FROM MOLECULE TO MARKET: GLOBAL SCENARIOS ON HYDROGEN AND NATURAL GAS INTEGRATION VIA TRADE

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Overview

Hydrogen is rapidly emerging as a flexible solution of the global energy transition, offering pathways for deep decarbonization in hard-to-abate sectors such as heavy industry, transportation, and power generation. Inspired by the development of U.S. hydrogen hubs, ambitious targets set by the EU (including the European Hydrogen Backbone plan), and growing investment in hydrogen and ammonia production in the Middle East and Asia, this study seeks to integrate these regional initiatives into a unified, global perspective. In the U.S., the Department of Energy has prioritized hydrogen development through the Hydrogen Hubs initiative. With significant federal funding, multiple hubs are being developed across the country, with the Gulf Coast region playing a pivotal role. Texas alone accounts for over 50% of the production capacity for ammonia exports, leveraging its robust natural gas infrastructure and industrial base to drive hydrogen and ammonia production. Europe's hydrogen strategy, underpinned by the European Hydrogen Backbone initiative, envisions meeting 50% of its future hydrogen demand through imports by 2030, recognizing the fact that, even in a decarbonizing world, Europe will continue relying on the international markets to meet its energy needs. This highlights the need for an interconnected network of pipelines and international trade corridors to ensure supply security and decarbonization goals. Simultaneously, the Middle East is emerging as a global leader in hydrogen and ammonia investments, leveraging its cost advantages in natural gas and renewables. Gulf Cooperation Council (GCC) countries are establishing themselves as key exporters, targeting European and Asian markets. In Asia, policy commitments from countries like Japan, South Korea, and Singapore underscore the strategic importance of hydrogen and ammonia as energy carriers to meet national decarbonization targets.

Building on previous work presented at USAEE 2024 (Baton Rouge, LA, U.S.A.) and World Gas Conference 2025 (Beijing, China), which explored hydrogen integration into natural gas networks in the U.S. and Europe, respectively, this study extends the analysis to a global framework with collaborative work from researchers and experts from U.S., Europe and Middle East. This research incorporates detailed network modeling of pipelines and value chains for hydrogen and ammonia, enabling a comprehensive assessment of cross-regional trade dynamics and market integration.

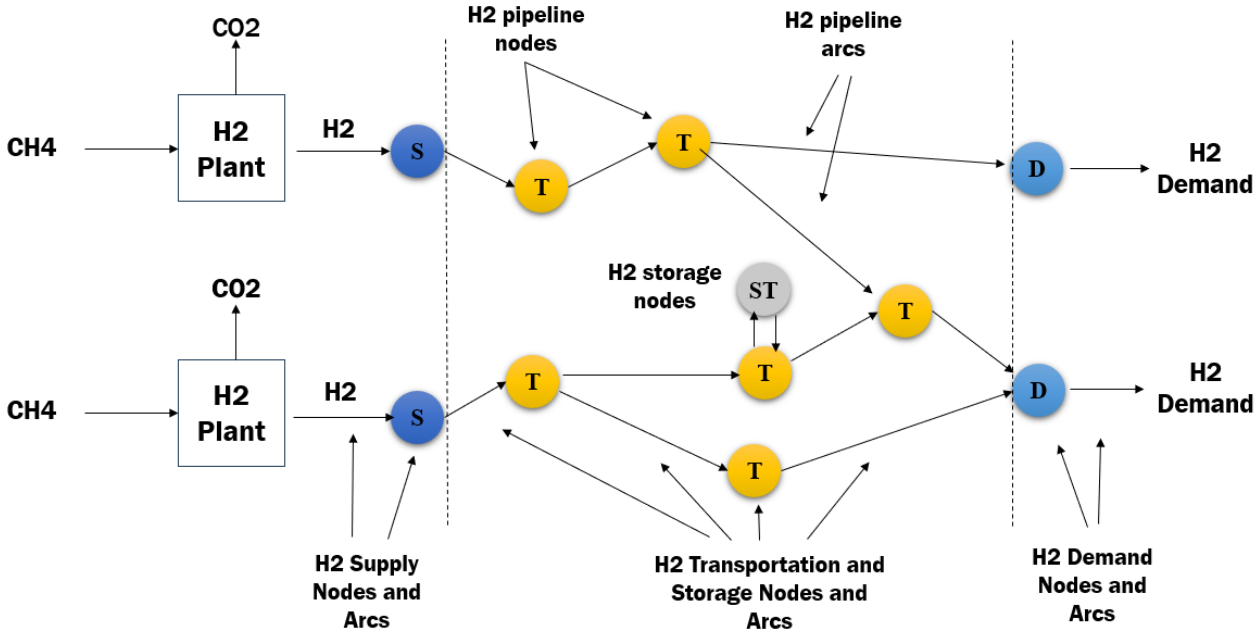

Figure 1 Network Flow Mode Including Hydrogen from Natural Gas

Methods

This study integrates regional hydrogen and ammonia developments into a global market clearing simulation model. Using the G2M2 Market Simulator, the methodology includes a detailed representation of pipeline networks, storage facilities, and production capacities for hydrogen and ammonia, drawing parallels to the existing natural gas and LNG value chains. Key features of the methodology include:

Expanded Regional Scope: The model incorporates new regions, including the Middle East and Asia, alongside the U.S. and Europe. Each region's unique production, infrastructure, and policy characteristics are represented, with a particular focus on the Middle East's export capacity and Asia's import-driven demand.

Integration of Hydrogen and Ammonia: Ammonia is modeled as a key transport medium for hydrogen, with the ability to convert back to hydrogen at destination markets. Production costs, transportation efficiency, and conversion losses are included to assess ammonia's role in global hydrogen trade.

Scenario Design: The study explores several scenarios to capture the interplay of regional and global policies, carbon pricing, and infrastructure investments. Proposed scenarios include:

1. **Green vs. Blue Hydrogen Trade**: Examining the trade-offs between green and blue hydrogen production in regions like Europe and Asia under varying carbon pricing policies.
2. **Harmonized Carbon Pricing**: Simulating global carbon pricing mechanisms and their impact on hydrogen production and trade patterns.
3. **Ammonia Trade Corridors**: Assessing the feasibility and economic implications of ammonia transport between key exporting and importing regions (e.g., Middle East to Europe, U.S. to Asia).
4. **Regional Self-Sufficiency**: Evaluating the potential for localized hydrogen production to meet regional demand, reducing the reliance on international trade.

Results

Preliminary results from the U.S. and European studies provide insights into the potential for hydrogen integration into natural gas networks. In the U.S., scenarios modeled for the Gulf Coast show that leveraging existing natural gas infrastructure reduces costs for hydrogen and ammonia transport, while federal subsidies like the 45Q tax credit enhance the economic viability of blue hydrogen production. For example, early results indicate that pipeline repurposing could lower transport costs by 30-40% compared to building new hydrogen-specific pipelines. In Europe, the European Hydrogen Backbone plan demonstrates significant cost savings through the repurposing of natural gas pipelines. However, the region's reliance on intermittent renewables for green hydrogen production necessitates substantial investment in storage to stabilize supply. Scenario analysis reveals that hydrogen storage could mitigate up to 60% of supply volatility, supporting Europe's decarbonization goals. The results of the global scenario highlight ammonia trade as a critical role in connecting hydrogen supply from the Middle East to demand centers in Europe and Asia. Ammonia's compatibility with existing LNG infrastructure provides a cost-effective alternative to direct hydrogen transport, particularly for long distances.

Conclusions

This study bridges regional hydrogen integration analyses to create a global framework for understanding hydrogen and ammonia trade dynamics. By incorporating insights from U.S. and European case studies and expanding to include the Middle East and Asia, the research highlights the interdependencies between regional markets and the critical role of infrastructure in enabling hydrogen's role in the global energy transition. The findings underscore the importance of cross-regional collaboration and coordinated policy approaches to optimize trade flows and infrastructure investments. The integration of ammonia as a transport medium further enriches the analysis, addressing key challenges in hydrogen storage and long-distance transport. Future work will refine the scenarios presented here, with a focus on quantifying the economic and environmental impacts of alternative trade and production strategies.

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