PROSPECTS OF PIPELINE INFRASTRUCUTURE DEVELOPMENT FOR HYDROGEN INTEGRATION INTO THE EUROPEAN ENERGY SYTEM TOWARDS 2050

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Overview

With the aim of reducing carbon emissions and seeking independence from Russian gas in the wake of the conflict in Ukraine, the use of hydrogen in the European Union is expected to rise in the future. As a clean and versatile energy carrier, renewable hydrogen can be produced from a wide range of renewable energy sources, including wind and solar power. This makes it a promising solution for decarbonizing not only the energy system, including heat, transportation and electricity, but also the manufacture of a wide range of chemicals, materials, and products. As such, renewable hydrogen can further reduce the reliance on fossil fuels, leading to substantial reductions in greenhouse gas emissions and a transition towards a more sustainable and low-carbon energy system. While small amounts of hydrogen might end up being produced close to the location of its utilization, larger amounts will likely imply a regional separation of production and consumption. Regions with high renewable potentials (i.e., wind (offshore) and solar) could prove to be beneficial for the production of renewable hydrogen, whereas regions dominated by industry could become the main consumers. In this regard, hydrogen transport via pipeline will become increasingly crucial, either through the utilization of existing natural gas infrastructure or the construction of new hydrogen dedicated pipelines.

By introducing sensitivities for hydrogen blending in the Global Energy System Model (GENeSYS-MOD), this paper explores how hydrogen blending options affect production, transport options, and regional localization of hydrogen generation in Europe. The study contributes to the current discussion around hydrogen utilization and transport by generating new insights to help guide the conceptualization of a European hydrogen network best fit for its future purpose.

Method

For this work, a model setup used in the Horizon 2020 project openENTRANCE is used in which low-carbon transition pathways for Europe were modeled in GENeSYS-MOD as part of an open modeling platform. The four pathways represent three very ambitious scenarios and one slightly less ambitious, yet still compatible with a 2 °C climate target, considering different political, societal, and technological developments. The Gradual Development scenario is used as the baseline in this work, representing a moderate mixture of all three dimensions. Europe is disaggregated into 30 regions (mainland EU-25, Norway, Switzerland, UK, Turkey, and an aggregated Balkan region) and a pathway from 2018 to 2050 is calculated in 5-year steps. 2018 is used as a reference year for calibration purposes. To ensure an adequate representation, hydrogen production and hydrogen transport technologies are refined within the model. This includes the possibility of retrofitting natural gas pipelines to allow hydrogen transport. In order to achieve the hydrogen blending within existing natural gas infrastructure, a new fuel (H2_blend) was added to the model formulation. Then, to address the question of how different proportions of hydrogen in natural gas pipelines affect hydrogen production and transportation infrastructure, various sensitivities in the form of model runs allowing different shares of hydrogen are computed. To do this, the model is allowed to add hydrogen (in volume) to the gas network in 5% increments utilizing a dedicated hydrogen switch in the model for each model run from 2018-2050. A model run is performed for each possible ratio from 0% (no hydrogen-blending allowed) to 100% (only hydrogen in existing gas pipelines is allowed), resulting in a total of 21 model runs.

Results

Preliminary results suggest that increasing hydrogen transport through existing natural gas pipelines has a significant effect on regional distribution and trade of hydrogen within Europe. However, the overall demand for hydrogen is highly inelastic given the high CO2 prices and emission reduction targets (100% in 2050). Furthermore, the demand for hydrogen is not very elastic due to its specific use cases and high costs compared to existing competing technologies (e.g. heat pumps and BEV). Hydrogen production and consumption still have high costs which often exceed direct electrification.

Europe's consumption of hydrogen remains similar regardless of other factors, but regional production is greatly impacted by the availability of hydrogen transportation through pipelines (see Figure 1).

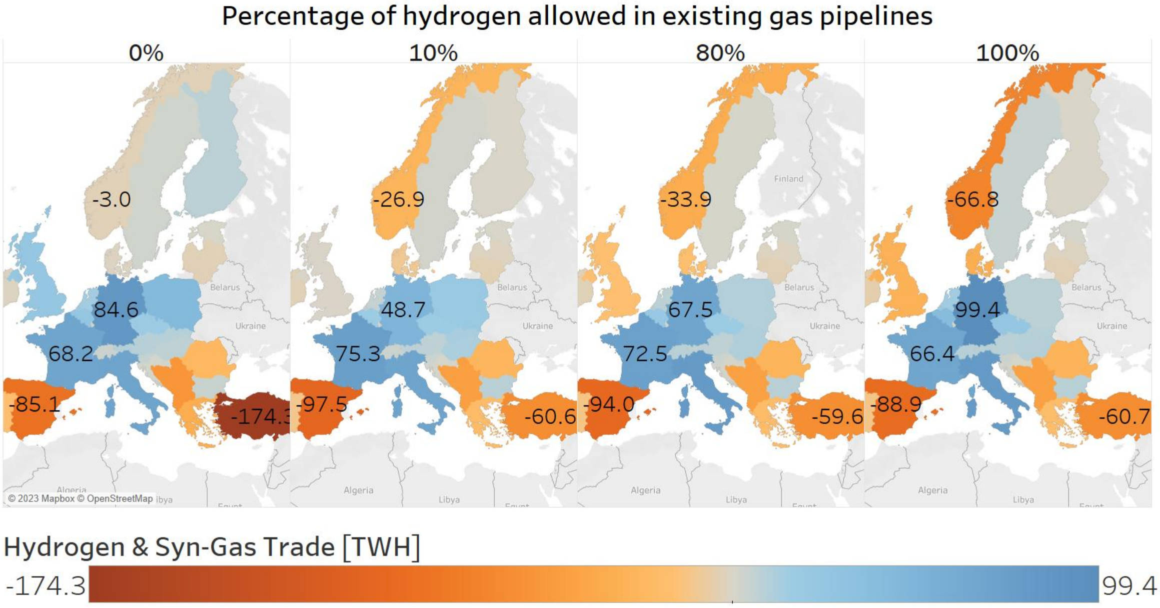

Figure 1: Hydrogen & Syn-Gas Trade at different percentages of hydrogen allowed in pipelines

With an increasing share of hydrogen in existing gas pipelines, hydrogen trading is increasing in countries with high generation potential. Simultaneously, the use of methanation, an alternative for storing and trading produced energy, is decreasing. As blending becomes more prevalent, Norway becomes a major hydrogen exporter while Turkey's significance decreases. France, Germany, and Italy are the largest hydrogen importers in 2050. However, France's imports decline while Norway stops importing as their own hydrogen production increases.

Conclusion

The addition of hydrogen to the existing energy mix does not significantly affect the production and consumption of hydrogen - even when not considering additional costs related to retrofitting. However, its impact on the location of production and the reliance on imported hydrogen, as well as the possibility of creating new dependencies, must be carefully evaluated when planning for hydrogen's future in Europe.

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