of hydrogen. During the drafting process, Spain advocated for the establishment of equal criteria for imported hydrogen as well as the geographical correlation between electricity of origin and electrolyser location.

Guarantees of Origin (GO) of renewable electricity production have been a case of success in Spain which has reached a considerable volume of more than 100GWh per year. The development of a stable European market for green hydrogen guarantees of origin would allow Spain to obtain extra financing from other European markets. These Spanish guarantees of origin would most likely trade at a premium in European markets, as is the case with Spanish solar PV GOs, 42% of them being exported in 2020 (CNMC, 2021). However, the late development of low carbon gases in Spain contrasts with the development of guarantees of origin markets in other European geographies for biogas and biomethane (Gas for Climate, 2021). In May 2022, Spain launched a GO system for renewables gases, including biogas, biomethane, and green hydrogen. This is expected to help ramp up their production and allow Spain to catch up with other EU markets. As a transition measure, and due to the lack of human and technical resources in the public administration, Spanish TSO Enagás will oversee implementing and monitoring this mechanism, a sign of the administrative and technical challenges that green hydrogen could generate.

Finally, Spain participated in the development of the CertifHy Project as a potential international tool to guarantee an upper limit from the carbon footprint of green hydrogen. In addition, Spanish private companies have advocated for the creation of premium low carbon products and the enforcement of European-wide guarantees of origin for green hydrogen-related industrial products. These mechanisms would allow the ramp up of low carbon fertilizers, steel, aluminium, and ceramics projects that are under study in Spain. Currently, two transnational projects dedicated to the creation of standards are being developed by the Spanish research centre IMDEA with the financial support of the Clean Hydrogen Partnership. The E-Ghost project is the first initiative to create guidelines for hydrogen systems based on the European Eco-Design Directive. The SH2E project is developing reliable assessment and benchmarking procedures of life-cycle emissions of fuel cell hydrogen systems.

3.4 Partners and competitors in the hydrogen economy

As identified by Eicke and De Blasio (2022) new tensions can arise between industrialized countries with import needs and hydrogen producers with substantial resource potentials and skilled labour forces. Potential exporters such as Spain have an interest in attracting the respective green hydrogen

industrial applications instead of relying on hydrogen exports. Locating industrial facilities close to low-cost green hydrogen production would create value by increasing the producing country's control over supply chains and capturing a higher level of added value (Van de Graaf, 2022). These countries could thus reap the most extensive benefits and become geopolitical and market winners, rather than mere energy exporters. These competing interests can result in conflicts; EU importers would protect national markets through state aid and subsidized hydrogen imports, as in the case of H2Global or the proposed carbon contracts for difference support scheme, while hydrogen producers would try to attract those hydrogen-related industries. This situation could lead to tensions within the EU at a time when industrial policies, notably those associated with energy transition technologies, have regained their geostrategic value (Maihold, 2022). The proposed relaxation of state aid allocation criteria in the EU in response to the US Inflation Reduction Act could lead to a subsidy race benefiting countries with deep pockets and greater fiscal leeway (Meester, 2022). In parallel, renewable resources seem to increasingly be embedded in resource nationalism narratives traditionally limited to raw materials, as it is the case of hydropower exports from Scandinavian countries (Hansen, and Moe, 2022), with potential ramifications for other low carbon energy exporters.

This process of diverging interests between EU hydrogen producers and importers must be considered carefully when analysing the future of the Spanish hydrogen strategy and its potential competitors and partners. While current projects are focused on substituting existing fossil fuels and hydrogen demand, the Spanish hydrogen narrative of reindustrialization implies attracting new low carbon energy-intensive activities. These new industries could come from other Member states affected by the natural gas crisis and the EU energy decoupling from Russia, whose long-term effects on Central and Eastern European energy-intensive industries are yet unknown. Spain could develop a hydrogen diplomacy aimed at ensuring a level playing field in industrial policy, bringing together major electricity and (future) competitive hydrogen producers, to counterbalance possible protectionist policies within the EU. In the absence of hydrogen export infrastructure, Spain and Portugal would favour an inward-looking strategy of active industrial onshoring. This scenario seems more conflictive in political terms, mostly at the EU level, than an interconnected and open export-oriented model.

4. Conclusion

Renewable hydrogen represents an opportunity for Spain to reconfigure its position from the periphery to the core of the European energy system. Besides contributing to the Energy Union with a diversified supply of natural and renewable gases and electricity, Spain can provide a significant amount of cost-efficient, socially, politically, and environmentally sustainable green hydrogen. However, there are uncertainties around whether Spanish green hydrogen (or in the future North African hydrogen) could reach Europe through France via H2Med. This is amplified by past experiences around both gas and electricity interconnections, highlight existing barriers for the integration of Iberian renewable resources. Spain's hydrogen diplomacy priority is guaranteeing the integration of the Iberian Peninsula in the EU-wide hydrogen market. To this end, regulatory efforts in Brussels have targeted establishing a regulatory framework that valorises renewable hydrogen (under strict sustainability criteria) over other low carbon options.

In the meantime, at the domestic level, the Spanish strategy has focused on developing industrial clusters and valleys based upon a narrative of industrialisation, just transition, and regional development. If the current European energy crisis accelerates, and the development of low carbon hydrogen consumption and hydrogen corridors towards Europe are open through the Pyrenees or elsewhere, the Spanish Government has expressed its willingness to adopt an export-oriented strategy; and, in the longer term, Spain is eager to integrate into a wider Euro-Mediterranean hydrogen backbone as both a hub and a competitive producer. Alternatively, Spain also considers the more inward-oriented strategy of concentrating on hydrogen production for the Iberian market to lower prices and attract energy-intensive industries. Infrastructure development will be decisive in defining the prevailing model, as will European regulation on the definition of low carbon hydrogen and industrial policy.

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