Challenges of Modeling Hydrogen in the U.S. Energy System

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Executive Summary

As countries focus on mid-century net-zero GHG targets, finding alternative clean energy sources and decarbonization technologies is critically important. Hydrogen, produced from renewables, nuclear, or fossil fuels with carbon capture, could be a major decarbonization pathway, *however, much more research and development is required to fully understand and appreciate* its potential in a future U.S. energy system.

This summary is from a webcast forum on the challenges of modeling hydrogen in the U.S. energy system held in late March 2022. Participants were from federal agencies, DOE research labs, and leading energy system modeling teams. The forum highlighted decarbonization technology priorities related to hydrogen and compared modeling approaches and challenges of incorporating hydrogen into the U.S. economy in the future.

DECARBONIZATION AND HYDROGEN RESEARCH PRIORITIES: COMMON THEMES

- Incorporating hydrogen technologies into energy systems models is in its initial stages and still incomplete in many models, including EIA's NEMS and EPA's TIMES.
- EIA has a robust program to add more low carbon technologies into NEMS, for example, carbon capture and storage (CCS), direct air capture (DAC), and hydrogen; however, hydrogen technology data collection has been limited but is ramping up.
- Most hydrogen is produced through steam methane reforming, so the additional technologies are in general pre-commercial, which can make modeling far more challenging.
- A competing technology to hydrogen to complement intermittent resources for electric power generation is battery storage. With electrolysis, there is a tradeoff between dedicated renewable energy for hydrogen vs. using hydrogen for grid decarbonization.
- Medium and heavy-duty trucks are one of the early candidates for hydrogen conversion. However, hydrogen's competitive value compared to electricity depends on the duty cycle of the vehicle, and the time available for recharging. Obtaining updated data on truck technology and is a priority. Additional transportation sector roles for hydrogen may include the off-road (e.g., forklifts) and marine sectors.
- Hydrogen will have opportunities in sectors difficult to decarbonize (e.g., heavy duty transportation, industry, long-duration energy storage, iron refining, synfuels).
- In addition to obtaining best available data on hydrogen technology costs and performance, other areas of research include potential environmental effects from the generation, transport, storage, and use of hydrogen. Hydrogen leakage is an area of concern and can react with other gases causing additional air pollution and greenhouse gas concerns.

- Modeling a regulatory structure differentiating between grey, blue, and green hydrogen based on CO_2 intensity is challenging (e.g., SMR has fixed CO_2 intensity, while electrolysis depends on CO_2 intensity of electricity grid).
- Environmental, social, and governance (ESG) and environmental justice (EJ) concerns related to hydrogen also will be important to address in the evaluation of various energy transition pathways.
- Full Life Cycle, GHG Accounting for hydrogen needs to be developed.

HYDROGEN MODELING CHALLENGES: COMMON THEMES

- Current uses of hydrogen are primarily refining and chemicals.
- We are modeling a market that essentially does not exist. Currently, 90 percent of hydrogen production is from Steam Methane Reforming (SMR) with no Carbon Capture and Storage (CCS). It is an appreciable step to model the rest of the hydrogen pathways in the economy, and there are gaps in our understanding of how models should incorporate future hydrogen markets.
- The utility sector may be a key application of hydrogen.
    - Hydrogen provides a different value proposition than batteries for storage. While batteries have generally equivalent charging/discharging capabilities, the combination of using electricity in electrolyzers to produce hydrogen and combustion turbines to turn it back into electricity means the rate of consumption of electricity and its production are much more nearly independent.
    - Modeling hydrogen requires evaluating production and consumption using seasonally or more granular time intervals.
- Significant uncertainties exist on various elements of the technology pathway, including production costs, the costs of many demands (such as off-road equipment), pipeline costs, and the availability of storage sites.
- Hydrogen market and H_2-production business model evolution is crucial to consider.
- The non-linear nature of the cost of capturing CO2 depending on its varying intensity in H2 production may require dynamic incentives to encourage hydrogen production.
- Water demands seem relatively low compared to most fossil technologies. It is not clear if hydrogen production will affect water scarcity anywhere, or conversely, whether water scarcity will influence hydrogen production technology choice or its geographic distribution.
- Additional modeling challenges include, but are not limited to:
    - Interaction with the electric sector is complex and need detailed dispatch representation
    - U.S. regional cost differences for electrolysis, fuel cell, storage, transport, and delivery
    - Global H_2 market interactions

- Distribution costs are challenging to identify, though best represented using levelized costs
- Effects of non-economic factors such as consumer preferences
- Impact of decarbonization on the reliability of the grid, especially with the increasing presence of inverter-based resources vs. inertial resources
- Need to model temporal demands for non-power hydrogen and develop hydrogen demand curve formulations

Forum Speakers

- Francisco de la Chesnaye, VP, Energy Strategy & Economic Policy, OnLocation, Inc.
- Jose Benitez, Dir., Div. of Systems, Economic and Environmental Analysis, Fossil Energy, DOE
- Geoff Blanford, Senior Technical Executive, EPRI: US-Regional Energy GHG Model (REGEN)
- Morgan Browning, Economist, Climate Economics, Climate Change Div., EPA
- Steve Capanna, Director, Technology Policy, Office of Policy, DOE
- Page Kyle, Research Scientist, Joint Global Change Research Institute: Global Change Analysis Model (GCAM)-USA
- Angelina LaRose, Assistant Administrator for Energy Analysis, EIA
- Chris Namovicz, Team Lead for Electricity, Coal & Renewables, EIA: National Energy Modeling System (NEMS)
- Neha Rustagi, Technology Manager, Hydrogen and Fuel Cell Technologies Office, DOE
- Daniel Steinberg, Group Manager, Economics and Forecasting, NREL: Renewable Energy Deployment System (ReEDS) Model
- Peter Whitman, Senior Consultant, OnLocation, Inc.: NEMS

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