P178 QUICK INSIGHTS

RESOURCE PLANNING FOR ELECTRIC POWER SYSTEMS

KEY INSIGHTS

- Combusting hydrogen in turbines to produce electricity is operationally similar to using natural gas but produces no carbon dioxide.
- Hydrogen can be produced from fossil fuels (with or without carbon capture) or electrolytically from water and electricity.
- Electrolysis could shift electricity seasonally by producing hydrogen when renewable energy is abundant and storing it for long durations.
- Using electrolytic hydrogen for power generation would require additional upstream power generation.
- Power generated from combusting low-carbon hydrogen would likely be expensive due to energy losses incurred in conversion steps.
- Safety concerns and technical challenges can be mitigated. Standards for safe handling of hydrogen already exist.

Hydrogen in Energy System Resource Planning

by Romey James

Hydrogen holds potential as a carbon-free fuel source for dispatchable power generation, but it presents some technical and economic challenges.

Hydrogen is a smaller molecule than methane, which makes it more prone to leaking through pipe connections and embrittling steel pipelines. Its higher flame speed and temperature result in combustion behavior different from that of natural gas. Much research is being conducted to understand the effects of hydrogen in existing pipelines and turbines.

The most significant barrier to hydrogen deployment as a utility fuel source is its economic viability. Including the Inflation Reduction Act’s Section 45V tax credit of up to $3/kg (with the bonus for low carbon intensity), replacing natural gas with electrolytic hydrogen could increase the fuel cost by between four and twelve times, with the low end of the range representing electrolysis powered by wind in a windy region and the high end by solar in a poor solar region. The less an electrolyzer runs, the less hydrogen is produced over which to spread the capital costs. The DOE target goal, Hydrogen Shot, of $1/kg by 2031 requires about 80% cost reduction. Achieving this goal will be a key enabler for hydrogen’s potential in power generation. Renewable, nuclear, and storage resources could all play a role in a hydrogen economy with both technological and cost advancements.

The US EPA recently proposed emissions standards for carbon dioxide from power plants under section 111 of the Clean Air Act. The proposal includes hydrogen blending as a best system of emissions reduction (BSER) for gas turbines, requiring baseload turbine plants without CCS to cofire 30% H_2 by 2032 and 96% H_2 by 2038.

Hydrogen production pathways

There is already a market for hydrogen in the petroleum refining and ammonia-based fertilizer industries, and most of this hydrogen comes from fossil fuels. Hydrogen can be produced by gasifying solid hydrocarbons such as coal, biomass, or plastic waste, but the most common pathway is steam methane reforming (SMR), a process in which natural gas is heated with steam in the presence of a catalyst to produce hydrogen and carbon dioxide.
Steam methane reformation: $CH_4 + 2H_2O \rightarrow 4H_2 + CO_2$
When carbon capture and sequestration is applied, these methods of hydrogen production can be low-carbon, though this is not generally the case today.

Hydrogen can also be produced from natural gas via methane pyrolysis, the biproduct of which is solid carbon rather than gaseous carbon dioxide. Methane pyrolysis: $CH_4 \rightarrow 2H_2 + C$

The "Colors" of Hydrogen
Green: Renewable electricity
Blue: Fossil fuels with CCS
Grey: Fossil fuels without CCS
Turquoise: Methane pyrolysis
Pink: Nuclear energy

Alternatively, electrolyzers can split water into its constituent parts with electricity, and this can be zero-carbon if the electricity is from renewables or nuclear.
Electrolysis: $2H_2O \rightarrow 2H_2 + O_2$

The optimal production pathway would depend on local factors such as availability of renewable energy, water, and favorable geology for CO_2 sequestration.

Thinking about hydrogen from a utility resource planning perspective

Electrolytic hydrogen would necessitate new upstream generation. For example, a 100 MW hydrogen-fired turbine facility with a 10% capacity factor could require 600 acres of dedicated solar for electrolysis. This turbine facility would output 86 GWh of peaking generation per year from 382 GWh of intermittent solar generation, over four times as much upstream power as delivered. Though the round-trip efficiency would improve from around 22% to around 37% with a base-load combined cycle turbine facility rather than a peaking simple cycle, the total energy losses and fuel expenses would be larger due to the higher capacity factor.

In addition to the cost of the hydrogen itself, resource planners must also consider the costs associated with building hydrogen transportation and storage infrastructure or converting natural gas infrastructure to handle hydrogen. Some hydrogen pipelines already exist, so there are standards and best practices. As with natural gas, underground storage is the most economical option for shifting seasonal demand of hydrogen, but availability of geology suitable for underground storage varies by region, and greater distance from storage may increase the delivered cost. Electric utilities may not need to bare these costs alone, as a broader hydrogen economy would allow the costs and benefits of hydrogen pipelines and underground storage facilities to be shared across several sectors including vehicles, buildings, and industry.

Utility planners must balance the costs and risks associated with hydrogen deployment over time. The individual elements to produce hydrogen exist today and are beginning to scale. Therefore, hydrogen use can be considered a technically viable option in future years. The commercialization driven by a future hydrogen economy is less certain, so utilities should recognize both the time and ability to deploy in an integrated approach will require significant advancement.

CONTACT
Romey James
Project Set 178A: Energy System Technology Cost, Performance, and Technoeconomic Analysis
RJames@epri.com
Contributions by EPRI's Low-Carbon Resources Initiative

FOR MORE INFORMATION
Explore EPRI's
Energy Systems and Climate Analysis
research at **esca.epri.com**
August 2023