Carbon targets, technology and energy policy impacts on H2 penetration and infrastructure in the US

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Overview

This study was conducted to quantify and map hydrogen fuel distribution pathways for the continental United States reflecting technological changes, barriers to deployment, and end-use cases from 2020 to 2100. The study clarifies the key influences of hydrogen distribution methods for major population centers, the formation of trade pathways between major international and domestic energy consumption areas, and the potential impact of hydrogen deployment on sustainability and social adoption.

Methods

The methodology for this study consists of two parts: first, a linear optimization of the global energy system constrained by carbon reduction targets and system cost is undertaken to determine the potential range of hydrogen penetration and end uses in the US. Second, based on the linear optimization results, a projection of hydrogen infrastructure requirements for the US, including interconnections with the bordering nations of Canada and Mexico will be undertaken for each time-step between 2020 and 2100 of global energy system outputs. The model nodes investigated are detailed in Figure 1.

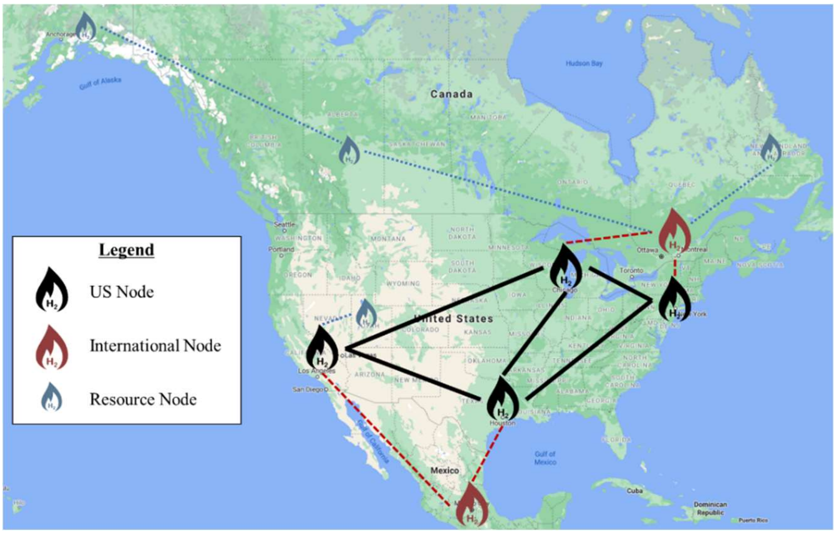

Figure 1. Node and interconnection schematic

Results

Through the linear optimization model, energy supply, system cost, carbon capture and storage (CCS) deployment and hydrogen end uses are estimated as shown in Figure 2. Building on these scenario outputs, key findings include the emergence of trade pattern diversification, with a greater variety of end uses associated with imported fuels and greater annual hydrogen consumption over time (Figure 3). In addition, sensitivity analysis identified the influence of complementary technologies including nuclear power and carbon capture and sequestration technologies.

Our energy system optimization model, cognizant of energy policy, energy technologies, carbon targets and system costs explored the potential for a growing contribution of hydrogen to the US energy system, reaching approximately 7.6% of energy needs in the year 2100. Main uses for hydrogen in the US begin solely with transportation in 2020, growing to include blending with city gas by 2050, and maturing to include electricity generation, conversion to chemical feedstocks, and exports between national nodes by the year 2100. Hydrogen's predicted role in the US energy system grows in line with an increased role for renewables, reducing energy related carbon emissions.

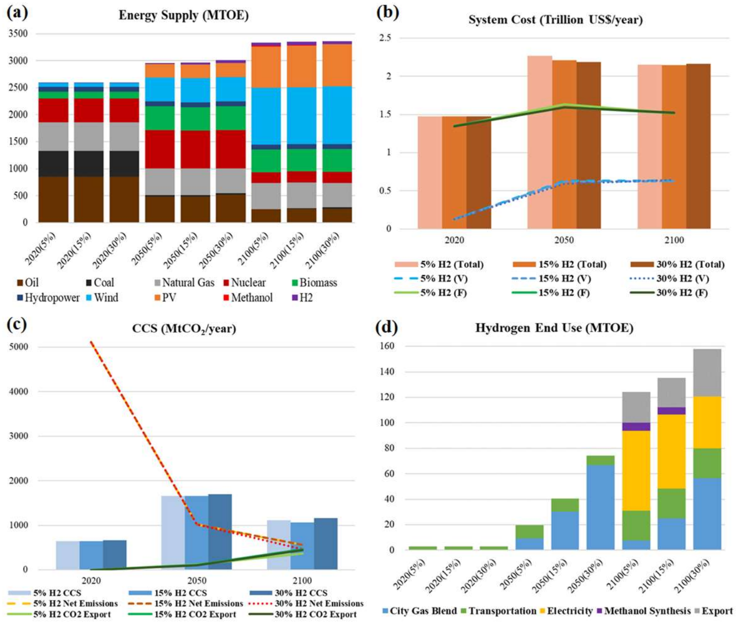

Figure 2. Baseline Scenario (a) Energy Supply, (b) System Cost: Total, Variable (V) and Fixed(F), (c) CCS, exported and overall emissions, and (d) Hydrogen End Use Outcomes

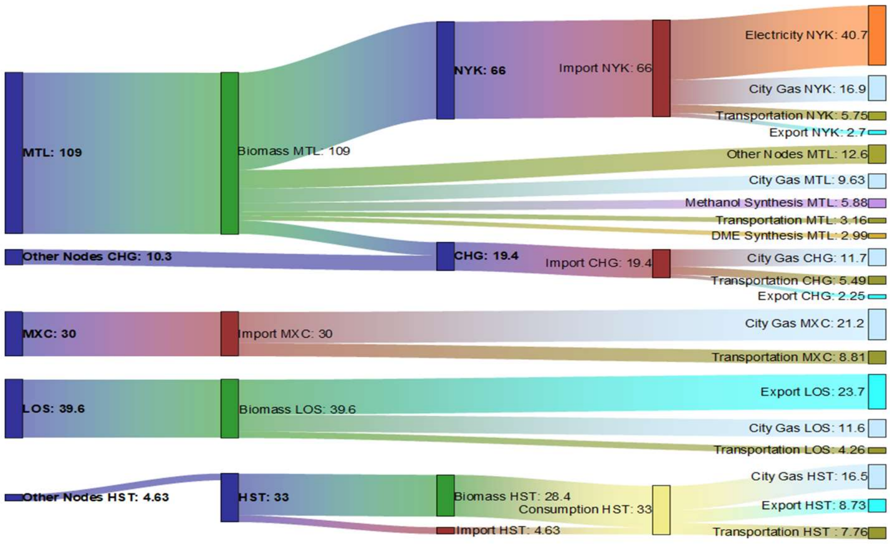

Figure 3. Modeled hydrogen production, distribution, and utilization for 2100 (MTOE)

As a result of the growth of hydrogen anticipated for the US, the need for infrastructure also changes over time. In the 2020s, refuelling stations and truck based delivery of hydrogen suffices, while post 2050, extensive use of natural gas pipelines and underground storage become necessary to underpin hydrogen based energy needs.

Conclusions

Based on our results, we conclude that hydrogen penetration into the US energy system is economically viable and can contribute toward achieving carbon reductions as outlined in the Paris Agreement by 2050, and more aggressive carbon reduction targets beyond this time. While this research identifies that hydrogen could account for approximately 7.6% of US energy needs by 2100, additional end use cases including a larger role for ammonia, the potential in industry for steel reformation, and the likelihood of hydrogen underpinning freight transportation could significantly increase hydrogen penetration as these technologies mature. Further, with the increasing cost of complementary carbon reducing measures such as nuclear power and CCS, means that their role may diminish over time, again providing the potential for an increased role for hydrogen as a cost-effective carbon reducing measure.