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RESEARCH PAPER · GREEN HYDROGEN

Techno-Economic Analysis of Green Hydrogen Production via PEM Electrolysis at Grid Scale

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EXECUTIVE SUMMARY

This paper presents a techno-economic model of grid-scale PEM electrolysis across a range of electricity price and utilization scenarios. We find that utilization rate and power price together explain the overwhelming majority of levelized hydrogen cost variance across the scenarios modeled, more than electrolyzer capital cost itself, reinforcing that power procurement strategy, not equipment selection, is the primary lever available to developers seeking cost-competitive green hydrogen in the near term.

Abstract

We construct a bottom-up techno-economic model of a 100 MW PEM electrolyzer facility and evaluate levelized hydrogen production cost across a matrix of electricity price ($20 to $80 per MWh) and capacity factor (25 to 90 percent) scenarios, incorporating stack degradation, balance-of-plant costs, and water and compression requirements. Results indicate that hydrogen cost is highly sensitive to the interaction between power price and utilization, with a defined efficient frontier of price-utilization combinations that achieve cost parity with steam methane reforming under representative carbon pricing assumptions. We further evaluate the sensitivity of results to electrolyzer capital cost reduction, finding diminishing marginal cost benefit from capital cost improvement alone absent complementary gains in utilization or power cost.

Introduction

Green hydrogen produced via electrolysis powered by renewable electricity is widely regarded as a critical decarbonization pathway for sectors that are difficult to electrify directly, including heavy industry, long-haul transport, and certain chemical feedstocks. Despite significant policy support and capital commitment across major markets, the pace of green hydrogen cost reduction and project financial close has lagged early industry projections, motivating closer technical and economic scrutiny of the underlying cost drivers.

This paper isolates the relative contribution of three primary cost drivers, electrolyzer capital cost, electricity price, and capacity factor, using a bottom-up techno-economic model, with the goal of clarifying which lever developers and policymakers should prioritize to accelerate cost-competitive deployment.

Methodology

We model a 100 MW PEM electrolyzer facility using a discounted cash flow framework over a 20-year operating life, incorporating capital expenditure for the electrolyzer stack, power electronics, water treatment, and compression, alongside operating expenditure for electricity, water, maintenance, and stack replacement at a modeled 7-year interval consistent with published PEM stack degradation literature. Electricity price and capacity factor are varied independently across a defined scenario matrix, holding other technical parameters constant, to isolate their individual and combined effect on levelized hydrogen cost.

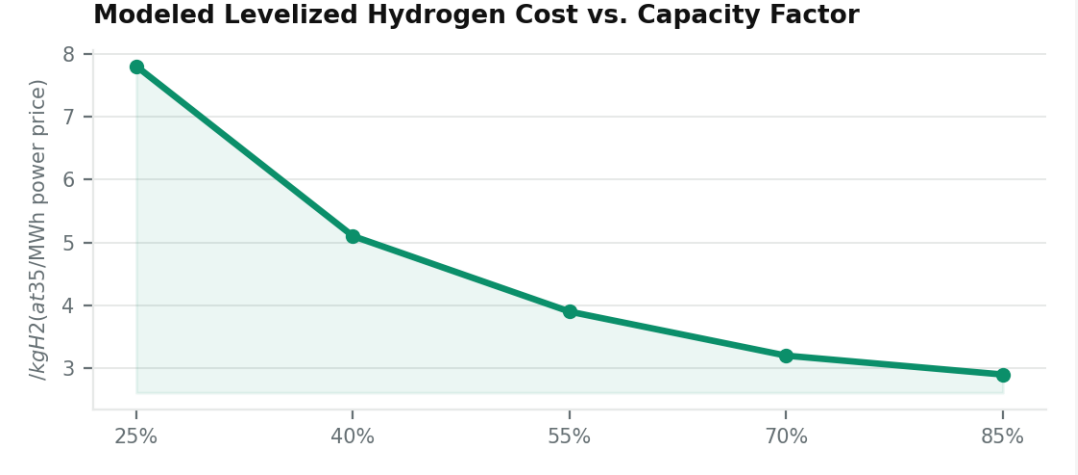
Electrolyzer efficiency is modeled at a representative 52 kWh per kilogram of hydrogen at rated output, degrading over the stack's operating life consistent with published field data, with balance-of-plant power consumption added as a fixed percentage overhead. Capital cost is modeled at a central estimate informed by recent published project cost disclosures, with sensitivity analysis applied across a plausible range to test the model's response to capital cost assumptions independent of the utilization and power price analysis.

- 20-year discounted cash flow model, 100 MW PEM electrolyzer facility
- Electricity price scenarios: $20 to $80 per MWh
- Capacity factor scenarios: 25 to 90 percent
- Stack replacement modeled at 7-year interval per published degradation data

Results

Across the full scenario matrix, levelized hydrogen cost ranges from approximately $2.10 per kilogram at the most favorable combination of low power price and high utilization, to over $9 per kilogram at the least favorable combination of high power price and low utilization. The model shows a clearly nonlinear relationship: at capacity factors below approximately 35 percent, hydrogen cost rises sharply regardless of power price, as fixed capital charges dominate the cost stack, while above roughly 70 percent capacity factor, further utilization gains produce comparatively modest additional cost reduction.

Sensitivity analysis on electrolyzer capital cost shows that a 30 percent capital cost reduction, holding power price and utilization at their central scenario values, reduces levelized hydrogen cost by approximately 11 percent, meaningfully less than the cost reduction achievable by moving from a 40 percent to a 65 percent capacity factor at constant capital cost, which reduces levelized cost by approximately 24 percent in the model.



Modeled output at fixed $35/MWh electricity price across varying capacity factor scenarios, illustrating diminishing marginal benefit above roughly 70 percent utilization.

Discussion

These results suggest that project development strategies emphasizing power procurement structures capable of delivering both low price and high utilization, such as hybrid renewable-plus-grid firming arrangements or co-location with curtailed renewable capacity, are likely to have a larger impact on near-term cost competitiveness than waiting for further electrolyzer capital cost reduction alone. This does not diminish the long-term value of continued capital cost reduction, particularly as it lowers the cost floor achievable even at high utilization, but reframes the near-term priority for project developers and policymakers designing support mechanisms.

A key limitation of this analysis is that it models a standalone facility; hub-scale deployments with shared infrastructure and diversified offtake may achieve more favorable utilization profiles than an individual facility optimizing against a single power contract, a dynamic we identify as a priority area for follow-on research using a multi-facility hub model.

References

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