Hydrogen and Natural Gas Infrastructure Transition in the Iberian Peninsula: A Case Study Using the MGET Model

Version 0.2.0

Contents

1 Introduction

The Multi-Gas Energy Transition (MGET) model is an optimization model developed as an extension of the Gas Grid Model (GGM) [1], specifically tailored to address infrastructure planning challenges during the energy transition. It expands the GGM structure to represent a multi-gas system, including natural gas, hydrogen, and blended gases. MGET employs a mixed-integer linear programming (MILP) approach to solve both investment and operational planning problems. The model determines minimum-cost solutions to meet gas demand and storage requirements while considering the existing infrastructure and varying transition scenarios. MGET supports decision-making by incorporating infrastructure investment options such as pipeline repurposing, network expansion, and storage optimization. Operational components include supply dispatch, gas and hydrogen flows, blending, and storage management. This integrated modeling approach enables the evaluation of cost-effective decarbonization pathways and facilitates the design of flexible and resilient gas networks aligned with long-term sustainability goals.

2 Case study and results

2.1 Case study: Iberian Peninsula

The case study focuses on the Iberian Peninsula, which plays a crucial role in the European hydrogen transition due to its abundant renewable energy resources and strategic location. This study examines the development of hydrogen and natural gas infrastructure in Spain, using data from the iDesignRES project (WP 1, Task 1.1 & 1.3).

The primary dataset, "*Gas_data_Spain_MGET.xlsx*," provides insights into Spain's gas system, integrated into the Multi-Gas Model for the Energy Transition (MGET). It covers Spain, Portugal, and neighboring French regions with gas pipeline connections, along with Algerian and Moroccan regions for pipeline imports. Rotterdam (NLD) and Marseille (France) are included for export modeling. This dataset supports the analysis of energy trade, pipeline repurposing, and hydrogen integration within the Iberian energy system. Figure2 presents the NUTS3 regional breakdown used in the model. Figure3 illustrates the existing gas transmission infrastructure, and Figure1 shows the locations of the LNG terminals.

Figure 1: Major LNG terminals in the Iberian Peninsula.

2.2 Results and discussion

In this section, key results for the Spain case study are presented. To assess the effectiveness of the optimization model, two scenarios are analyzed: Moderate Hydrogen and Ambitious Hydrogen. The fundamental difference between these scenarios lies in the pace of natural gas phase-out and hydrogen integration. By 2040, in the Moderate Scenario, natural gas demand declines by approximately 50% compared to 2025, while hydrogen penetration remains limited, supplying only 8% of total energy demand. Conversely, the Ambitious Scenario envisions a more rapid transition, with natural gas demand decreasing by nearly 90% and hydrogen meeting over 30% of energy needs. By 2050, both scenarios aim to achieve carbon neutrality.

The first set of results examines border capacity expansion between Spain and Portugal to validate the model's logical consistency, as summarized in Tables 1 and 2. Both arcs start with the same capacity, indicating an existing infrastructure for energy transport for fuel gas. Both arcs are already bidirectional, meaning that energy flow can occur in both directions from the beginning. In the Ambitious Scenario, the ES431-PT186 arc has a higher share of expansion, increasing by 0.73 GW, compared to 0.24 GW for PT186-ES431. Repurposing from gas to hydrogen occurs only for PT186-ES431, with 0.73 GW shifting from gas to hydrogen in 2035. This suggests a higher priority for

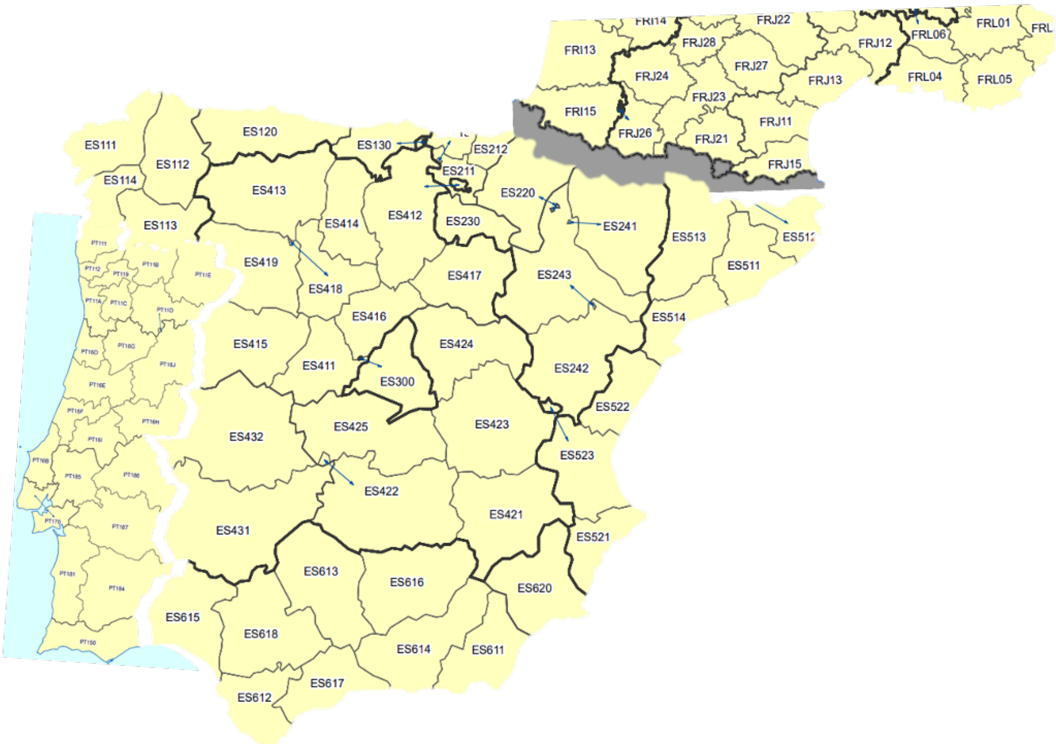

Figure 2: NUTS3 regional classification for Spain and Portugal used in the MGET model.

hydrogen transport in this direction.

More bidirectionality is introduced for PT186-ES431 in 2030, indicating an increasing demand from PT186 to ES431. Both arcs undergo significant expansion in 2035, supporting large-scale hydrogen transport in both directions, with an expansion of 5.17 GW. By 2040, the final expansion values reach 11.53 GW for PT186-ES431 and 6.36 GW for ES431-PT186. This shows that PT186-ES431 experiences almost twice the expansion of ES431-PT186, making PT186 to ES431 the dominant transport route by 2040.

Figure 3: Existing gas transmission network in the Iberian Peninsula.

Table 1: Transmission Arc Results for ES431–PT186

F	Scen	2020	2025				2030					2035					2040		
		cap	**bidir**	**capBD**	**cap**	**expans**	**purp**	**bidir**	**capBD**	**cap**	**expans**	**purp**	**bidir**	**capBD**	**cap**	**expans**	**bidir**	**capBD**	**cap**
G	M	3.00	3.00	3.00									0.08	0.08			0.51	0.51	
	A	3.00	3.00	3.00		0.73	0.24	0.97	0.73		0.00	-0.73	0.24	0.24	0.05	0.06	0.21	0.21	0.11
H	M																		
	A						5.17	5.17	5.17	5.17		0.73	5.17	5.91	0.73	5.62	6.36	11.53	6.36

Table 2: Transmission Arc Results for PT186–ES431

F	Scen	2020	2025				2030					2035					2040		
		cap	**bidir**	**capBD**	**cap**	**expans**	**purp**	**bidir**	**capBD**	**cap**	**expans**	**purp**	**bidir**	**capBD**	**cap**	**expans**	**bidir**	**capBD**	**cap**
G	M			3.00	3.00			0.00	3.00	3.00					3.00				3.00
	A			3.00	3.00		0.24	-3.00	0.73	0.97	0.24				0.24				0.24
H	M				0.02			0.05	0.06				0.05	0.06	0.02		0.11	0.12	0.02
	A				2.17	3.00			5.17			0.73	5.91	5.17			06.36	11.53	5.17

Spain's aggregate mass balance under the Moderate and Ambitious scenarios for a multi-gas energy transition between 2025 and 2040 is illustrated in Figure 4.

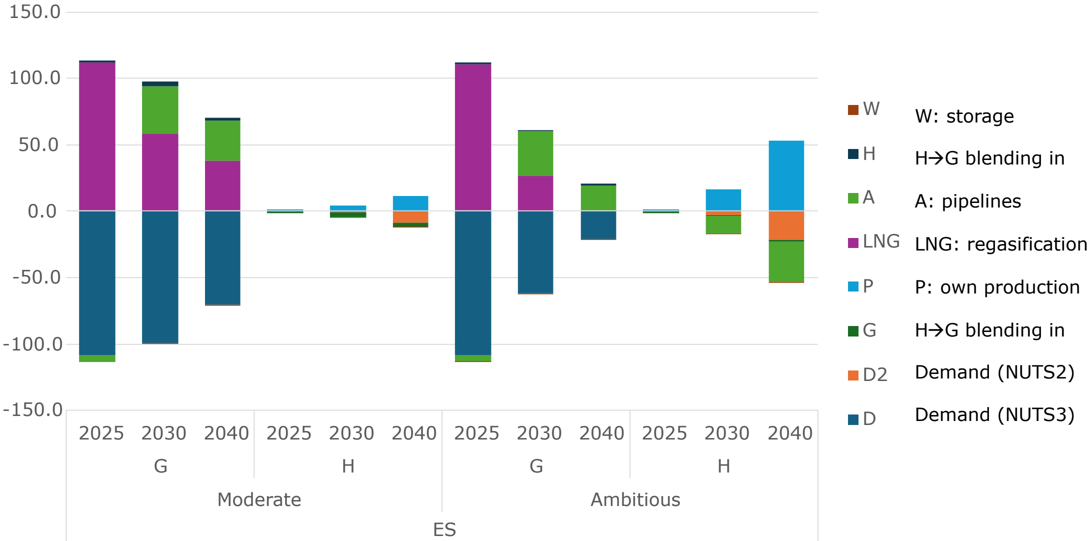

Figure 4: Spain's aggregate mass balance (TWh)

In the Moderate Scenario, Spain remains highly dependent on natural gas (G), primarily through LNG regasification and pipeline imports. LNG remains the dominant energy source in 2025, while domestic gas production plays a minor role. Hydrogen (H) adoption is slow, with only limited H $\rightarrow$ G blending in the gas network. Pipeline infrastructure (A) continues to transport natural gas, with minimal repurposing for hydrogen.

In contrast, the Ambitious Scenario accelerates hydrogen adoption. While LNG imports persist in 2025, they decline sharply by 2030, replaced by hydrogen transport through repurposed pipelines. By 2040, Spain's hydrogen production (P) becomes the primary energy source, significantly reducing natural gas imports. Pipeline repurposing expands considerably, allowing for greater hydrogen flow, while H $\rightarrow$ G blending increases, reinforcing the shift toward hydrogen-based energy.

A key distinction is the growth of pipeline capacity for hydrogen in the Ambitious Scenario, whereas in the Moderate Scenario, repurposing remains limited. Energy storage (W) remains low in both scenarios, suggesting a preference for continuous hydrogen transport over large-scale storage.

By 2040, the Moderate Scenario retains a mixed energy system, with LNG and natural gas imports still playing a role alongside hydrogen. In contrast, the Ambitious Scenario envisions a near-complete transition to hydrogen, driven by domestic production and expanded pipeline transport. This aligns with Spain's 2050 decarbonization targets, which prioritize renewable hydrogen and a reduction in fossil fuel reliance. The extensive pipeline repurposing and increased hydrogen blending in the Ambitious Scenario highlight the feasibility of a large-scale hydrogen economy, provided there is strong policy support and investment. Following this, Figure 5 presents country-level arc capacity expansions.

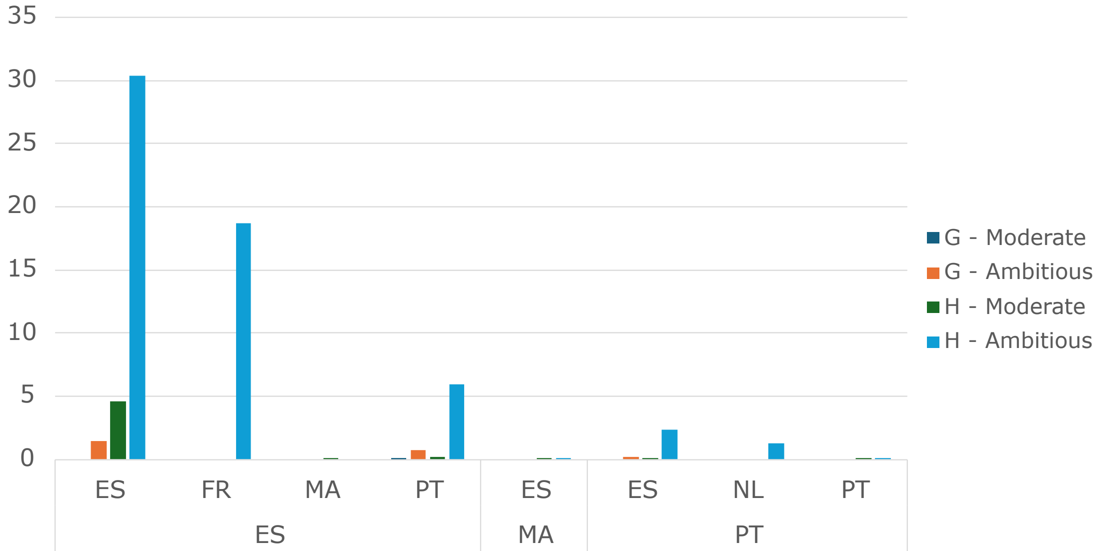

Figure 5: Country-level arc capacity expansions from 2025 to 2040 (GW).

In the Moderate Scenario, hydrogen expansion is limited, with only Spain (ES) showing a notable increase, while natural gas infrastructure remains largely unchanged. Small capacity expansions are observed in the ES-ES, ES-FR, ES-MA, and ES-PT arcs, but there is minimal infrastructure repurposing for hydrogen transport. Morocco (MA) and Portugal (PT) exhibit only modest growth in hydrogen infrastructure, reflecting a gradual transition.

In contrast, the Ambitious Scenario demonstrates a strong shift towards hydrogen transport, with significant capacity expansions in Spain and its interconnections. Spain sees the largest hydrogen infrastructure expansion, exceeding 30 GW, while France (FR) follows with nearly 20 GW, reinforcing Spain's role as a hydrogen hub. Notably, the PT-ES and ES-PT arcs also experience expansion, indicating the potential for bidirectional hydrogen trade. The Morocco-Spain (MA-ES) connection exhibits smaller-scale growth, reflecting its role in energy diversification.

A key aspect of the Ambitious Scenario is the expansion of natural gas infrastructure, particularly in Spain, where minor capacity additions are observed in gas pipelines. This could be attributed to hydrogen blending strategies (H $\rightarrow$G), where higher natural gas flows facilitate increased hydrogen blending, potentially explaining the artificially elevated gas transport capacity in some arcs. Additionally, the PT-NL shipping connection emerges, indicating the potential for maritime hydrogen trade along the Sines-Rotterdam route.

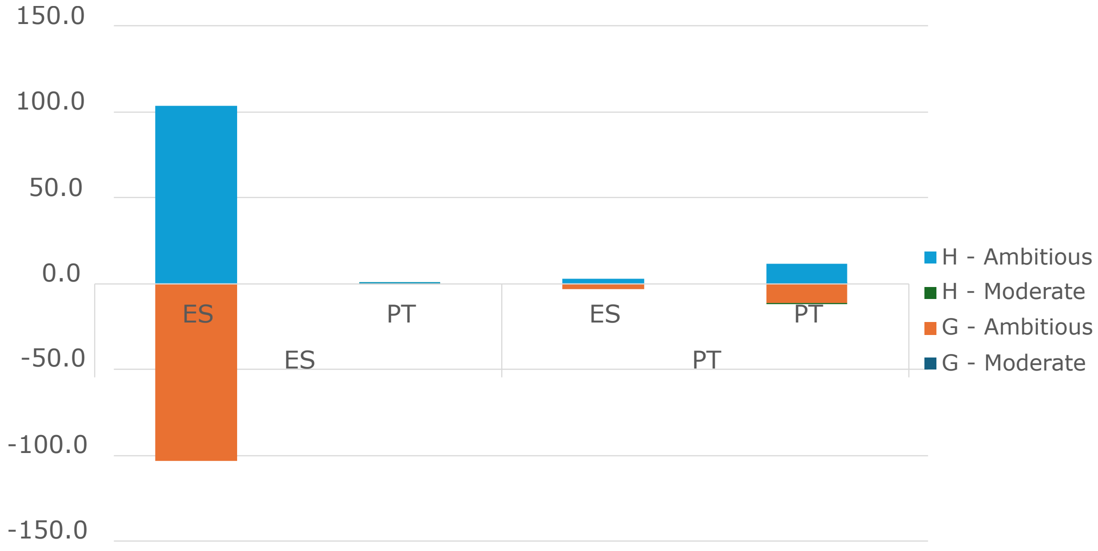

Figure 6: Repurposed arc capacity from 2025 to 2040 (GW).

Under the Ambitious Scenario, Spain undergoes the most significant transformation, with 103.5 GW of gas infrastructure repurposed for hydrogen within domestic connections (ES-ES). Portugal also repurposes 11.4 GW in the PT-ES and PT-PT arcs, though at a smaller scale. In contrast, the Moderate Scenario exhibits minimal repurposing, with only negligible shifts in PT-ES (-0.1 GW), reflecting a slower hydrogen adoption pathway.

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References

[1] N. E. M. Hub, Gas grid model (ggm), https://www.ntnu.edu/iot/energy/energy-models-hub/ggm, accessed: May 2025 (2025).