Pathway Study for Large-Scale Hydrogen Production from Solid Oxide Electrolysis Cell Technology

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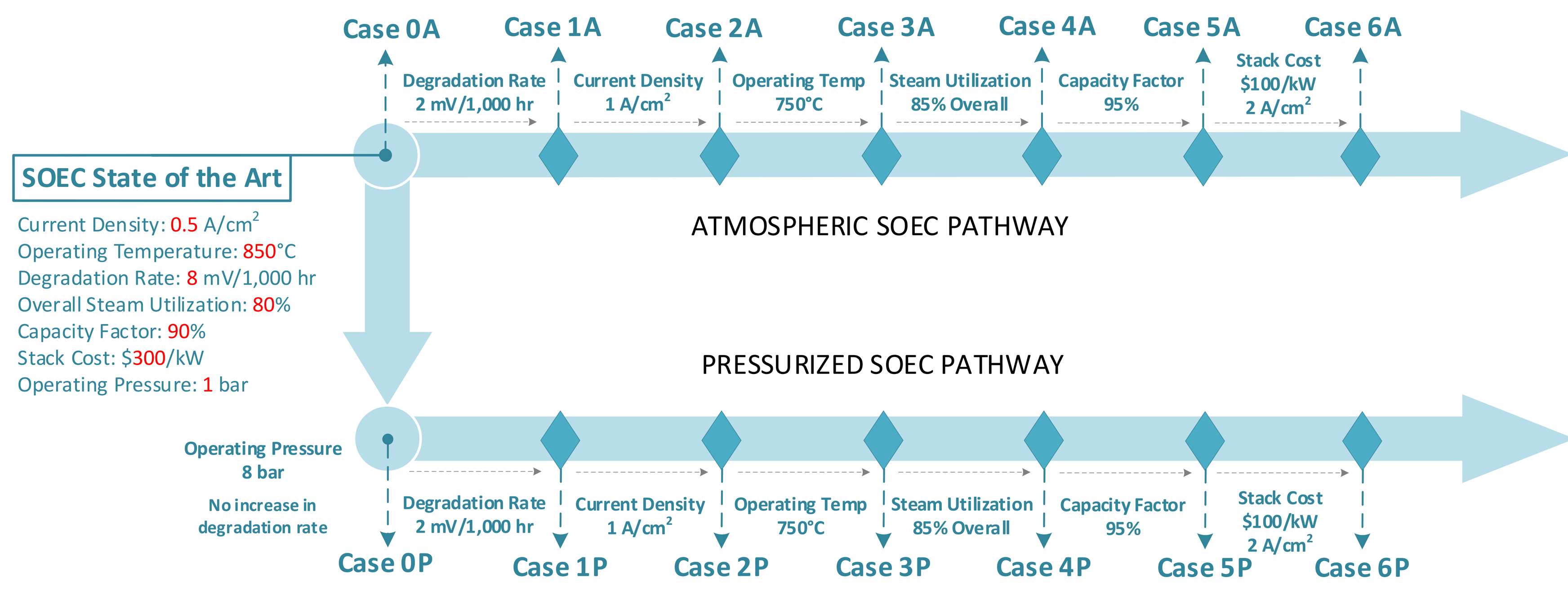
Objective

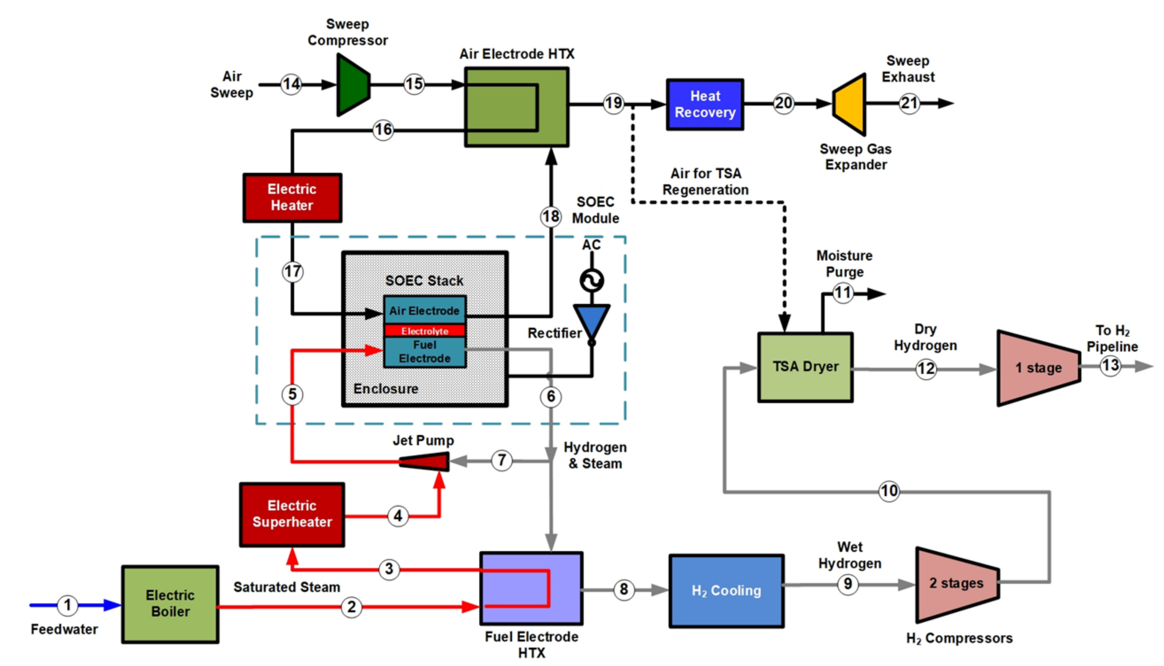
This study seeks to elucidate the research and development pathways to reach the Hydrogen Shot goal of producing hydrogen at \$1/kg or less via solid oxide electrolysis cell (SOEC) technology. Techno-economic analyses were carried out to investigate the impact of a series of stepwise technology improvements on the cost and performance of a large-scale 1 GW_e class hydrogen production plant.

SOEC Research & Development Pathway



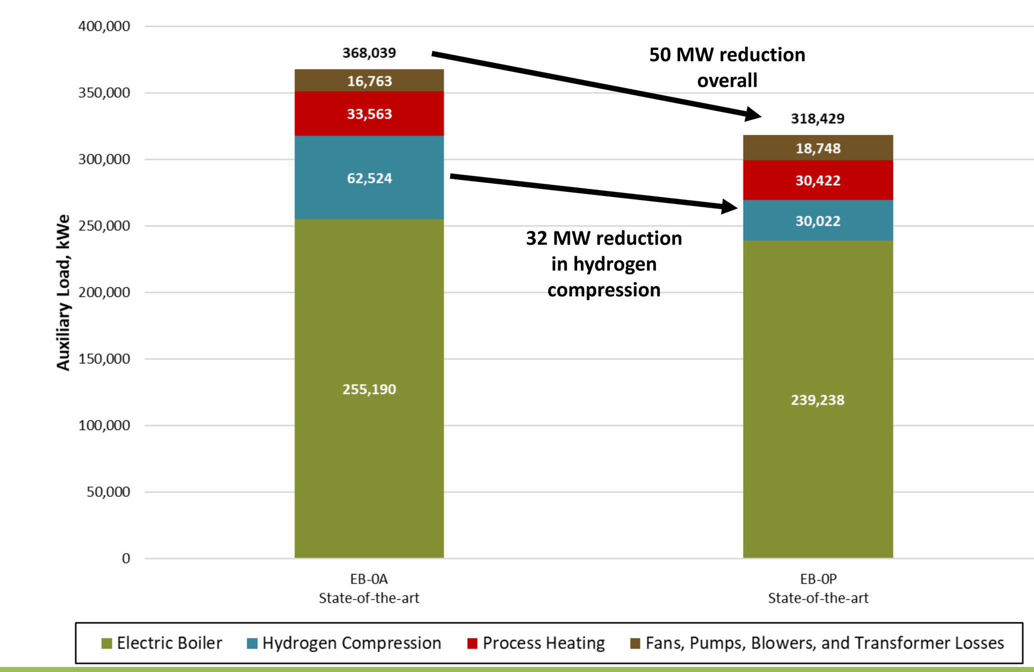
Fully electric design to produce pressurized pipeline hydrogen via electrolysis.

SOEC System Diagram



- Electrolyzer operates at thermoneutral voltage 1.28 V
- Electrolyzer power requirement =1 GW_{DC}
- All steam and heat generated by (carbon-free) electric boilers and heaters [1]
- Hydrogen purified to 99.9 vol% and compressed to 940 psia [2]

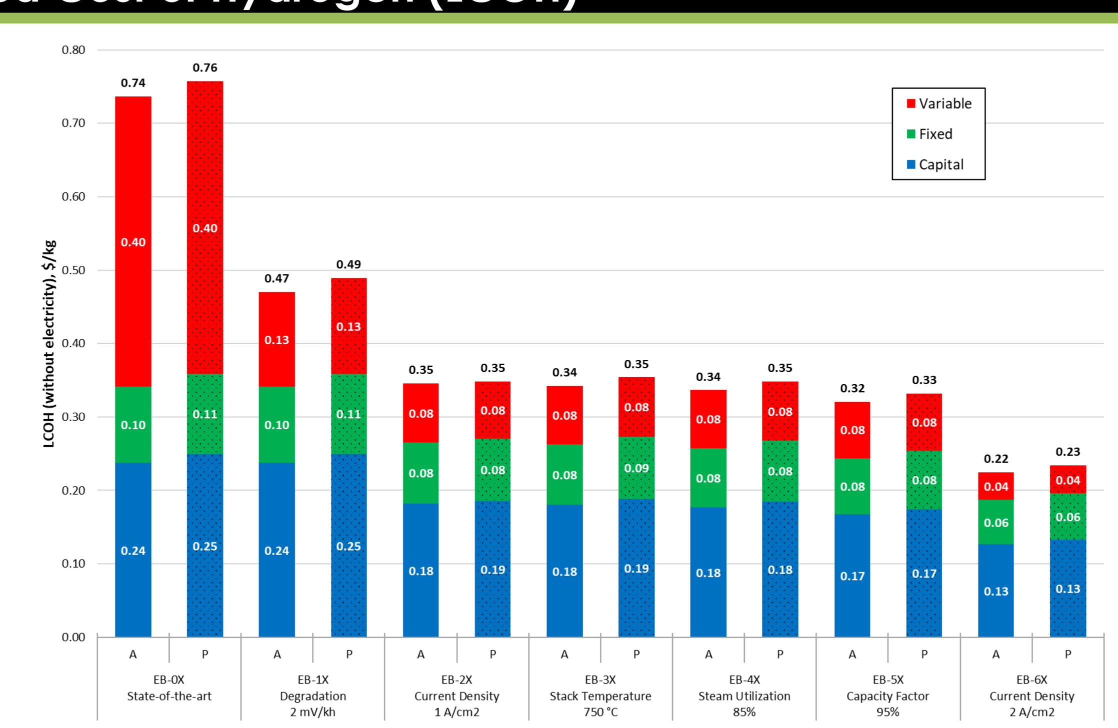
Atmospheric vs Pressurized



- Pressurized systems reduce the overall auxiliary power requirements of the system primarily through reduced hydrogen compression.
- Pressurized systems require additional components such as air compressors and pressure vessels.
- Literature sources indicate up to a four times increase in cell degradation rate for pressurized over atmospheric operation.

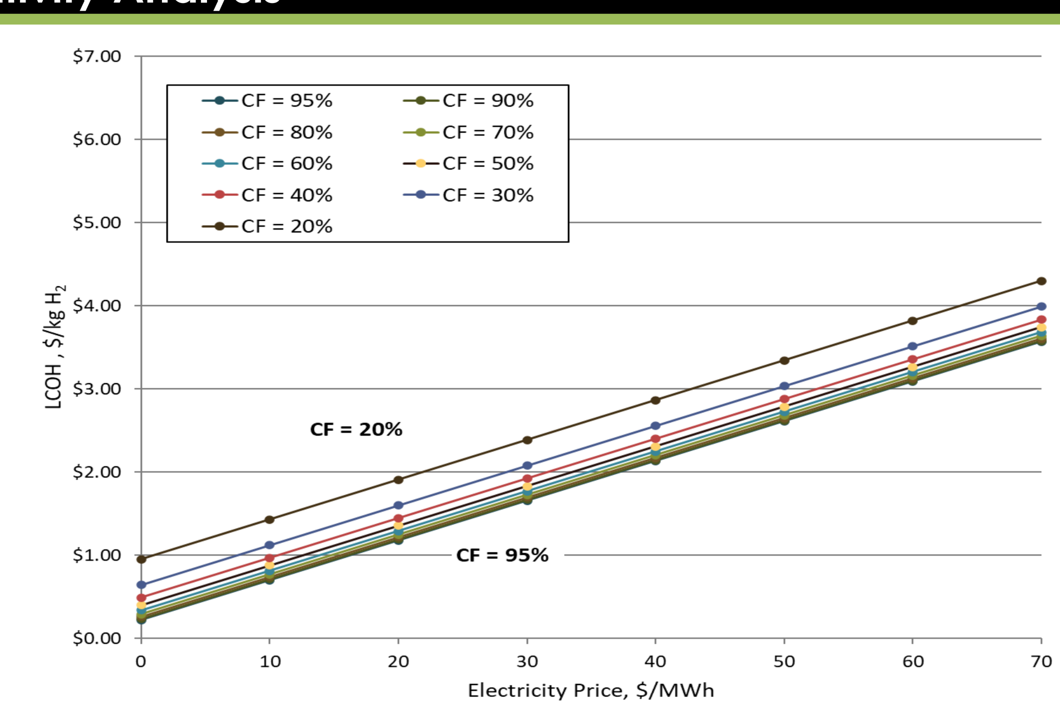
Overall Cost Target for the Hydrogen Shot Goal: \$1/kg Hydrogen

Pathway Comparisons for Levelized Cost of Hydrogen (LCOH)



LCOH for both atmospheric and pressurized cases along the pathway with electricity included (left) and electricity excluded (right).

Electricity Price Sensitivity Analysis



Electricity price needed at full capacity to reach the \$1/kg H_2 target (left). LCOH based on electricity price and capacity factor for Case 6A (right).

Results

- Electricity costs dominate the LCOH along the entire pathway with a baseline cost of \$60/MWh.
- Pressurized systems have higher capital costs but lower auxiliary loads, resulting in a net decrease in LCOH at the baseline electricity cost.
- Improved degradation rates and increases in current density are the largest technological factors for reducing LCOH.

Conclusions

- R&D efforts identified here lead to modest improvements in SOEC system performance with an LHV efficiency increase of 1 percentage point across the pathway.
- The total LCOH reduction (without electricity) over both pathways was roughly 70 %, and roughly 15 % with electricity costs included.
- Electricity prices around \$16/MWh would achieve the Hydrogen Shot goal of \$1/kg hydrogen at the end of the pathway while \$38/MWh would allow for \$2/kg hydrogen.

Discussion

- A Market study could determine which industries may be hybridized to utilize any waste heat streams to reduce the electric heater auxiliary power requirement.
- Quantification of start-up, shut-down, and stand-by characteristics of SOEC systems to study low-capacity-factor operation, which could capture instances of low power prices in a variable electricity market.

References

[1] A. Noring et al, "Techno-Economic Analysis of Reversible and Paired Solid Oxide Cell Systems for Hydrogen Production," ECS Transactions, DOI 10.1149/11106.2445ecst

[2] E. Lewis, S. McNaul et al, "Comparison of Commercial, State-of-the-Art, Fossil-Based Hydrogen Production Technologies," National Energy Technology Laboratory, Pittsburgh, April 12, 2022

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