Decarbonizing the TransMED Natural Gas Pipeline Network through Green Hydrogen Blending.

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ABSTRACT –
Green hydrogen is considered as a cornerstone of global decarbonization strategies. North-Africa endowed with huge solar resources and an extensive natural gas pipeline network connected to Europe, is strategically positioned to become a major exporter of renewable hydrogen. This paper reviews the feasibility of hydrogen transport through existing Algerian natural gas pipelines e.g. TransMED. Using thermo-hydraulic models, we evaluate different blending scenarios of natural gas (NG) with hydrogen (H_2), ranging from 10% to 100%. Comparative analysis highlights technical constraints such as hydrogen embrittlement, high flow velocities, stratification and leakage risks, while identifying opportunities for gradual hydrogen integration. Results show that up to 20% H_2 blending is feasible without major infrastructure modifications, whereas higher shares and pure hydrogen transport will require extensive retrofitting.

Keywords: Hydrogen transport, TransMED gas pipelines, hydrogen blending, embrittlement, green hydrogen export, energy transition.

1. INTRODUCTION

Green Hydrogen is widely recognized as a versatile energy carrier that can enable deep decarbonization across multiple carbon hard to abate sectors, including heavy industry, power generation, long-haul transport, and residential heating (IEA, 2024; IRENA, 2024). In the European Union (EU), the **REPowerEU plan** sets ambitious targets of 20 million tonnes of hydrogen consumption by 2030, of which 10 million tonnes are expected to be imported from external partners (European Hydrogen Backbone, 2024). Given its geographical proximity, abundant renewable resources, and extensive gas infrastructure, **North Africa**—particularly Algeria and Tunisia—emerges as a natural supplier of renewable hydrogen to Europe (Boulahya et al., 2024; Alami et al., 2024). One of the main challenges in scaling up hydrogen use is the development of cost-effective and reliable transport infrastructure. Dedicated hydrogen pipelines represent the long-term solution but require high upfront investments and long construction timelines (Zhang et al., 2025; Piebalgs & Scarlat, 2025). A more immediate alternative is the **repurposing of existing natural gas pipelines** to transport hydrogen, either through blending with natural gas or through full conversion. International demonstration projects, such as **HyDeploy in the UK** (HyDeploy Project, 2023) and **GRHYD in France** (GERG, 2023), have shown that up to **20% hydrogen blending** can be achieved without major technical modifications, while higher shares introduce challenges related to flow dynamics, material compatibility, and safety (Chaczykowski et al., 2025; Nguyen et al., 2024). A growing body of literature has focused on the **technical implications of hydrogen blending** in transmission systems. Hydrogen's distinct physical properties—low density, high diffusivity, and high flame velocity—result in higher flow velocities and lower energy densities compared to natural gas, potentially impacting pipeline pressure management and compressor operations (Chen et al., 2025; Zhou et al., 2024). In addition, hydrogen embrittlement of steel, flow mstratification, leakage through seals, and acoustic vibrations have been identified as critical material and safety issues (Gangloff et al., 2024; Karakatsanis et al., 2024). Research suggests that polymer or composite liners, advanced steel alloys, and surface coatings may mitigate some of these challenges (Wang et al., 2024). From a systems perspective, techno-economic studies have demonstrated that hydrogen blending up to 20% is a cost-effective transitional strategy, while larger shares (>30%) require substantial upgrades to compressors, valves, and metering equipment (Nguyen et al., 2024; Elsing et al., 2024). A comprehensive risk assessment framework developed in the EU indicates that repurposed pipelines can be integrated into the **European Hydrogen Backbone (EHB)** with manageable safety concerns, provided that blending levels remain below 20–25% (ENTSOG, 2024; DNV, 2023). The **EHB** initiative aims to develop a 58,000 km **hydrogen pipeline network** by **2040**, with about 60% consisting of repurposed natural **gas** pipelines.

Recent strategic projects underscore the importance of **trans-regional hydrogen corridors** for securing Europe's future energy supply. Among these, the **South H_2 Corridor**, launched in 2022, is particularly relevant as it aims to connect renewable hydrogen production in the Iberian Peninsula and North Africa with major European demand centers in France and Germany. The corridor's planned capacity of 2 Mt/year, with potential to exceed 4 Mt/year, makes it a critical component of the EU's hydrogen import strategy (European Hydrogen Backbone, 2024; Rossi et al., 2024). For North Africa, participation in the South H_2 Corridor provides a unique opportunity to export hydrogen at scale by leveraging existing infrastructure such as the **TransMed**, **Medgaz** pipelines, while progressively transitioning to dedicated hydrogen transport highlighted by three converging topics:

1. **Technical feasibility**: Up to 20% hydrogen blending is achievable in existing natural gas pipelines without extensive modifications.

2. **Infrastructure adaptation**: Higher shares of hydrogen require significant retrofitting, while 100% hydrogen transport necessitates new or fully converted pipelines.

3. **Strategic alignment**: The integration of North African pipelines into the South H_2 Corridor could transform the region into a leading supplier of renewable hydrogen to Europe.

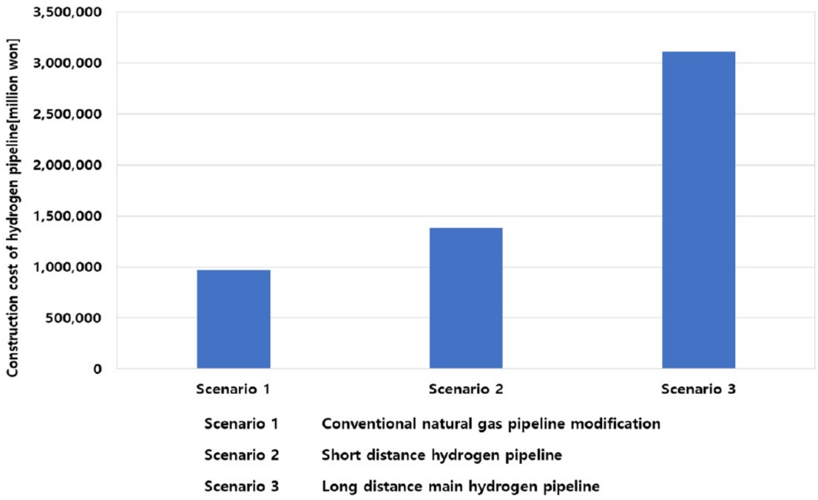

Figure 1: Construction Cost of Hydrogen Piplines based on Case Scenarios

2. METHODOLOGY

The present study investigates the thermo-hydraulic behavior of hydrogen–natural gas mixtures in a large-scale transmission pipeline through mathematical modeling and numerical simulations. The methodology combines the application of fundamental conservation equations, a realistic case study configuration, and systematic scenario analysis. Validation of the numerical framework is performed against recognized experimental benchmarks. Pipeline transport of gases is governed by the fundamental principles of mass, momentum, and energy conservation. Real gas effects are accounted for using the **Soave–Redlich–Kwong (SRK) equation of state**, which is widely applied in gas pipeline simulations for high-pressure flows (Chaczykowski, 2010). The reference case is a TransMED high-pressure natural gas transmission pipeline, 100 km in length and 46 inches in diameter. Six scenarios are defined, with hydrogen blending ratios ranging from **0% (pure natural gas)** to **100% (pure hydrogen)**. Intermediate cases (10%, 20%, 30%, 50%) allow quantification of both gradual and nonlinear effects of hydrogen injection. This comparative approach highlights how increasing hydrogen content modifies the thermo-hydraulic balance and identifies thresholds beyond which retrofitting or new design criteria are required.

3. RESULTS AND DISCUSSIONS

Simulation results confirm that hydrogen blending has a significant impact on the thermos hydraulic behavior of the studied transmission pipeline. As expected, the volumetric flow rate increases with the hydrogen content due to hydrogen's substantially lower density compared to methane. Figure illustrating the impact of hydrogen percentage on relative volume flow rate and gas velocity in the pipeline. We clearly observe a near-linear increase in volume flow rate with H_2 content and an exceedance of the safety threshold of 25 m/s at 30% H_2, confirming operational constraints.

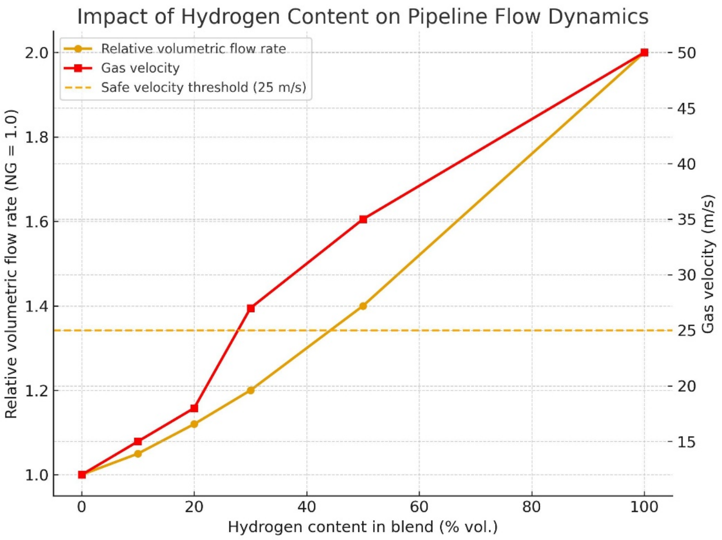

Fig.1: illustrating the impact of hydrogen percentage on relative volume flow rate and gas velocity in the pipeline

For instance, at a constant outlet pressure of 42 bar, the volumetric throughput for a 30% H_2 mixture is approximately 15–20% higher than that of pure natural gas. This increase reflects the lower energy density of hydrogen on a volumetric basis, requiring greater gas volumes to deliver the same energy content downstream. However, this higher volumetric flow translates into elevated gas velocities. While natural gas flow remains below 15 m/s in the base case, velocities progressively increase with higher blending ratios. These results indicate that although blending up to 20% H_2 appears hydraulically manageable, higher concentrations introduce challenges for flow stability and energy efficiency. Table 1 compares the different blending scenarios in terms of feasibility, infrastructure modifications, and risks.

Table 1. Summary of simulated scenarios and feasibility assessment.

Scenario	H_2 Content	Feasibility	Infrastructure Modifications	Risks
A	0% (pure NG)	Reference	None	High CO_2 emissions
B	10% H_2	Feasible	None	Minor increase in flow velocity
C	20% H_2	Feasible	Minimal upgrades	Within EU blending limits
D	30–50% H_2	Limited	Compressor adaptation, sealing upgrades	High velocity, embrittlement
E	100% H_2	Long-term	Full retrofit or new	Leakage, safety issues

	pipeline

This comparison highlights several key insights. Scenario B (10% H_2) represents the lowest-risk option, aligning with international pilot projects such as HyDeploy in the UK, where 20% blends were achieved without major issues. Scenario C (20% H_2) remains technically feasible with minimal upgrades and corresponds to blending limits already tolerated in parts of the European Union. In contrast, Scenario D (30–50% H_2) poses significant challenges: velocities exceed safe thresholds, compressors require adaptation, and the risk of embrittlement grows. Finally, Scenario E (100% H_2) is only conceivable in the long term, requiring either a full retrofit or construction of dedicated hydrogen pipelines.

CONCLUSIONS

This analysis highlights North-Africa's strong potential to position itself as a central hydrogen hub in the Euro-Mediterranean region with a unique combination of assets: a well-established natural gas export infrastructure, direct connections to European markets through Medgaz and Transmed, and abundant renewable resources that can underpin large-scale green hydrogen production. These advantages provide a solid foundation for North-Africa to play a strategic role in Europe's low-carbon energy transition. From a technical perspective, the results demonstrate that hydrogen blending of up to 20% by volume in natural gas pipelines is feasible without requiring major infrastructure modifications.

Building on these findings, this paper examined the opportunities and challenges of transporting green hydrogen through the North African natural gas pipeline network, with a specific focus on the role of the South H_2 Corridor in enabling large-scale exports to Europe, thereby contributing both to its national energy transition and to Europe's ambition of achieving climate neutrality by 2050. Success, however, will depend not only on technological adaptation but also on coherent policy frameworks, sustained investments, and strong regional cooperation.

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