The Hydrogen Economy

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Abstract:

Hydrogen is an energy carrier that is of considerable interest for diverse applications under decarbonization. Given hydrogen's potential role in difficult-to-decarbonize applications, including as an industrial feedstock for steel; as a highly dispatchable and storable fuel for power generation; and as an input to synthetic hydrocarbon fuel production, both the potential scale of a future hydrogen economy and the means by which hydrogen might be produced are major research areas. The hydrogen economy is currently small and dominated by refining and chemical production applications, which suggests that long-lived capital investments in both hydrogen production and hydrogen consumption could be substantial. As such, careful attention to how this buildout can facilitate just, sustainable decarbonization is warranted.

Not all hydrogen production pathways are consistent with long-term decarbonization goals. For example, although electrolytic hydrogen production capacity can produce zero-greenhouse gas hydrogen as electricity decarbonizes, natural gas-based hydrogen production with CCS cannot reach zero-greenhouse gas life cycle emissions without compensatory carbon dioxide removal. Similarly, although investing in infrastructure to use hydrogen is generally compatible with hydrogen from any source, not all hydrogen consumption pathways are consistent with long-term decarbonization goals. For example, building out infrastructure to support fractional hydrogen blending with natural gas is not a path to zero emissions unless the infrastructure is capable of accepting 100% hydrogen. Overall, the environmental benefits and potential negative impacts of the hydrogen economy, including material intensity, energy consumption, water consumption, and others, are highly dependent on the scale of the hydrogen economy. This scale is in turn highly dependent on choices like whether to deploy hydrogen selectively for extremely high value applications where there are few other options for decarbonization (e.g., grid support and steel manufacturing) versus for lower value, high volume applications where alternatives might be available (e.g., residential fuel).

Identifying hydrogen production pathways that support the necessary scale of a hydrogen economy with minimal environmental, social, and financial burdens is potentially transformative, and numerous investigations into bioinspired production pathways are underway. For example, most chemical catalysts for hydrogen conversion used in electrolyzers or fuel cells contain precious metals such as palladium and platinum, which are too rare to enable a future hydrogen economy on a global scale. Learning from nature for the development of efficient, bioinspired hydrogen conversion catalysts are potentially promising. In nature, hydrogenases catalyze the reversible oxidation of hydrogen into electrons and protons, relying on abundant transition metals such as iron and nickel. Other bioinspired approaches extend to novel hydrogen production approaches. For example, protein engineering of chimeras between photosystem (light collection, water splitting) and hydrogenases (proton reduction) in recombinant cyanobacteria enables light-driven hydrogen production that could facilitate decentralized photofermentation. Further, the development of synthetic biology tools is paving the way for the development of recombinant biorefineries that use H2 to produce a variety of chemicals. Oxyhydrogen bacteria use H2 as a cheap and atom-efficient energy source that is also sustainable when produced by electrolysis with renewable wind or solar energy.

Speakers:

Aerobic Gas Fermentation for the Production of Chemicals and Fuels
Bastian Blombach, TUM Campus Straubing for Biotechnology and Sustainability

Hydrogenases Pitfalls and Ppotential of the Biological H2 Conversion
Giorgio Caserta, Technische Universität Berlin

Hydrogen for Grid Support
Tyler Ruggles, LIFTE H2

Energy Systems Modeling including Hydrogen Deployment
Bethany Frew, National Renewable Energy Laboratory