Hydrogen from Next-generation Electrolyzers of Water

U.S. DEPARTMENT OF ENERGY

Project ID # P196D

H2NEW: Hydrogen (H2) from Next-generation Electrolyzers of Water LTE Task 3c and 9ciii: System and Technoeconomic Analysis

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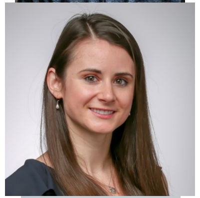
Washington D.C., United States

Task 3c team members

Alex Badgett (NREL):
Subtask lead

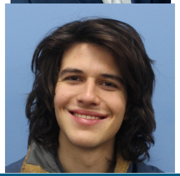
Bryan Pivovar (NREL):
H2NEW director, subtask co-lead

Joe Brauch (NREL):
Electricity supply modeling
Bottom up cost modeling



Lauren Sittler (NREL):
Aspen modeling

Chris Skangos (NREL):
Balance of plant cost analysis



Colby Smith (NREL):
Liquid alkaline modeling

Rajesh Ahluwalia (ANL):
Subtask co-lead
Performance modeling lead

Xiaohua Wang (ANL):
Performance and durability model development

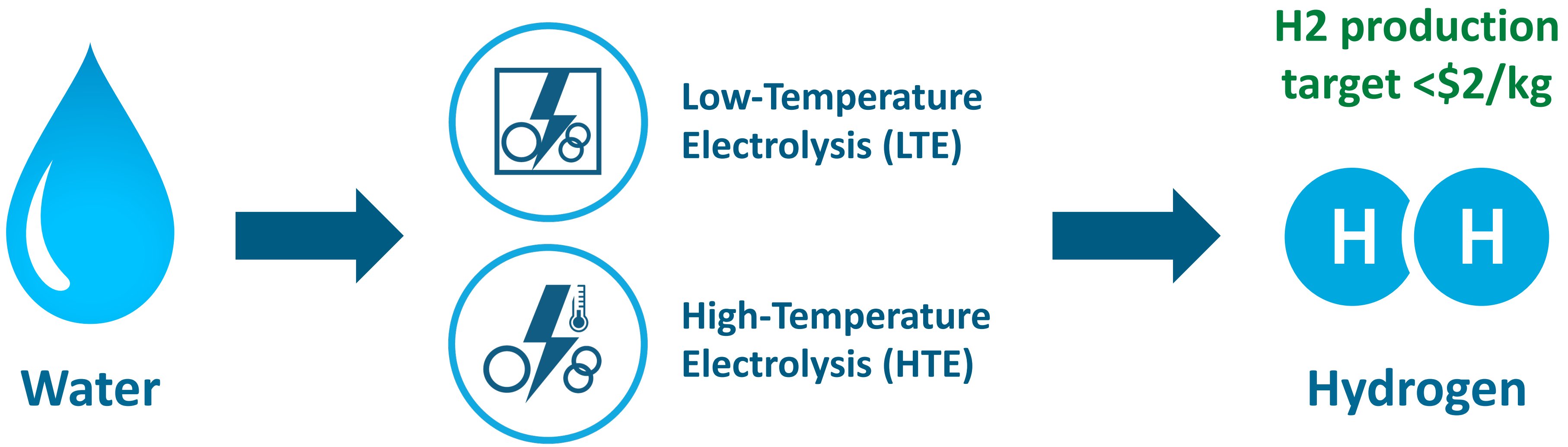
Dionissios Papadias (ANL):
Life cycle analysis

Luke Johnson (ANL):
Performance modeling

Samuel Kazmouz (ANL):
Performance modeling

Project Goals

Goal: H2NEW will address components, materials integration, and manufacturing R&D to enable manufacturable electrolyzers that meet required cost, durability, and performance targets, simultaneously, in order to enable \$2/kg hydrogen.



H2NEW has a clear target of establishing and utilizing experimental, analytical, and modeling tools needed to provide the scientific understanding of electrolysis cell performance, cost, and durability tradeoffs of electrolysis systems under predicted future operating modes

Overview

Timeline and Budget

- Project start date: 10/1/2021
- FY21 DOE funding: $400K ($275K NREL and $125K ANL)
- FY22 DOE funding: $400K ($275K NREL and $125K ANL)
- FY23 DOE funding: $900K ($550K NREL and $350K ANL)
- FY24 DOE planned funding: 1.225M ($825k NREL and $400k ANL) (alkaline and PEM)

Barriers/targets

- Developing affordable, reliable, and efficient electrolyzers
- $2/kg green hydrogen production

Partners

- Project lead: Bryan Pivovar (NREL)
- Task Leads: Alex Badgett (NREL) and Rajesh Ahluwalia (ANL)

Impact and Relevance

- Supporting development of appropriate H2NEW LTE stack cost, performance, and durability targets by:
  - Linking R&D measurements and objectives to performance and economic impacts
  - Providing operating conditions and cycles for consideration and testing
  - Highlighting operating requirements and manufacturability
- Evaluating cost, performance, and durability tradeoffs to determine optimum LTE deployment and operations to achieve $2/kg and $1/kg levelized cost of hydrogen production in renewable energy integration scenarios
- Involves optimization across multiple capabilities
  - System performance and durability assessment
  - Bottom-up manufacturing cost assessment
  - Systems analysis including interactions with the electricity grid and direct connection to renewable energy generation

Approach: Interfaces Between H2NEW Research Areas and Levelized Cost Targets

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H2NEW task 3c activities

- Levelized cost modeling
- Electricity market analysis
- Systems analysis

Key hydrogen levelized cost factors

- Electrolyzer capital cost
- Electricity price and operating strategy
- Performance and durability

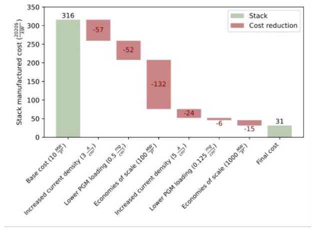
1 Dollar

1 Kilogram

Hydrogen levelized cost $/kg H2

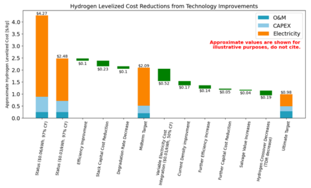
Experimental R&D

Outline: Key Areas of LTE Technoeconomic Analysis in H2NEW Included in this Poster



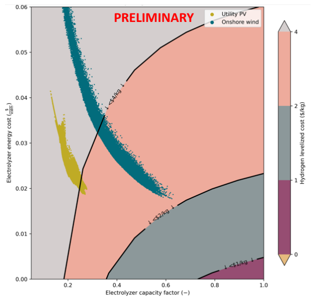
Bottom up PEM Electrolyzer Cost Modeling

Slides 8-11



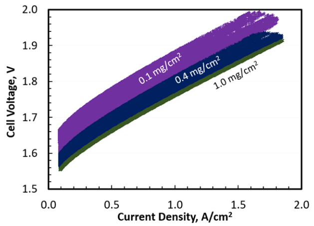
Economic Parameterization Analysis for Liquid Alkaline Electrolyzers

Slides 20-27



Analysis of Levelized cost of Hydrogen from PEM Electrolyzers

Slides 12-15



Integration of Performance Degradation in TEA for PEM Electrolyzers

Slides 16-19

Focusing technoeconomic analysis on these topics supports consortium work on evaluating cost, performance, and durability tradeoffs to determine optimum LTE deployment and operations. These learnings inform strategies to achieve $2/kg and $1/kg production cost targets in renewable energy integration and future grid scenarios.

Accomplishment: Recent Bottom-up Cost Analysis for PEM Electrolyzers Stack Focus

https://www.nrel.gov/docs/fy24osti/87625.pdf

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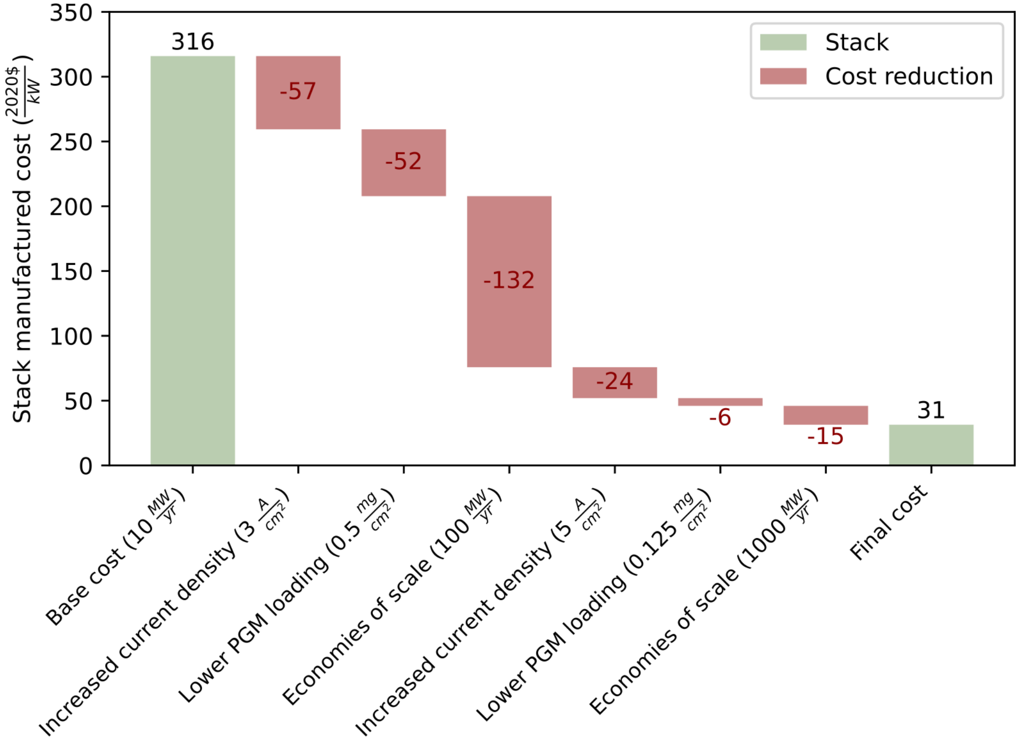
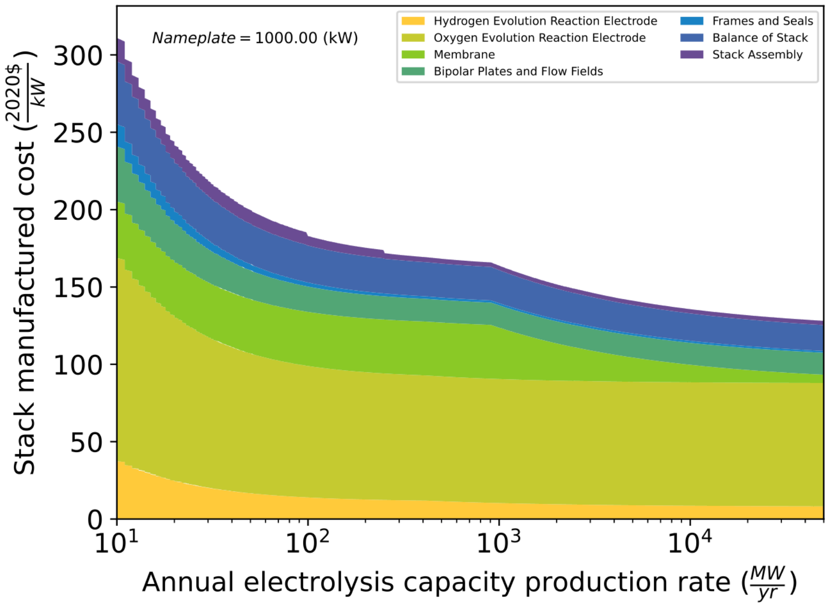
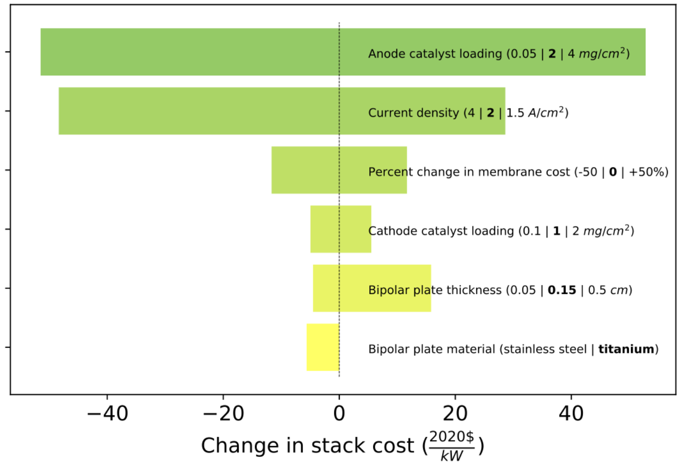
Waterfall chart analysis outlines strategies to reducing stack manufactured costs such as lower PGM loadings, higher current densities, and manufacturing economies of scale





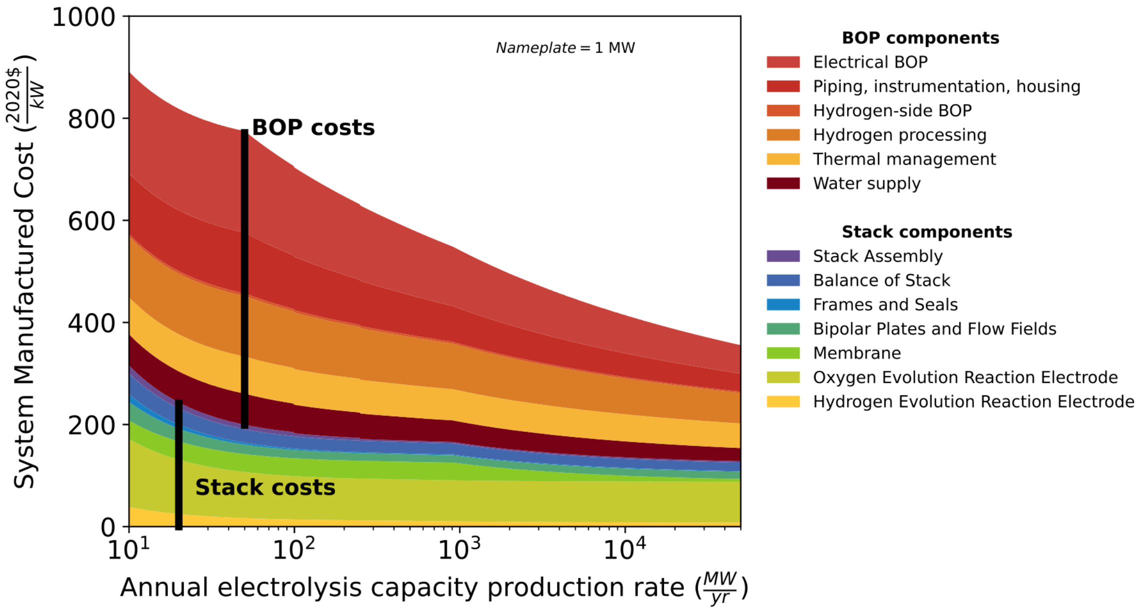
Platinum group metal used on the anode (Iridium) and cathode (Platinum) are large components of stack costs at scale, along with membrane costs



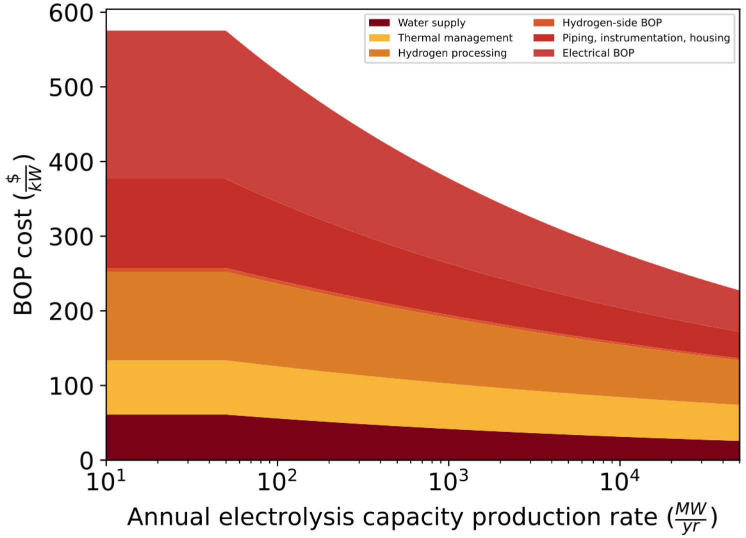
Stack sensitivity analysis outlines key cost drivers and relative magnitude of changes in each

Accomplishment: Recent Bottom-up Cost Analysis for PEM Electrolyzers Balance of Plant (BOP) Focus

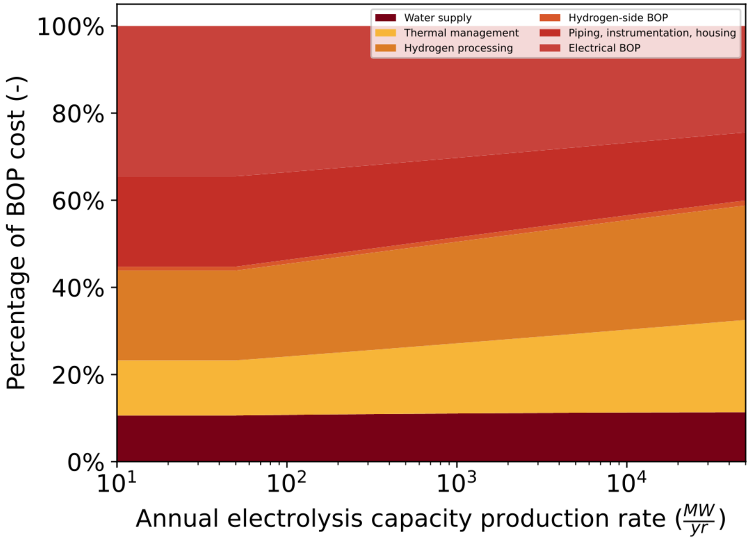
Balance of plant (BOP) costs are a large portion of total system manufactured cost



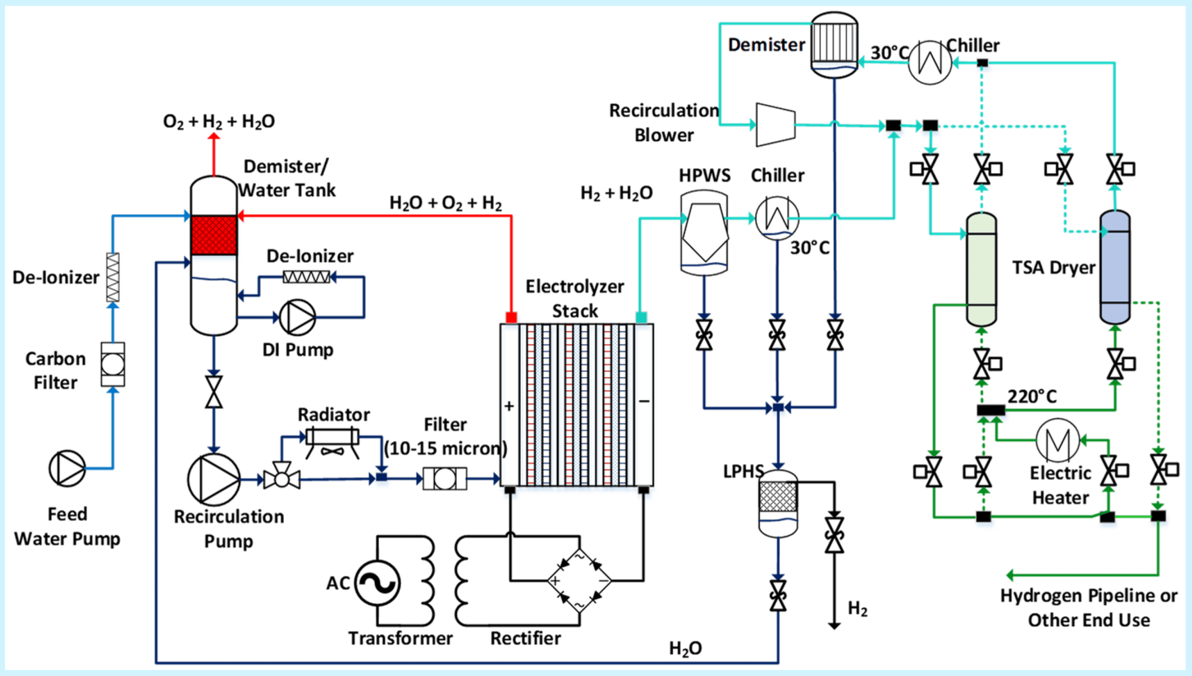
Assumed manufacturing economies of scale for 1 MW stack BOP components suggest notable cost reductions at GW scales, lowering total cost and shifting the largest components of BOP cost

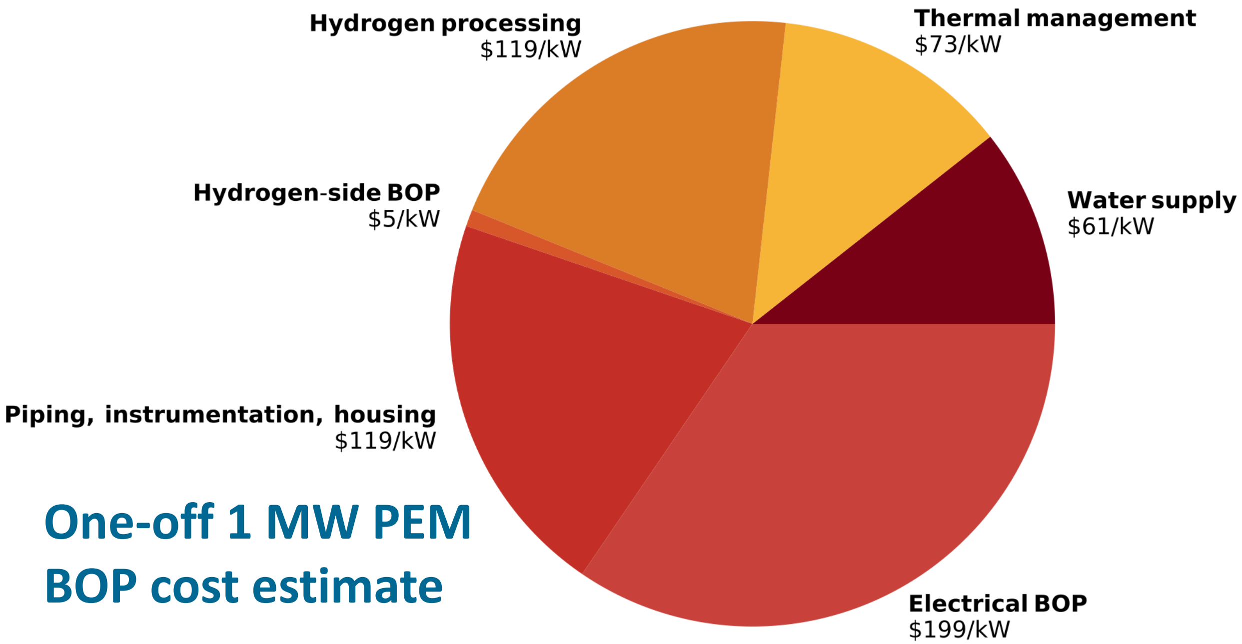


Current work focuses on estimating GW scale BOP costs and future work could focus on key BOP components such as power electronics



Approach: Modeling PEM BOP Costs at Scales Beyond 1 MW





One-off 1 MW PEM BOP cost estimate

- A need remains to understand the cost-reductions feasible from optimizing the stacks' supporting Balance of Plant (BOP) equipment and operation
- Recent work shows that for a 1 MW system, BOP is a large contributor to system costs, especially as stack costs drop
  - Stack cost reduction alone is probably not enough to reach targets; BOP cost reduction is needed
  - Economies of scale is a key opportunity for cost reduction that is not well quantified
  - Flexible operation at BOP turndowns is a key impact that is not well quantified
- Directed through Task 3c, this work will quantify the $/kW costs of BOP equipment at various plant system scales: 1 MW -> 1 GW

Results: ASPEN HYSYS model development

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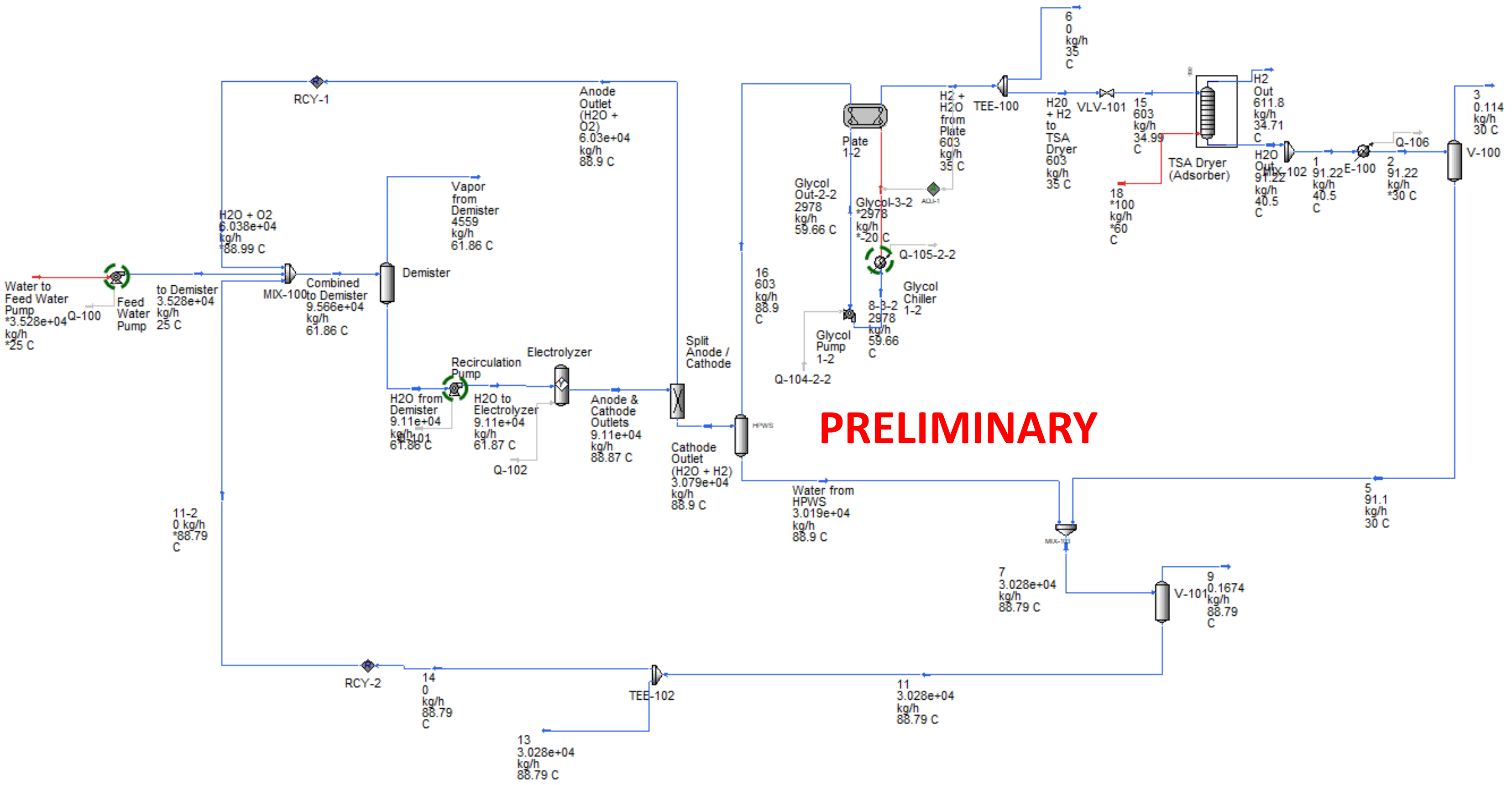
- Utilizing the previously developed BOP for a 1 MW PEM system, a more sophisticated, rigorous, and adaptable process flow model is being developed in ASPEN HYSYS
- This ASPEN HYSYS model takes advantage of rigorous equipment sizing based on material and energy flows, physics-based equations of state, and plant flowsheet design
- Using this equipment sizing, associated equipment costs are calculated through Aspen Capital Cost Estimator leading to a $/kW for capital/operating costs, and installation cost



Accomplishment: Outlining Future Work Opportunities for BOP Cost Analysis

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Current Modeling Capabilities

Detailed support unit operation equipment design modeling
Equipment of Critical Interest:
- -Pumps
- -Water Purification
- -Heat Exchangers
- -Hydrogen Separators

Equipment Designs will be driven by cell/stack performance & the optimum cost option

Scale-up system process modeling
- Initialize at 1 MW scale, then determine increased plant scales
-Understand equipment sizing and replacement cost implications

Dynamic Operation
BOP design for scenario case studies:
- Centralized Steady-State Operation
- Modular Dynamic Wind & Solar Operation
- Remote Rapid Response
- Centralized Dynamic Operation

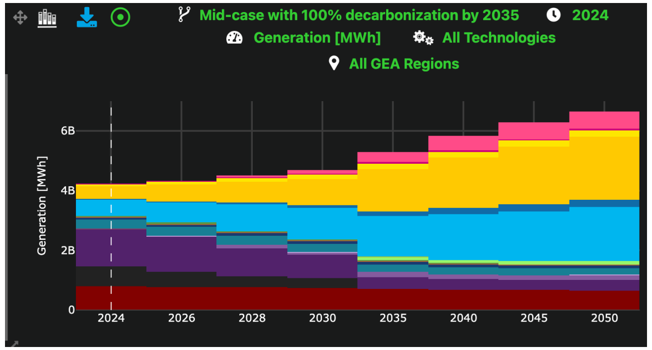
Rigorous PEM BOP System & Cost Model

Increasing Model Sophistication

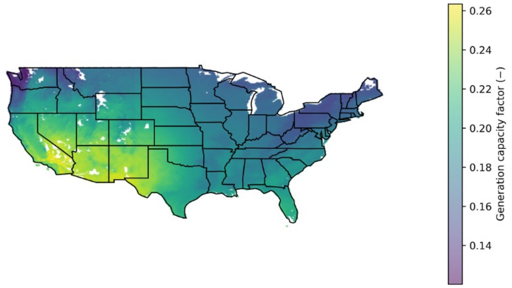
Approach: PEM Levelized Cost Analysis for Future Electrolyzers

Nationwide renewable and grid cost of energy and capacity factor datasets

Grid tied: NREL Cambium tool



Renewables: NREL NRWAL tool



PEM electrolyzer cost and performance trajectories 2022-2050

Consistent with other HFTO funded analysis work in progress

Discounted cash flow analysis frameworks

ProFAST used for cash flow modeling

H2A-Lite used for manual validation of results

Results: Contour plot for electrolyzer year and scenario showing possible levelized costs when grid tied or connected to renewables

Accomplishment: PEM R&D Advances can Enable Lower LCOH when Directly Connected to Wind or Solar Generation

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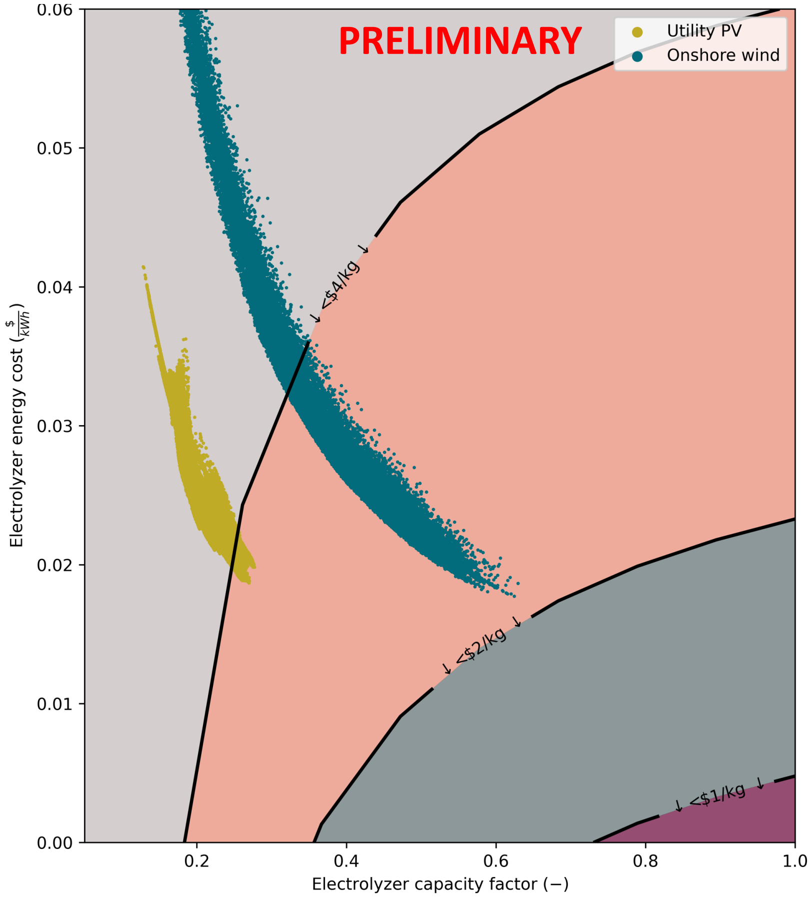
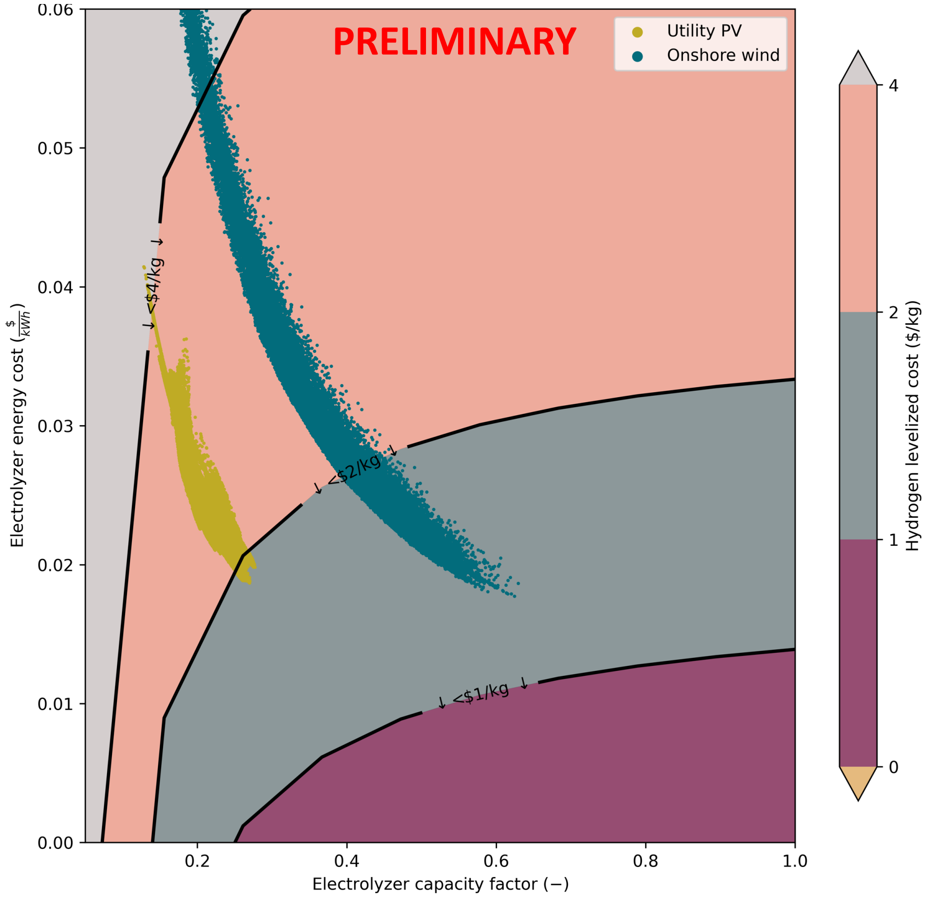
R&D advances including lower capital cost and degradation rates and improved efficiencies could enable significant progress towards $2/kg for direct connection to wind or solar.

The simplified renewable connected systems shown here assume a 1:1 wind or solar generation to electrolyzer nameplate power and it is likely that hybridized systems or those that can utilize supplemental grid power could achieve lower LCOH.



Energy source: wind or solar direct connection
Electrolyzer uninstalled cost: $640/kW
Electrolyzer stack degradation: 3.0 mV/khrs
System efficiency: 52 kWh/kg H_2



Energy source: wind or solar direct connection
Electrolyzer uninstalled cost: $150/kW
Electrolyzer stack degradation: 2.0 mV/khrs
System efficiency: 46 kWh/kg H_2

Accomplishment: R&D Advances on Durability and Capital Cost could Enable Grid Integrated PEM Electrolyzers to Produce Hydrogen at Costs Near Targets

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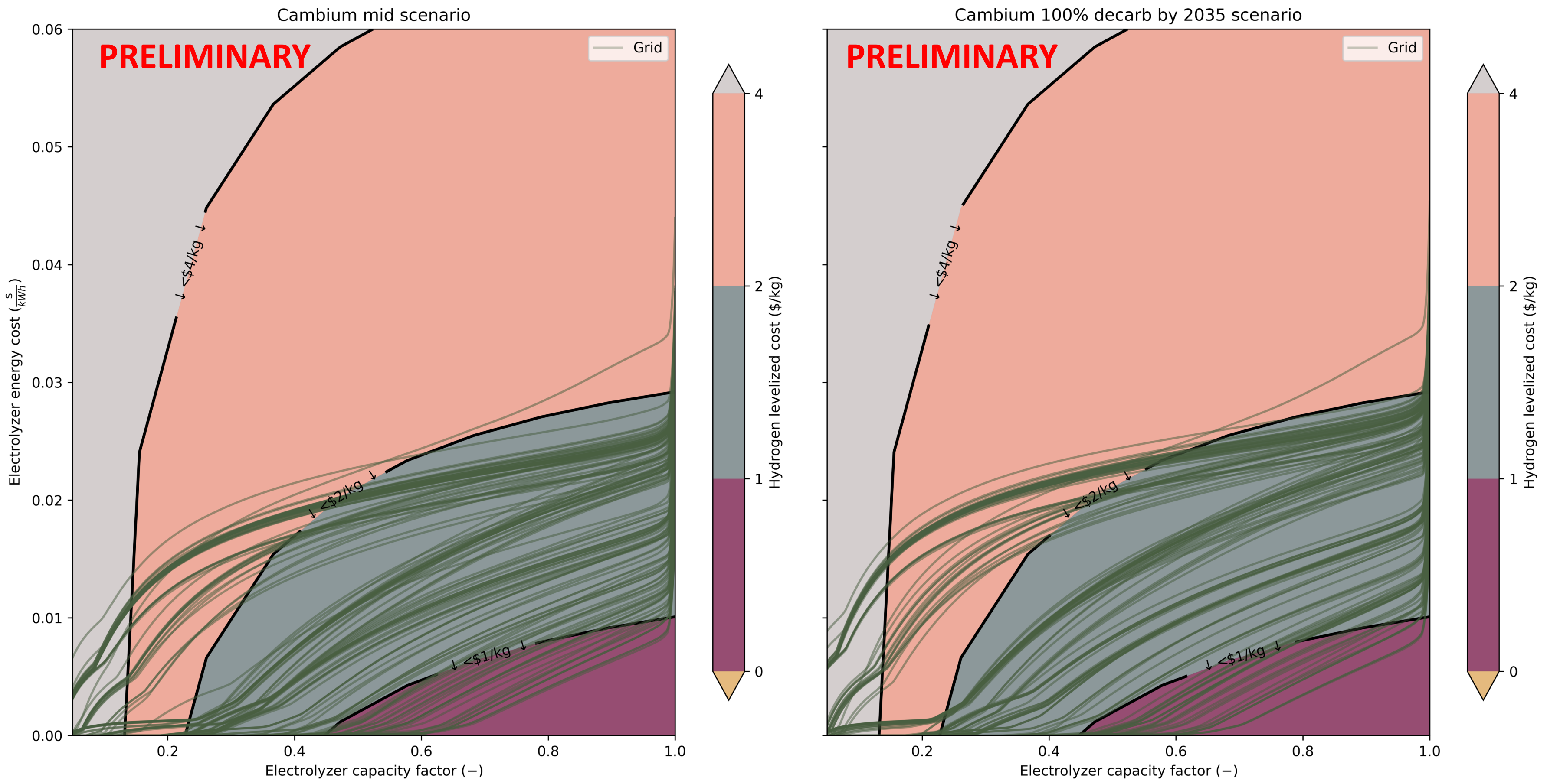
Curves of energy cost and capacity factor are estimated based on optimized operating strategies using hourly energy costs provided by NREL Cambium model for year 2030. Each curve represents one of >100 ReEDS model balancing regions.

Low energy costs at the busbar estimated by Cambium could represent opportunities for grid-tied electrolyzers to produce hydrogen at LCOH near the $2 and $1/kg targets but require R&D advances



Energy source: grid integrated, hourly pricing
Electrolyzer uninstalled cost: $640/kW
Electrolyzer stack degradation: 3.0 mV/khrs
System efficiency: 52 kWh/kg H_2

Accomplishment: Summarized Impacts of PEM Electrolyzer R&D on LCOH for Renewable and Grid Integrated Systems

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- **R&D advances in electrolyzer performance and cost are crucial to enabling progress to $2 by 2026 and the ultimate hydrogen shot goal of $1/kg**
- Simplistic direct wind or solar connected electrolyzers come close to achieving $1/kg by 2030 for Breakthrough scenario
- Further cost optimization is likely possible by varying generation to electrolyzer nameplate capacities but depends on the electrolyzer capital cost
- If able to access wholesale hourly pricing, grid integrated electrolyzers could produce hydrogen at lower levelized costs, increasing likelihood of achieving $2/kg and $1/kg targets
- Possible avenues to further cost optimization for renewable connected electrolyzers:
  - Hybridized wind/solar systems
  - Renewable + electrolyzer + grid systems

Approach: Improved Representation of Degradation in PEM Electrolyzers Resulting from Dynamic Operation can Provide more Realistic Analysis Results (Ongoing, completion Q3 FY24)

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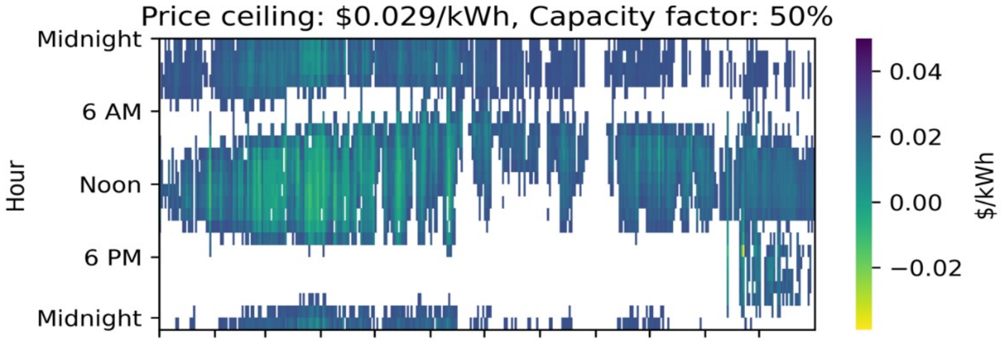
- Previous work for H2NEW has shown that dynamic electrolyzer operation could allow for low-cost electricity, which is key to low-cost hydrogen.
  - Electrolyzers tied to variable wholesale markets could shut off or turn down during high-cost hours.
  - Electrolyzers tied to renewable resources will need to be able to follow dynamic generation profiles to avoid costly batteries.

This dynamic operation has the potential to exacerbate degradation. **Previous H2NEW work** (along with many similar studies outside of H2NEW) **is based on high-level assumptions about degradation and when completed this task will update those results with new insights.**

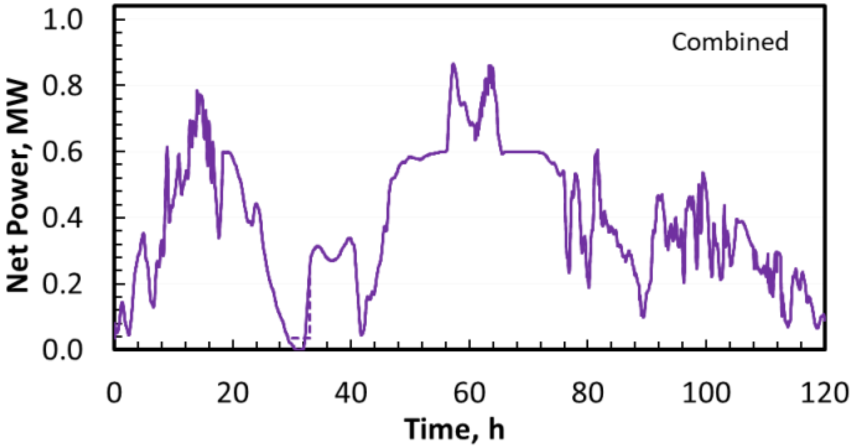
Operating profile for dynamic grid pricing



Historical locational marginal prices from wholesale market in Palo Verde, CA. Colored regions mark low-cost hours when an electrolyzer could operate, and white regions show high-cost hours when an electrolyzer could shut off or turn down to lower its electricity costs.

Badgett, A., Ruth, M. and Pivovar, B. (2022) 'Chapter 10 - Economic considerations for hydrogen production with a focus on polymer electrolyte membrane electrolysis', in Smolinka, T. and Garche, J. (eds) *Electrochemical Power Sources: Fundamentals, Systems, and Applications*. Elsevier, pp. 327–364.

Operating profile for hybrid wind-solar system



Even a hybrid wind-solar system has dramatic amounts of variation in power generation which would be passed to the electrolyzer. Without a battery or grid connection, the electrolyzer operation must follow this profile.

Status/Approach: NREL and ANL Analysis Model Interfaces

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KEY DATA INPUTS

- **Electricity profiles**
  - Hourly grid prices
  - Wind/solar profile + LCOE
- **Electrolyzer specifications**
  - Uninstalled cost, replacement cost, salvage value
  - Performance and degradation

Interfacing with ANL's model to capture degradation more accurately

SYSTEM MODEL

"Logic-based" inputs or model calculations:

- Operating profile based on maximum electricity price, minimum turndown, etc.
- Stack replacement schedule, e.g., from degradation threshold

Key stack/system model outputs:

- Hydrogen production
- Stack degradation
- Electricity used

FINIANCIAL MODEL

Financial inputs/assumptions:

- Installation costs and other adders for overnight CAPEX
- OPEX
- Interest, debt, equity, and tax assumptions

Key financial output: LCOH

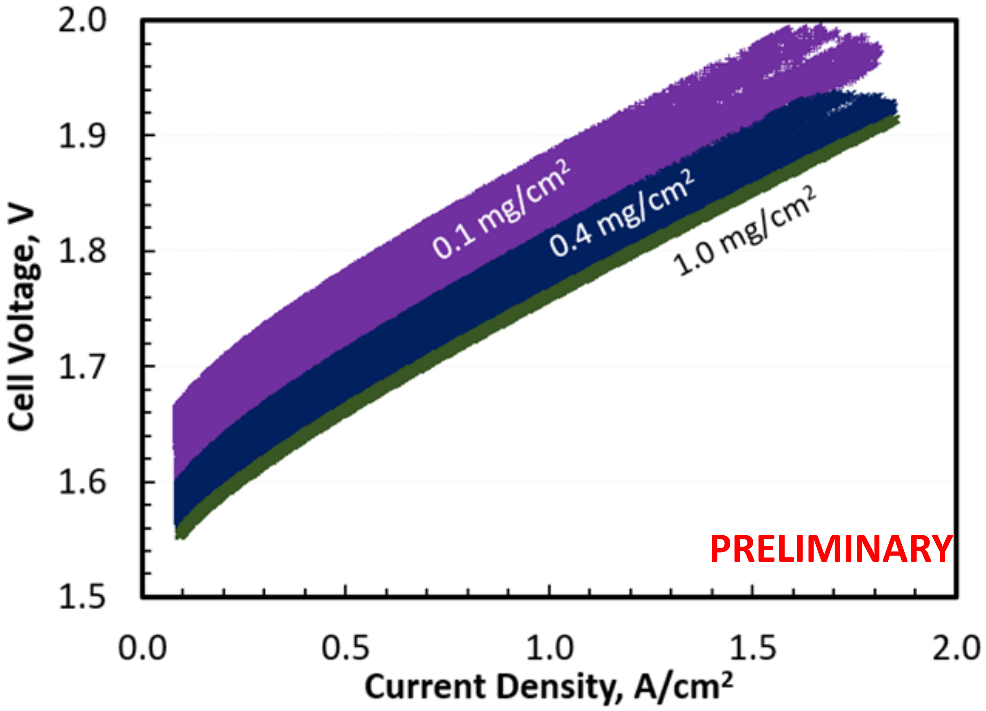
Status/Approach: ANL System and Stack Degradation Model

5.1 PEMWE System Performance on Grid-Independent Duty Cycles

Dynamic Polarization Curves on Combined Wind-Solar Duty Cycle with Mitigated N-117 Membrane

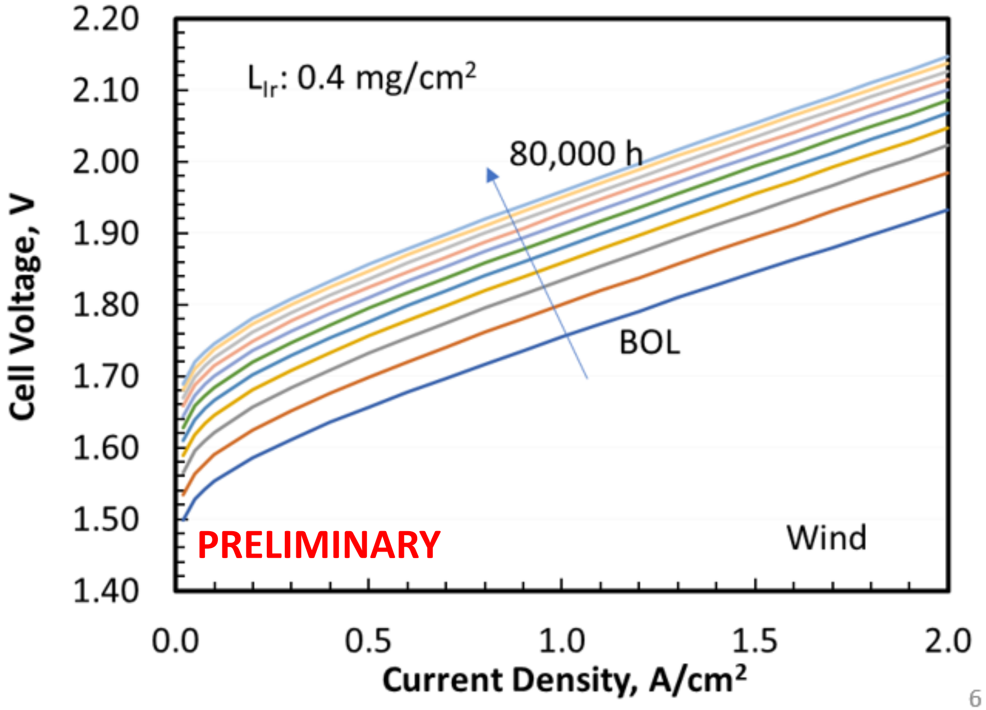
Polarization Curves in Year 1 of Operation

- Low Ir loading (0.1 mg/cm²) is likely unacceptable as it leads to 6% increase in cell voltage @ 1.6 A/cm² after just 1 year



Polarization Curves for 0.4 mg/cm² Ir Loading

- Slightly more than 10% increase in cell voltage at 2 A/cm² after 80,000 h



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Approach: Data Flows and Key Outcomes from Degradation and LCOH Modeling

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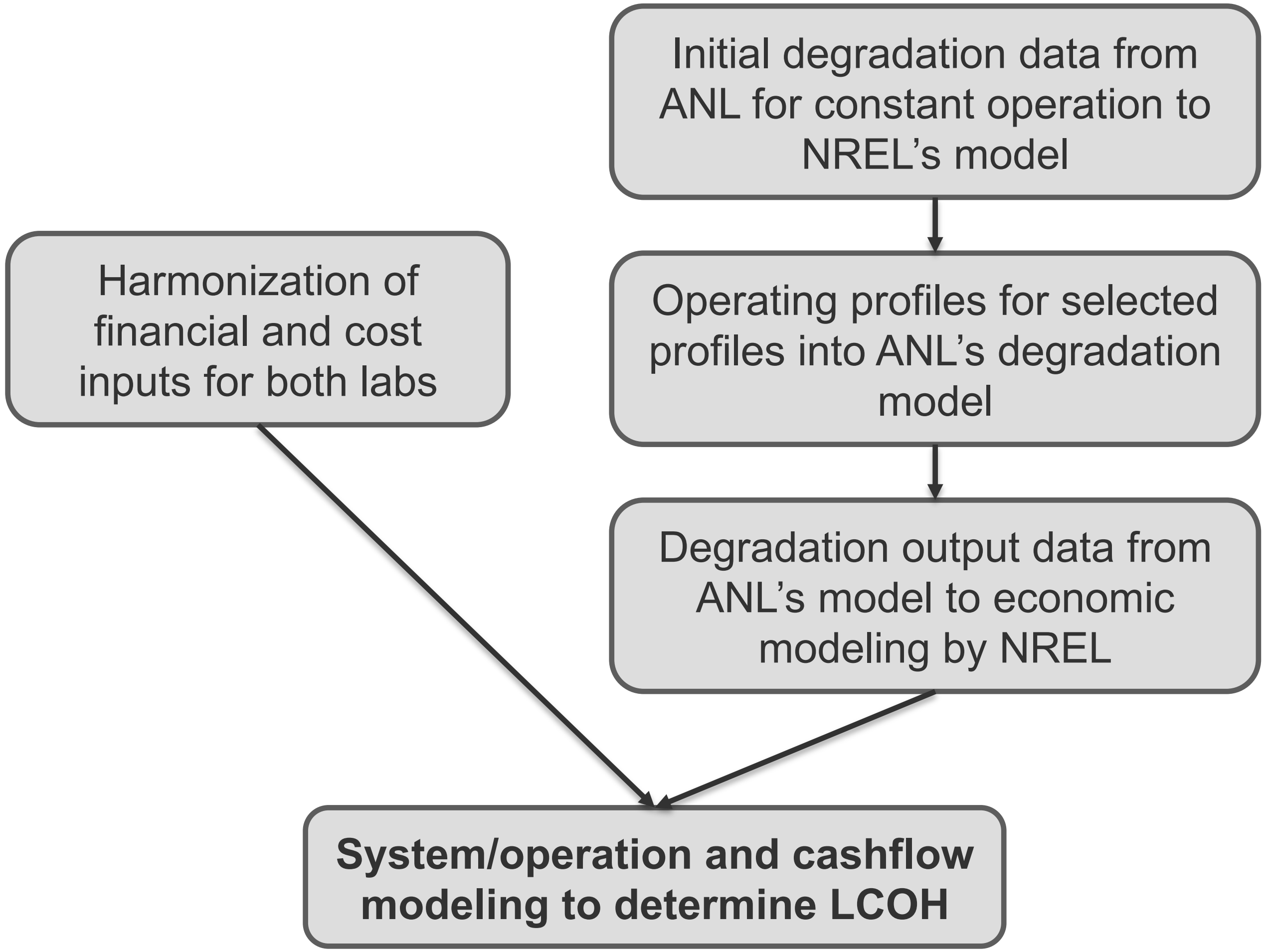
Key outcomes:

- Scenario analysis of levelized hydrogen cost inclusive of profile-specific degradation
- Comparison of results with detailed degradation representation to simplified studies
- Quantify impact on degradation of different catalyst loadings to set foundation for future work on cost/performance trade-offs
- Harmonized financial and cost inputs

Data flow:



Approach: Technoeconomic Analysis of Liquid Alkaline (LA) Electrolyzer Cost Drivers and R&D Efforts

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Experimental R&D baseline

Performance and durability

Electricity price and operating strategy

Electrolyzer capital cost

LA capital cost estimate

Electrolyzer Cost Model

Relative LCOH parameter sweep

Economic impact of parameter

LA Pathways to $1/kg H2

1 Dollar

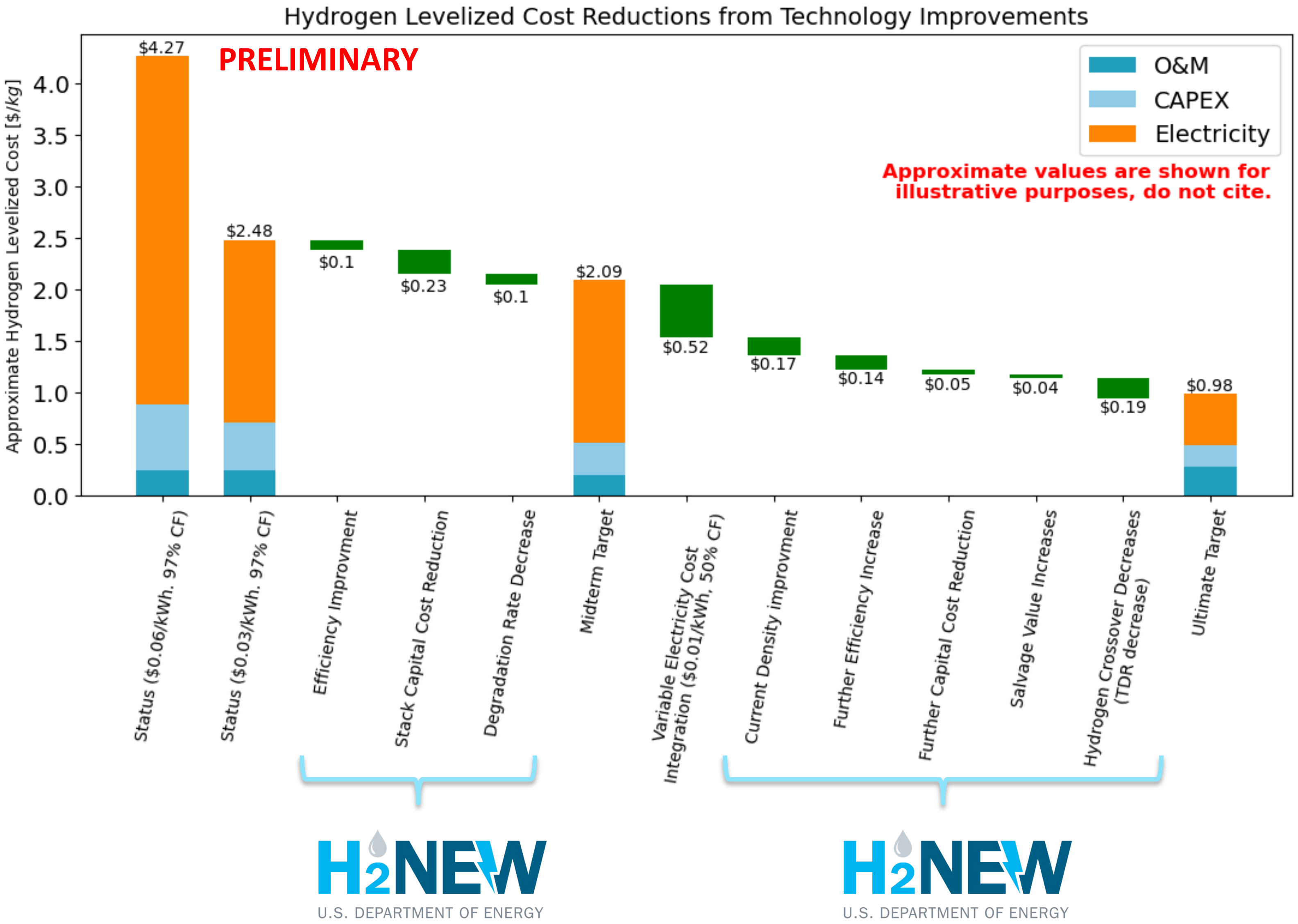
1 Kilogram

Q2 QPM. Parameterization study

Accomplishment: Initial Economic Parameterization Study of Liquid Alkaline Water Electrolyzers

H2NEW activities actively address the most critical R&D targets estimated to enable progress towards cost targets.

Trends in renewable generation deployment and evolution of power markets are integrated into analysis to inform near-term vs future LA R&D strategies to take advantage of low-cost energy.



Accomplishment: Estimating Cost Impact of Performance Gains for LA

Operating Points shown at right:

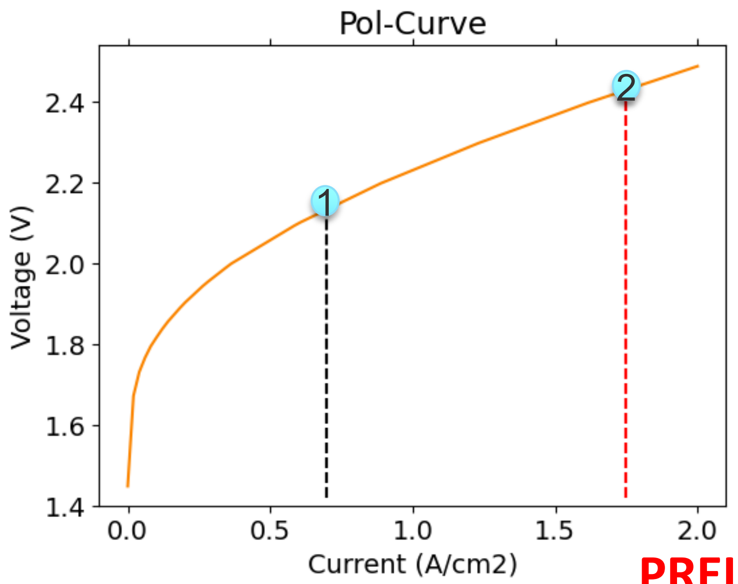
1. Low Current: 0.7 A/cm2, 2.136V, 58% efficiency LHV
2. High Current: 1.75 A/cm2, 2.43V, 65.3% efficiency LHV

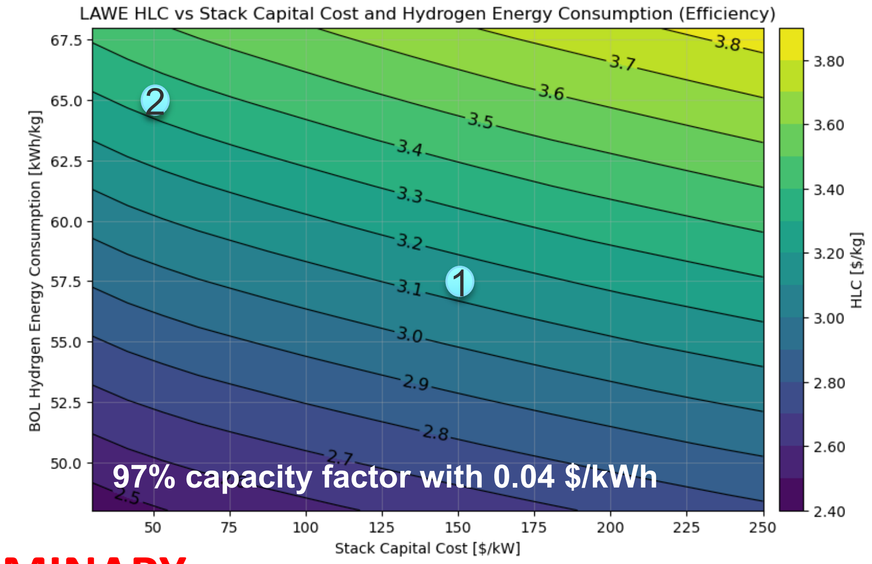
Moving from 1->2 (Increasing current density)

- **Modern electricity scenarios results in LCOH increase.**
- **Future electricity scenarios results in LCOH decrease.**

The amount to increase current density by is an optimization between capital cost and electricity cost:

- If electricity cost is low, increasing current density decreases capital cost more than the increase of electricity costs due to efficiency reductions on an NPV basis.
- If electricity cost is high, increasing current density decreases efficiency and thus increases electrical costs more than the reduction of capital cost on an NPV basis.





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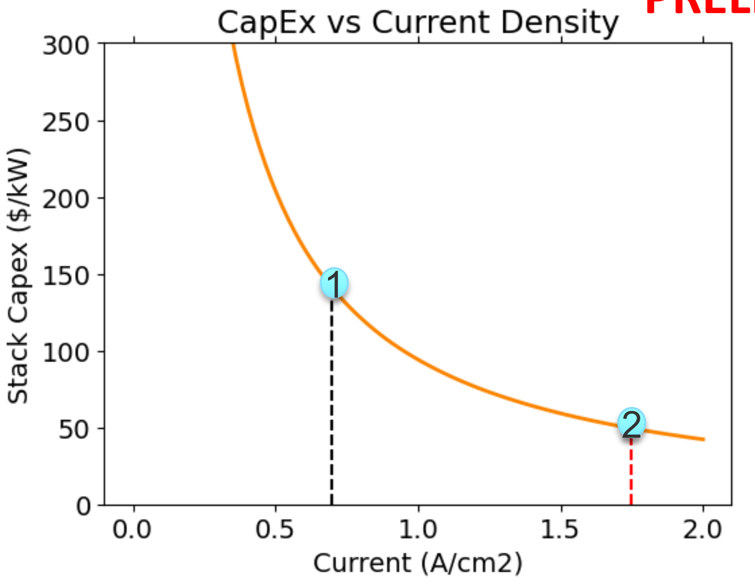
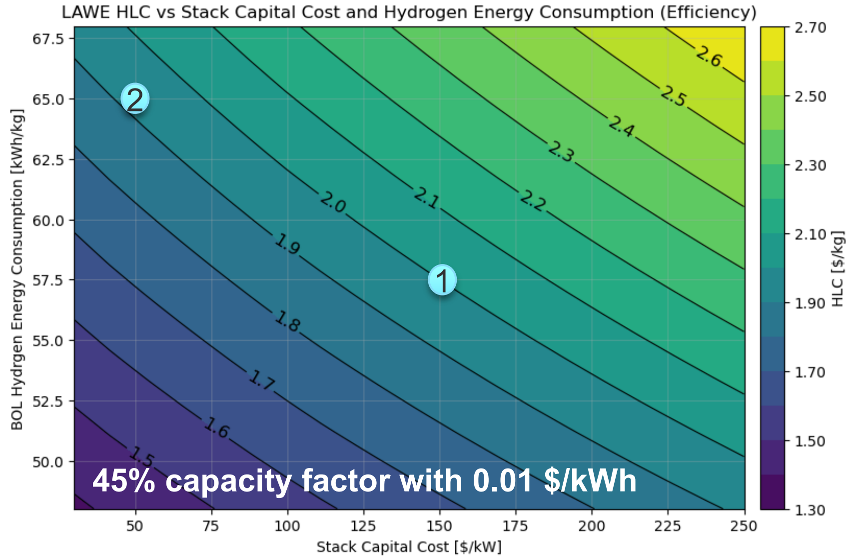
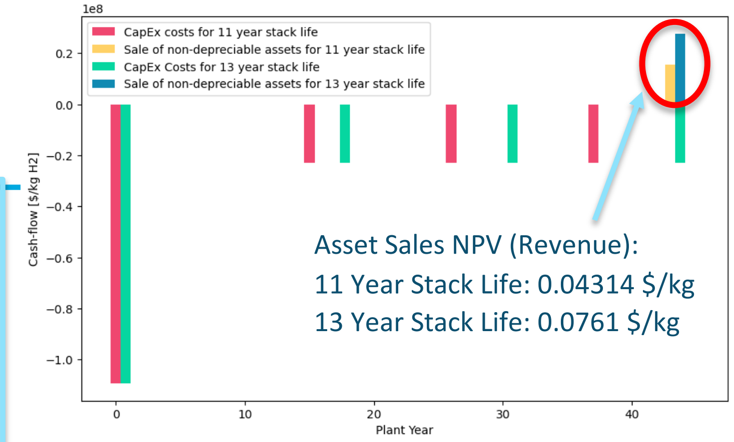
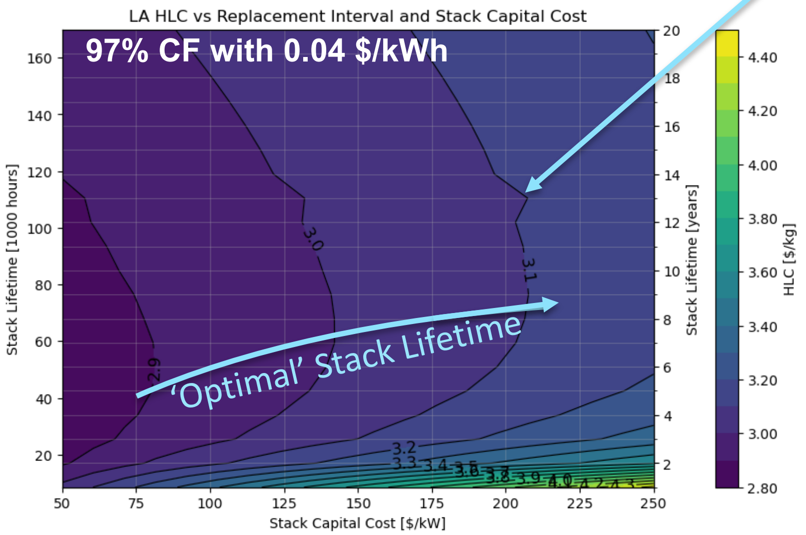


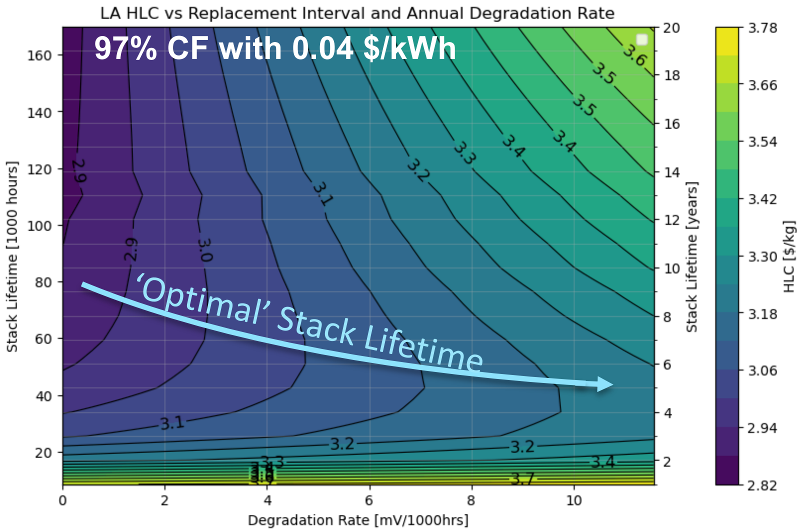


Accomplishment: LA Stack Lifetime Impact

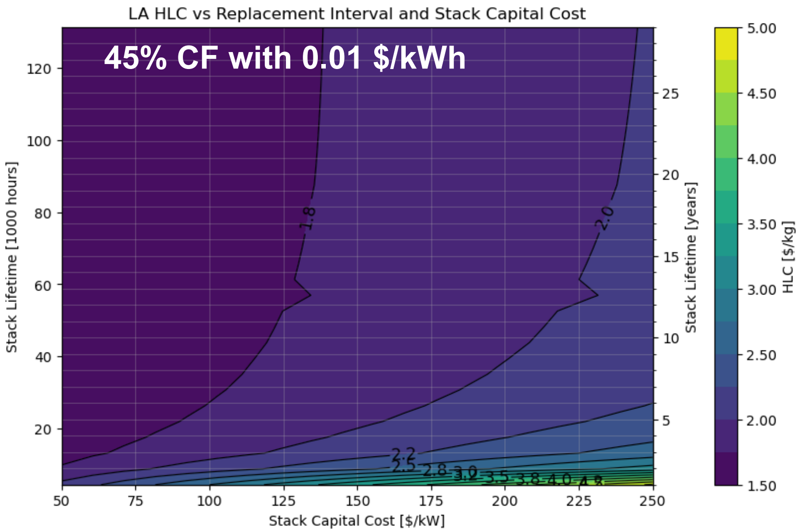
13 year stack life artifact from plant life of 40 years (Appears for other numbers that are multiples of 39). Sold assets are tallied at end of the year. Assets purchased at year 39 are sold with no depreciation so an operator gets one year of high efficiency and 'free' stack due to increase of sold assets. Additionally, the debt from an electrolyzer purchased before the end of the lifetime of the plant must be paid back with interest, so in this example, debt is paid back for 7 years for the 11 year stack life vs 0 years for the 13 year stack life.

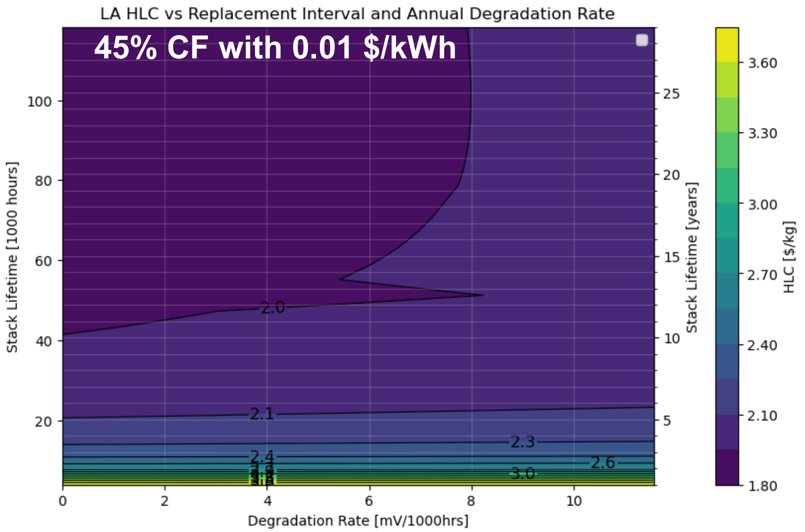






PRELIMINARY





Decreasing capital costs effectively decrease optimal stack lifetime, driven by the tradeoff between electricity costs at degraded efficiencies vs purchasing a new stack.

Decreasing degradation rate increases optimal stack lifetime at reduced LCOH for high capacity factor and high cost electricity operating strategies.

Accomplishment: Analysis of LA Turn Down Ratio (Hydrogen Crossover Limitations at Low Power)

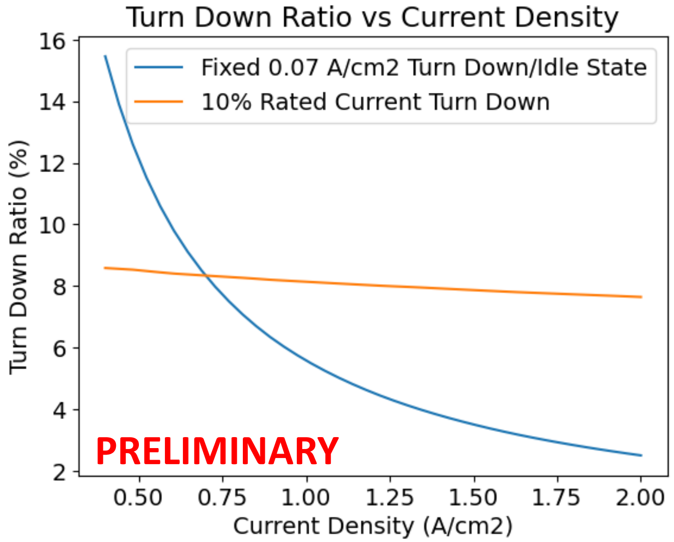
Turn down ratios are not impactful in operating strategies where electricity costs are less variable, as shown in 2024 vs 2035 busbar costs at the right. This can vary from location to location within specific power markets.

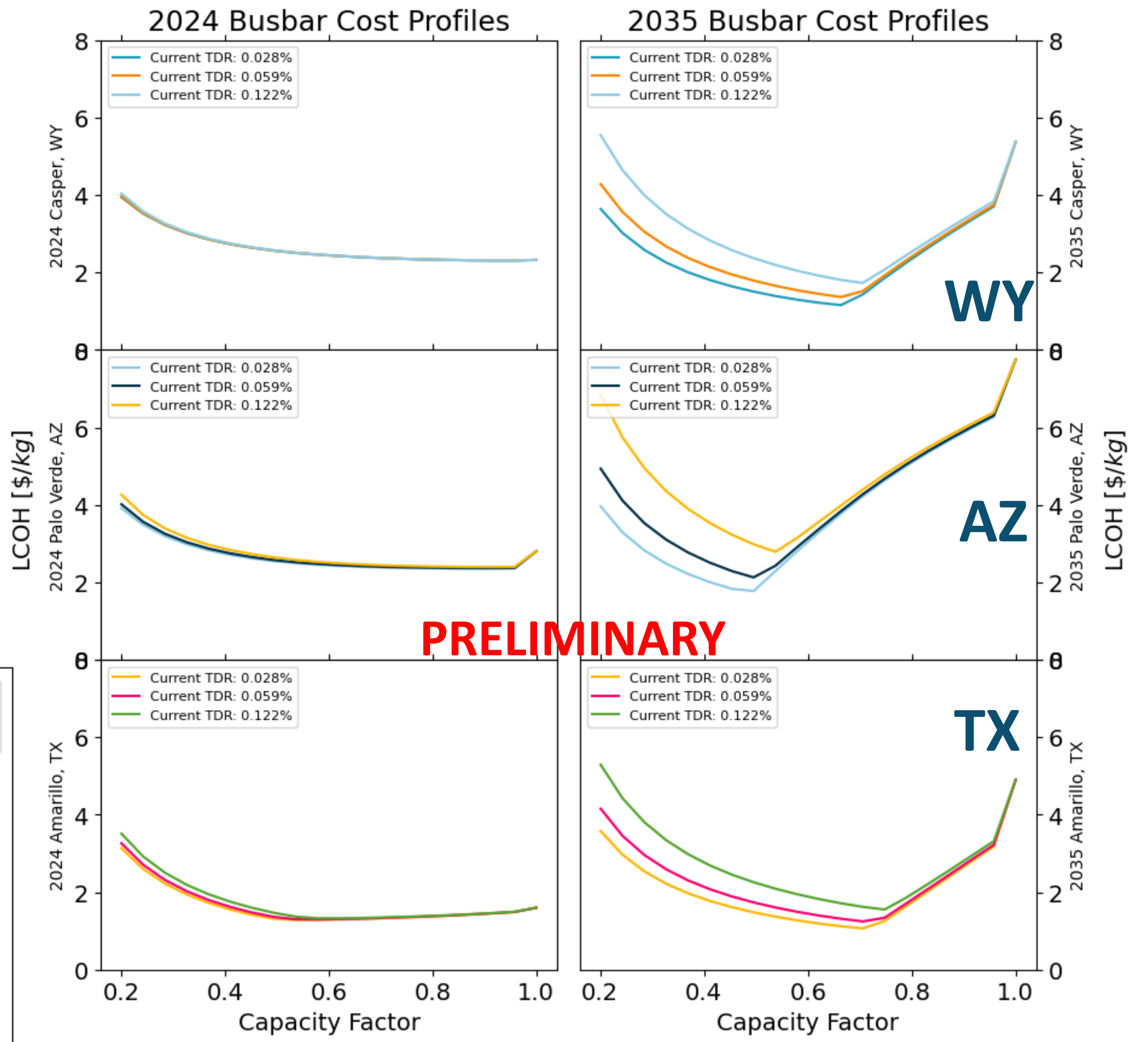
As future grid mixes change and have more variability in hourly electricity cost they will become an even more important LCOH cost driver

Turn Down Ratios (TDRs) can be an effective way to mitigate paying for high cost times of electricity.

- $TDR_{current} = \frac{i_{idle}}{i_{rated}}$

- $TDR_{power} = \frac{i_{idle}V_{idle}}{i_{rated}V_{rated}}$





Accomplishment: Impact of Degradation Rates on LA LCOH

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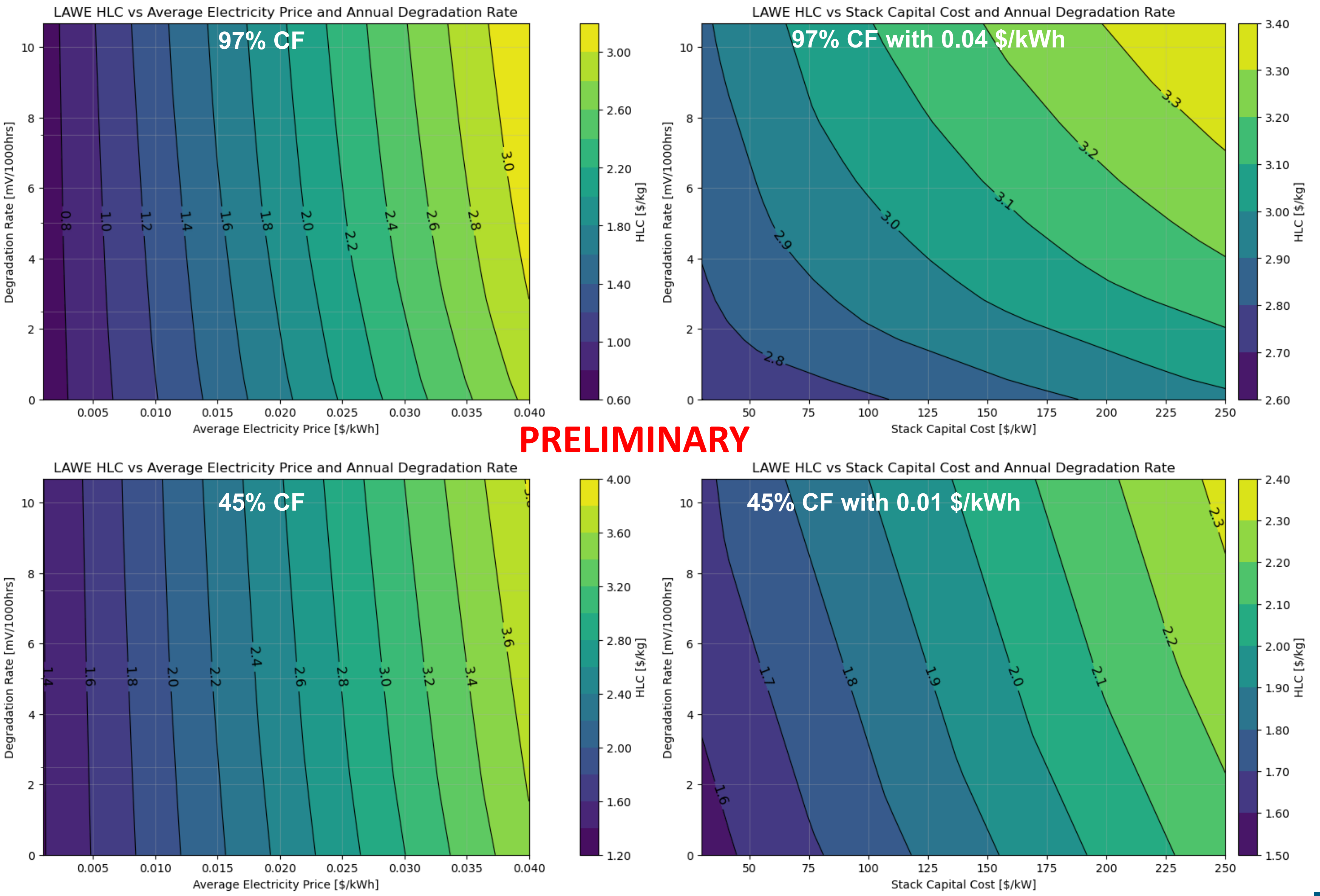
The impact of degradation on LA electrolyzers changes depending on stack capital cost and electricity price parameters.

As stack capital costs decrease, the stack can be replaced more often with less economic penalty. Frequent stack replacements result in higher average stack efficiencies across the lifetime of the plant.

As electricity costs become more variable (and cheaper), the impact of lower system efficiency is lessened.



Approach: System Modeling of Liquid Alkaline (LA) Electrolyzer - Major Sub-Models and Components

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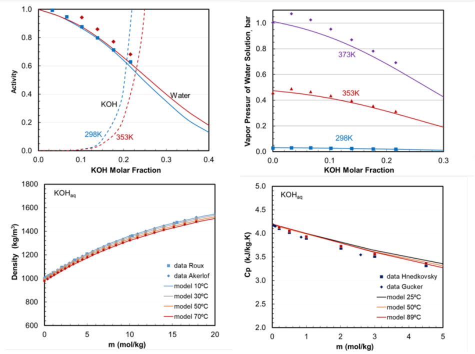
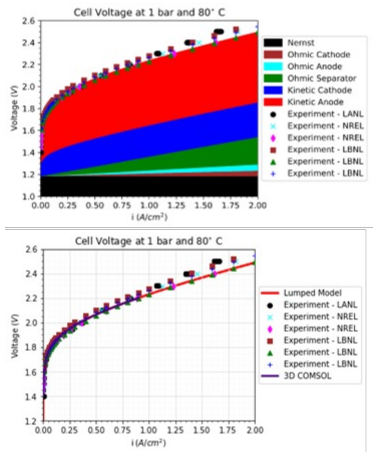
Objective: Develop system models to quantify and assess the economic impact of LAWE cost, performance, operation, and durability tradeoffs and connect with techno-economic analysis.

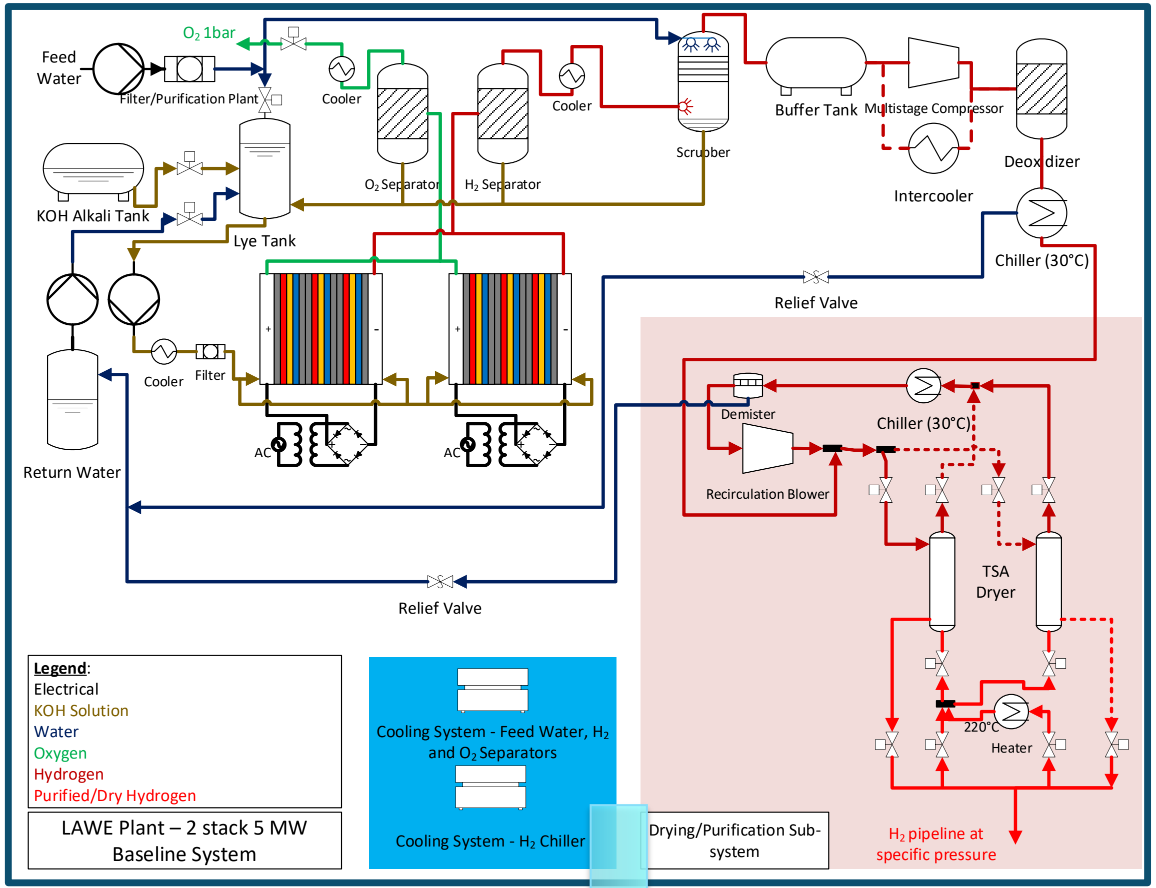
FY24 Summary: Integration of (1) cell model (with crossover) based on H2NEW Ni-Foam baseline cell configuration and (2) KOH thermodynamic model into system model. Preliminary simulations confirm stack as largest electrical energy cost.

Input: $KOH_{(aq)}$ Thermodynamic Model



Input: LA Cell Model (Pol Curves)

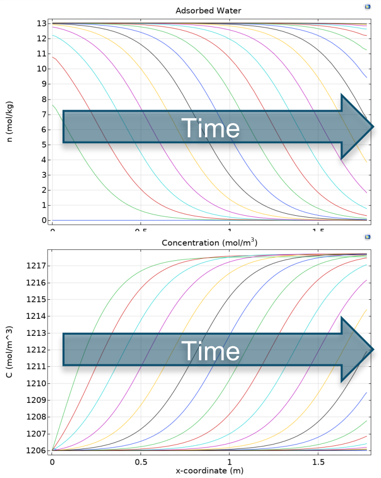




Input: Stack and BoP Parameters

- Stack parameters and dimensions
  - Lifetime
  - Thermal balance
  - Pressure drop
- Balance of Plant
  - Pumping costs
  - Dynamic operation and turn down ratios

Input: TSA/PSA Dryer Model

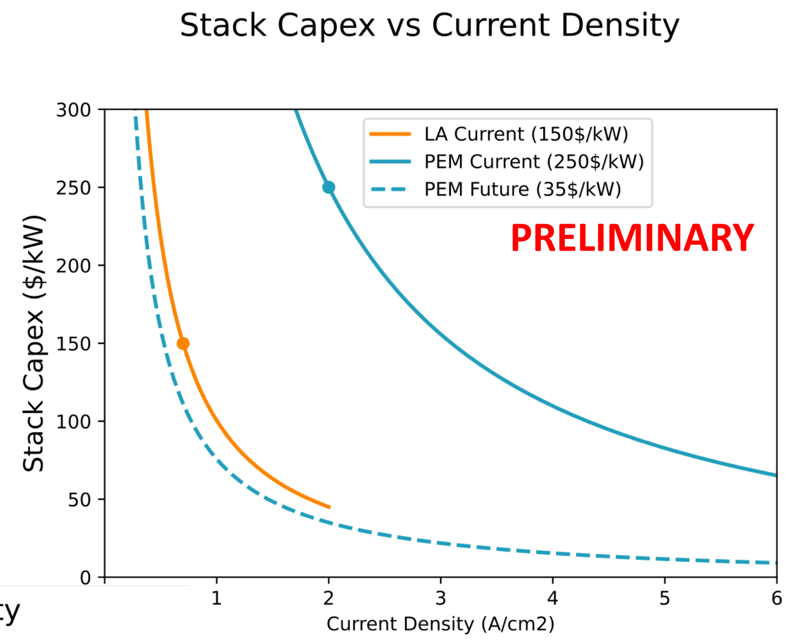


Output: System Model (GCTool)

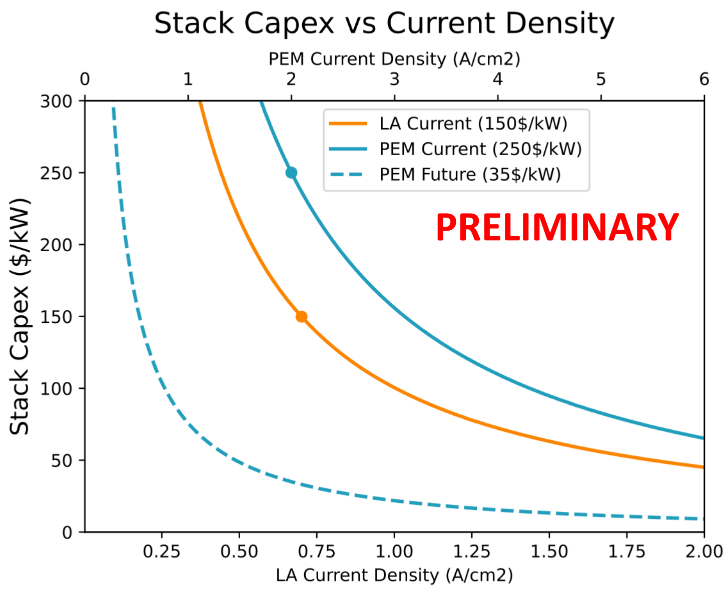
- Electrical energy consumption
- Dynamic operation regimes
- BoP sizing and tradeoffs

Future Work: Comparing LA vs PEM Electrolyzers

Ramp up in LA technoeconomic analysis capabilities facilitates comparative analysis between PEM and LA technologies from various lenses, including system integration, performance tradeoffs, and dynamic operation strategies.



For example, given a baseline set of materials and stack manufactured costs rated current densities for both technologies, the $/kW impact to performance changes can be estimated. (Draft analysis shown at right)



Accomplishment: Responses to Previous Year Reviewers' Comments (FY23)

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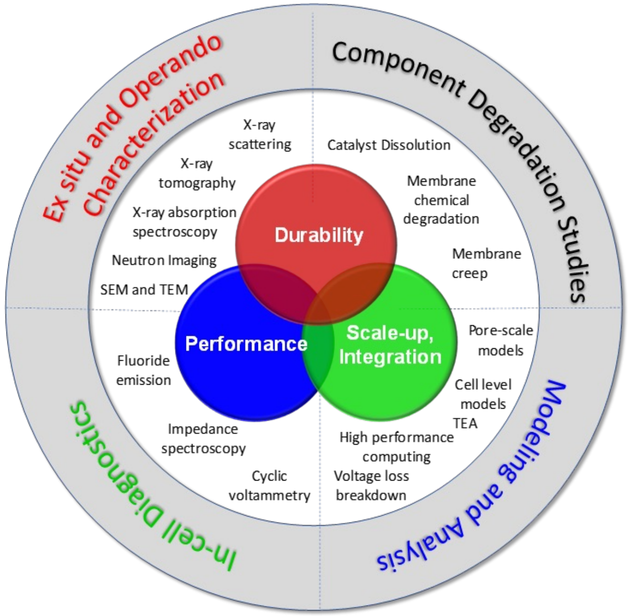
This poster was not reviewed in the previous year, however reviewer comments on 2023 H2NEW overview presentation (P196) relevant to task 3c are discussed below:

- The project could consider incorporating a top-to-bottom approach across the H2NEW consortium regarding understanding what customers need, who will be buying hydrogen, and what operators/owners who will be running hydrogen plants will need to meet customer demands. Major effort is spent on the technology but not enough on who would be buying, incorporating, or financing such technology.
- Variable operation is an important consideration covered in the presentation. Perhaps the team could consider variable operation from the perspective of boundary conditions of the entire hydrogen production plant, not just the electrolyzer system. The team could reconsider levelized cost of hydrogen (LCOH) cost calculations, especially capital and operating expenditures, depending on the type of hydrogen off-take agreement (whether the customer will accept any interruption/variability in hydrogen supply and how such interruptions are accounted for in the LCOH).
  - **We agree that there is value in considering market constraints in how electrolyzers will be operated and what offtake considerations are for hydrogen from various end-use applications. While work within the consortium to date has focused solely on the electrolyzer stack itself, there is absolutely value in understanding how end-use constraints might determine how future systems are deployed and integrated. This consideration along with how these strategies might vary between electrolyzer technologies like PEM and LA will be considered for future work.**
  - **Secondly, we agree with the reviewer that these is value in understanding dynamic operation from the whole system perspective, accounting for BOP constraints on dynamic operation. Our work on slides 22-25 of this presentation begins to address these questions on a GW scale, which we plan to continue in out years.**
- The project team could consider a side-by-side analysis of how development of alkaline technology in the United States compares to mature alkaline technology and technology deployment in the rest of the world.
  - **We agree with this comment regarding the value of benchmarking LA technologies. H2NEW approaches benchmarking current systems from a cost and materials standpoint, developing an understanding of fundamental performance and degradation mechanisms and the implications for cost optimization of hydrogen production. Given the recent expansion of consortium focus to include LA, we anticipate further results and publications on this topic moving forward.**
- However, the principal investigators need to consider the challenges of the integration between the intermittent renewables and the electrolyzer.
  - **We agree with the reviewer that there is significant value in understanding constraints imposed on operation of the electrolyzer from the perspective of the power supply that the system is integrated with. H2NEW considers these constraints from the perspective of technoeconomic analysis initially then iterates with experimental tasks to understand the cost and R&D implications of a given configuration.**
- The project could consider how LAWE can be integrated with the renewable impermanency. Reverse current during shutdown can lead to fast decay of the electrodes.
  - **Understanding tradeoffs between PEM and LA electrolyzers for dynamic operation is a key objective for current and future work in the consortium across experimental and analysis tasks. With a robust understanding of LA degradation mechanisms, we plan to develop cost optimized operational strategies for near-term and future LA electrolyzers.**
- The H2NEW consortium has achieved several significant milestones in the development of low temperature electrolyzers, including basic science approaches to durability and approaches to calculating the LCOH. The work on understanding utility pricing of electricity is also prized, as it is used by industry when considering hydrogen plant locations. Each of these accomplishments is a step that enables DOE to meet the $1/kg H2 goal.
  - **We appreciate these kind words and are grateful to hear that the work in H2NEW is valuable!**
- It is proposed that the H2NEW consortium develop a reference design for a gigawatt to help guide industry in this development.
  - **We thank the reviewer for this comment and fully agree – a GW scale BOP model is under development (see slides 22-25) with continuing work planned in this area.**

Collaboration and coordination across consortium tasks

- Cross-task collaboration and data exchange is key to ensuring consistency across assumptions
- Frequent collaboration ensures that activities in task 3c are informed by experimental work across the consortium and vice versa

H2NEW task 1-3 activities



Key data exchanges and collaboration:

1. Experimental degradation studies
2. Electrolyzer design and materials specifications
3. Manufacturing technologies and optimization
4. Systems analysis performance data

H2NEW task 3c activities

- Levelized cost modeling
- Bottom-up cost modeling
- Electricity market analysis
- Systems analysis

External collaboration and coordination

- This task is being performed by two laboratories: NREL and ANL
- This task interacts with the rest of the H2NEW consortium which includes seven additional laboratories and has a steering team involving industrial partners. Interactions include getting design and operating input and data from consortium partners and informing R&D staff of operating cycles and other considerations.
- Designs and assumptions are reviewed by industrial and academic partners on the consortium's advisory committee.
- Designs and manufacturing assessments and LA analysis involve interaction and collaboration with Strategic Analysis, Inc.
- Capabilities and collaboration between H2NEW analysis tasks and new HFTO Roll to roll consortium

Remaining challenges and barriers

- Data gathering efforts to inform analysis of the impact of degradation on techno-economics
- Impacts of adding a large number of electrolyzers to the grid on electricity prices and renewable deployment opportunities have not been analyzed specifically
- Expanding existing PEM analysis capabilities to LA is ongoing. Long-term needs include leveraging experimental research to map out drivers for performance degradation in LA electrolyzers and integrated analysis + R&D opportunities to address them

Ongoing and future work

- **Ongoing work during FY24**
  - Completion of analysis of BOP costs at scales greater than 1 MW
  - Leverage Aspen BOP model framework to understand BOP constraints on minimum electrolyzer turn down ratio and implications for operational strategies and capital cost
  - Technoeconomic analysis of PEM electrolyzer end of life salvage value and strategies to optimize tradeoffs for PGM loadings and recycling strategies
  - Improved representation of electrolyzer performance degradation for dynamic operational strategies using systems modeling and experimental insight across the consortium
- **Planned work during outyears**
  - Continue collaborative efforts with Strategic Analysis Inc. on bottom-up cost modeling for LA and integrate with operational strategy analysis ongoing in H2NEW
  - Integrate efforts for systems modeling and large-scale BOP analysis to improve representation of full electrolyzer system dynamic operation

Proposed future work is subject to change based on funding levels.

Summary

- Continued effort since the start of H2NEW: results will be used to evaluate cost, performance, and durability tradeoffs to determine optimum LTE deployment to achieve \$2/kg and \$1/kg production cost in renewable energy integration scenarios
- Recent work suggests that BOP costs are a large portion of total manufactured costs for 1 MW PEM electrolyzers, underscoring the importance of evaluating strategies to drive BOP costs lower at large manufacturing rates and electrolyzer nameplate rating
- High capital costs for PEM stacks seen today and driven by high iridium costs drive the need for robust evaluation of degradation characteristics of these systems under dynamic operation and opportunities for recovering valuable materials from the stack at end of life
- Evaluating technoeconomic aspects of near-term and future alkaline electrolyzers is essential to evaluating cost, performance, and durability tradeoffs for optimum deployment, materials engineering and operations
- Interactions with other tasks in H2NEW lead to improved analysis and provide opportunities for analysis results to guide research and target setting

Thank You!

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