Apr. 25, 2024

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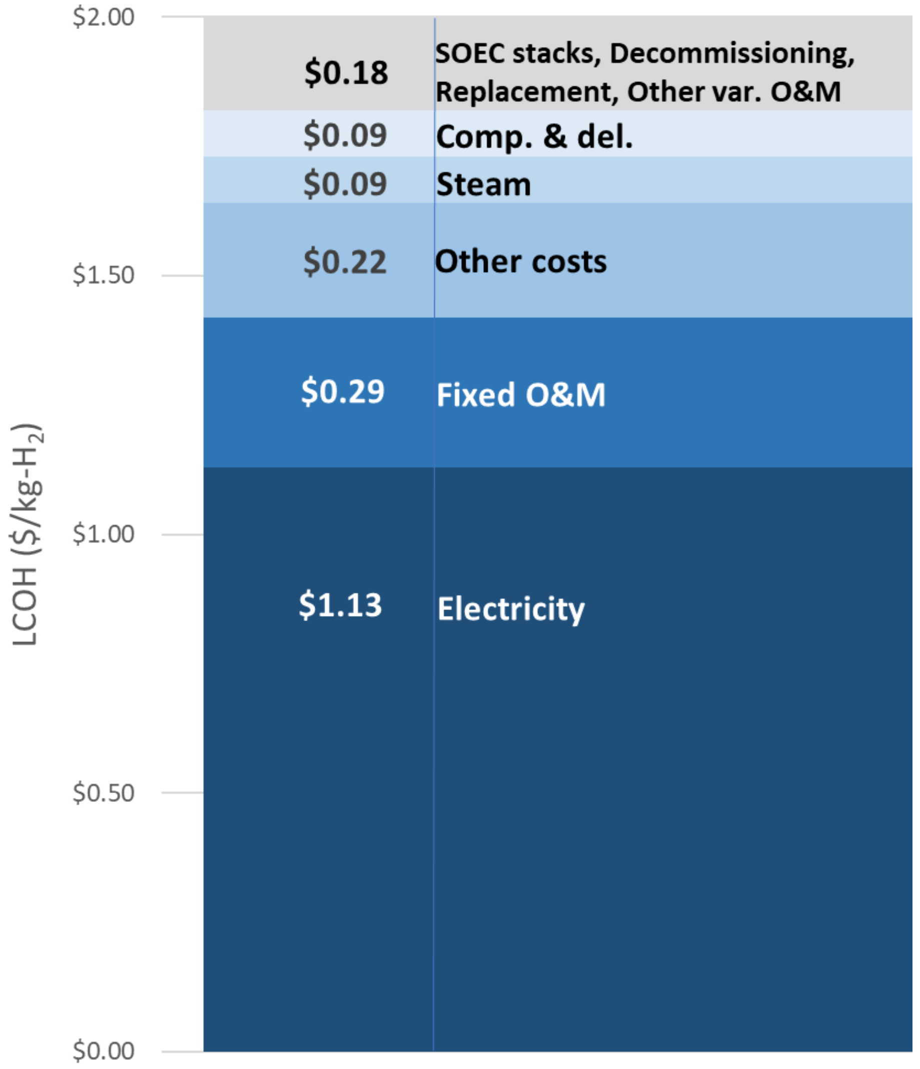
Performance Validation of a Thermally Integrated 50 kW High Temperature Electrolyzer System

DE-FOA-0002300: Grant 13163665
2024 FECM/NETL Spring R&D Project Review Meeting

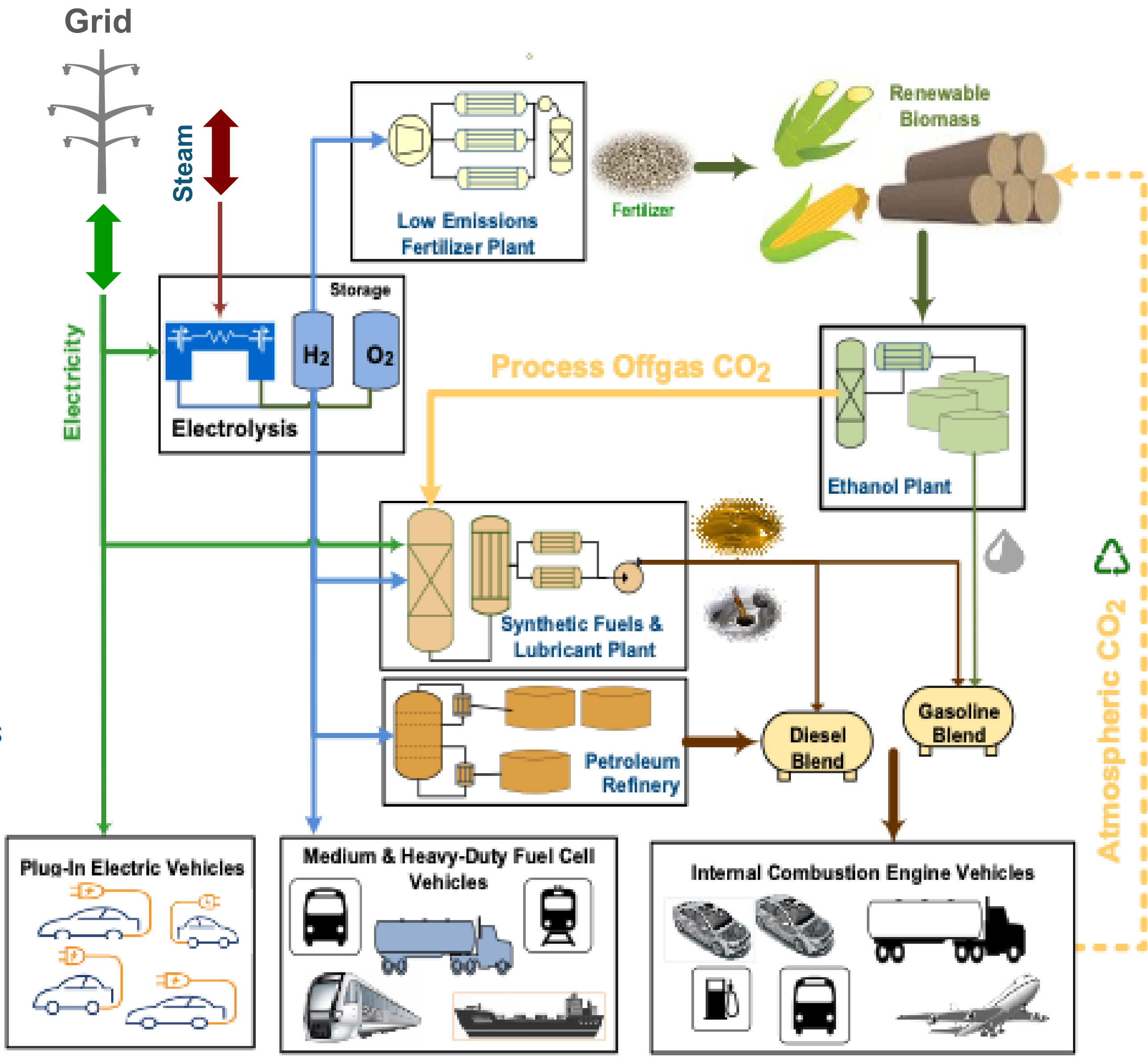
Project Goals

- Improve value proposition of reversible solid oxide electrolysis (rSOC) systems for H_2 production and distributed energy application.
- Our research to help industry move closer towards Energy Earthshot Initiative goals.
- Reconfigure a 50-kW test stand to allow
  - 30-kW electrolysis mode/10-kW fuel cell mode.
  - Accumulate ~1,000 hrs operating an rSOC system.
- Utilize an improved catalyst in the fuel electrode of the rSOC stacks.
- Conduct thermodynamic analyses that would demonstrate potential to achieve > 85% (HHV) system efficiency in electrolysis mode.
- Conduct technoeconomic analysis (TEA) that would demonstrate potential to produce hydrogen at a cost of $2/kg on a cost of electricity of $30/MWhr.



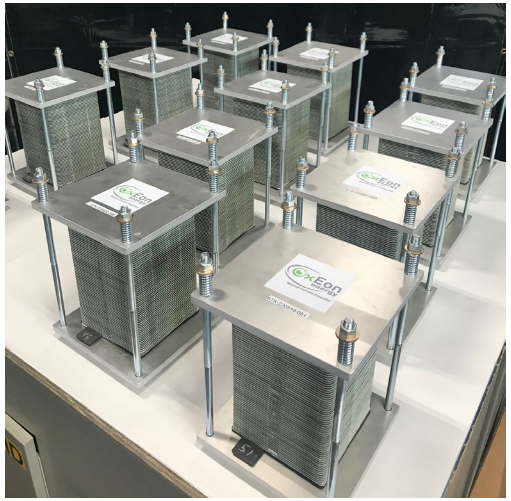
Relevance

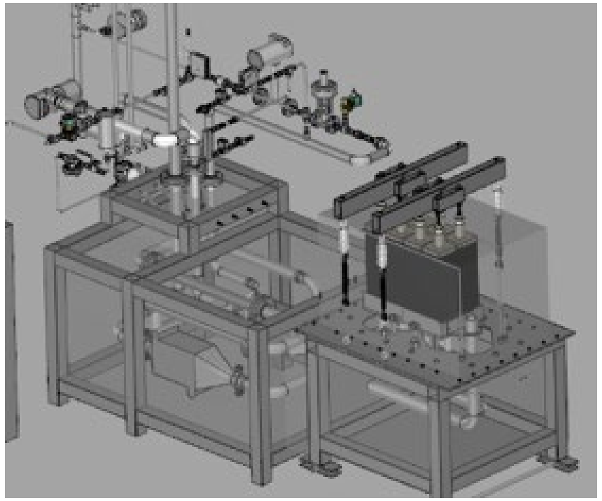
- DE-FOA-0002300 AOI 2:
  - Improving the cost, performance and reliability of reversible rSOC systems for clean hydrogen and clean power production
  - rSOC systems have opportunities to enter the marketplace but need proven system cost, performance, and reliability
  - rSOC systems can use the same system components (stacks, heat exchangers, piping, power converters, etc.) to reduce capital cost and increase component utilization.
  - May be deployed at small scale to meet needs of diverse users for clean energy utilization, storage, and supply (supports environmental justice)
    - Full design of BOP system will be open-access

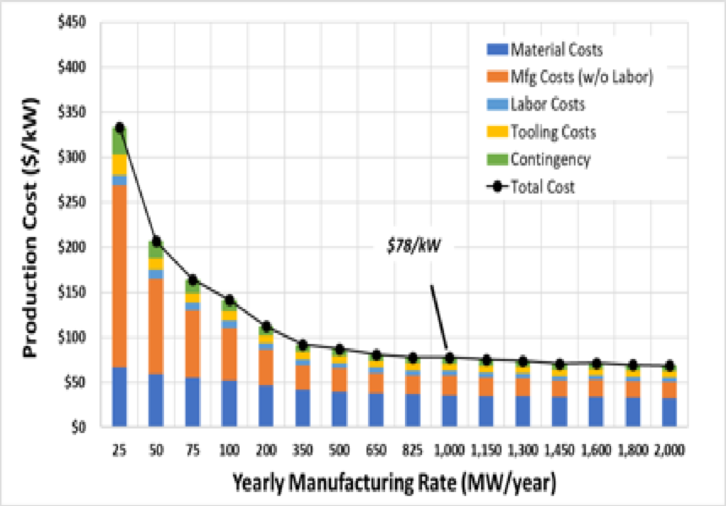


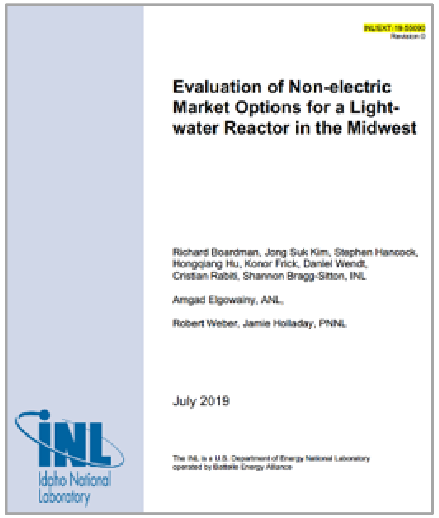
Approach

- **Task 1:** Revise Project Management Plan
- **Task 2:** Stack manufacturing (OxEon)
- **Task 3:** e^2 Catalyst Development (MIT)
- **Task 4:** Reconfigure 50 kW SOC test stand (INL)
- **Task 5:** System integration and testing
- **Task 6:** Technoeconomic Analysis
- **Task 7:** Data analysis
- **Task 8:** Final Report








Evaluation of Non-electric Market Options for a Light-water Reactor in the Midwest

Richard Boardman, Jong Suk Kim, Stephen Hancock, Hongqiang Hu, Konor Frick, Daniel Wendt, Cristian Rabiti, Shannon Bragg-Sitton, INL

Amgad Elgowainy, ANL,

Robert Weber, Jamie Holladay, PNNL

July 2019

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance

** Cost analysis of hydrogen production by high-temperature solid oxide electrolysis* (https://doi.org/10.1016/j.ijhydene.2023.07.084)

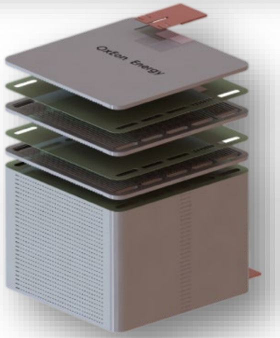
OxEon Energy, LLC

Utah R&D/Mfg Facility – Founded in 2017 after successful 30-year collaboration with founders of previous affiliation

- New 24,000 ft^2 (2230 m^2) office, laboratory, and manufacturing facility
- NASA, DOE, DOD and Commercial funding
- Tape casting, cell and stack production, and testing
- End-to-end power to synfuels pilot plant in operation

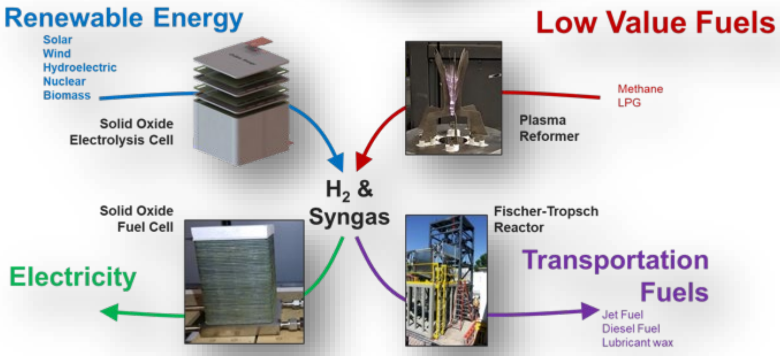
Solid Oxide Fuel Cell and Electrolysis Stacks

- Longest running solid oxide fuel cell & electrolysis group in world
- Only flight qualified, TRL 9 SOEC unit in history
- 30kW/10kW reversible system test program in process



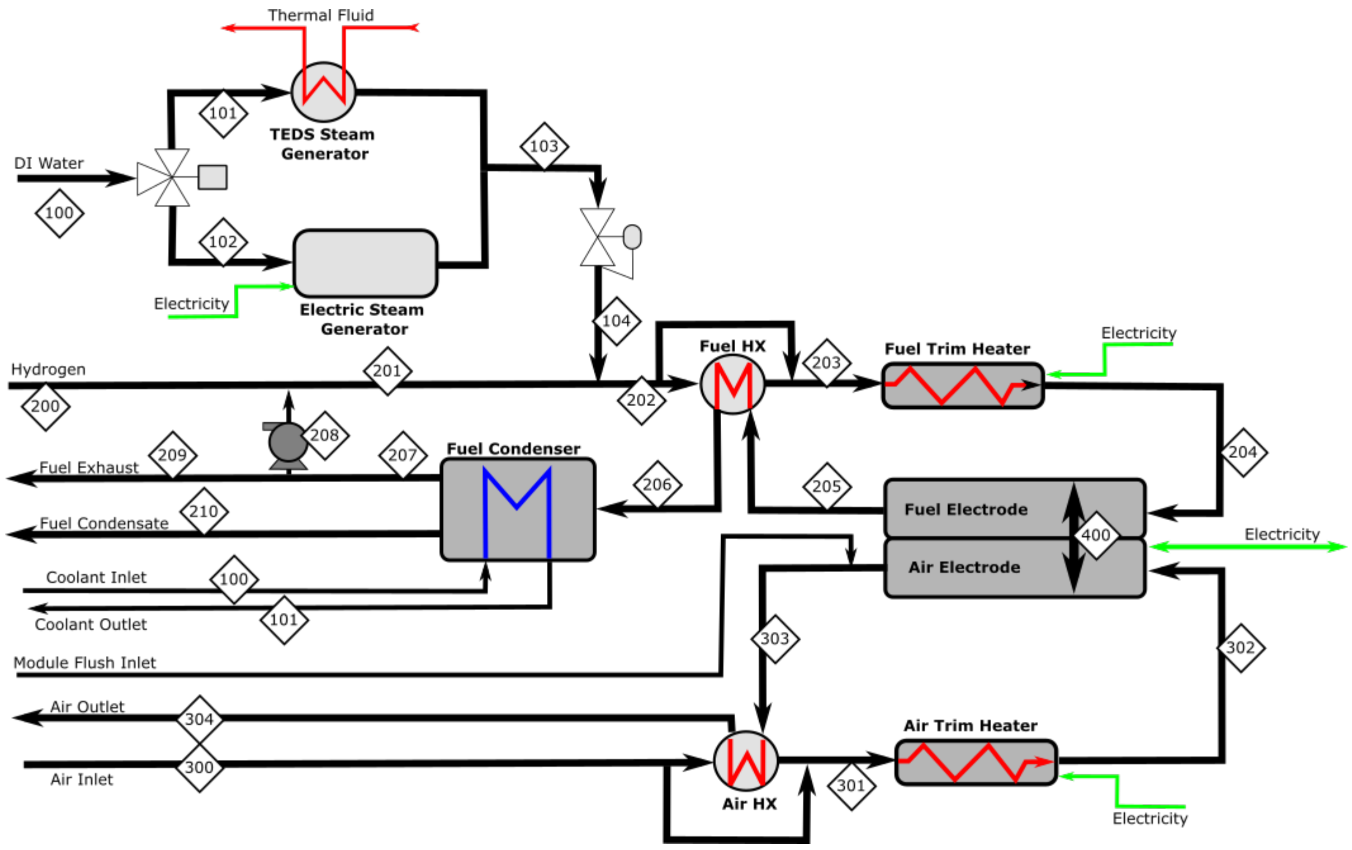
Fuel Reformation and Generation

- Plasma Reformer – H_2 and Syngas for flare curtailment
- Fischer-Tropsch Reactors – Modular design for transportation fuel production from H_2 and Syngas



System Design & Integration (1/4)

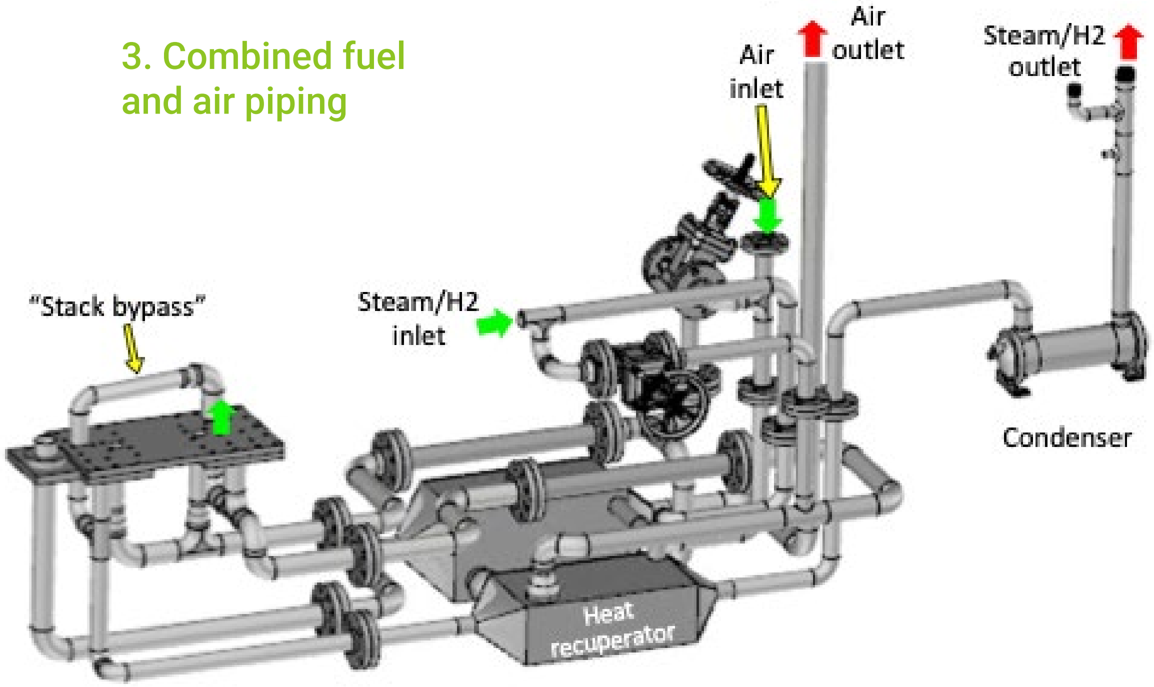
- **Standard SOEC/SOFC design:**
  - High temperature heat exchangers (HXers) on fuel and air streams.
  - Trim heaters for EC mode.
  - Fuel condenser to separate water from product H2.
  - H2 recycle loop with blower.
  - HXer bypasses for incoming fuel and air streams in FC model.
  - Steam is currently provided by an electric boiler. The plan is to also utilize steam from a steam generator that is coupled to a thermal energy distribution network.



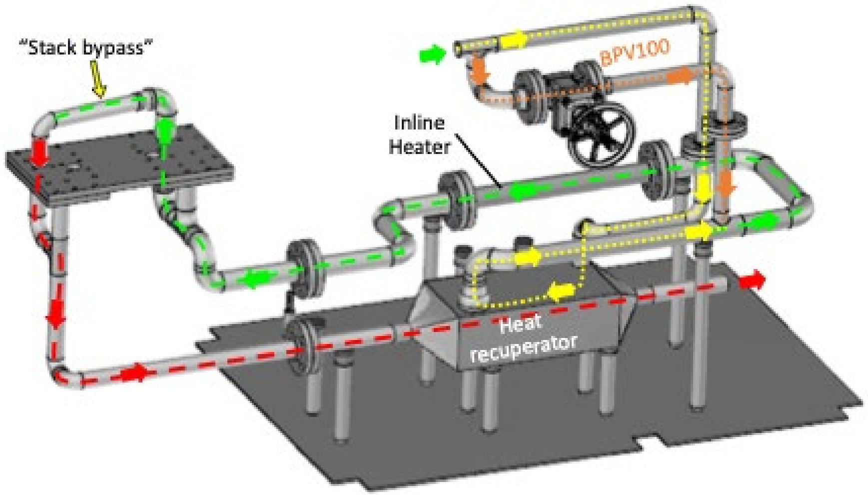
System Design & Integration (2/4)

- High temperature piping design:
  - Separate stack & HXer modules.
  - Piping components supported on springs to allow thermal expansion; no bellows flanges.

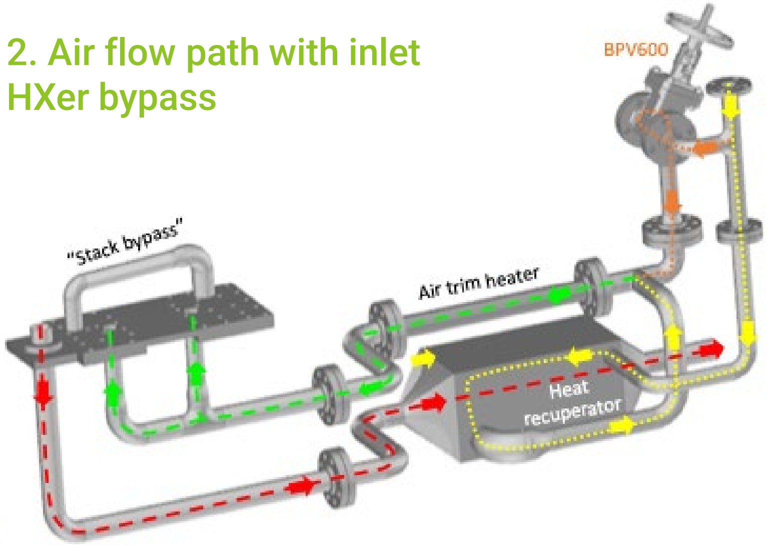
3. Combined fuel and air piping



1. Fuel flow path with inlet HXer bypass

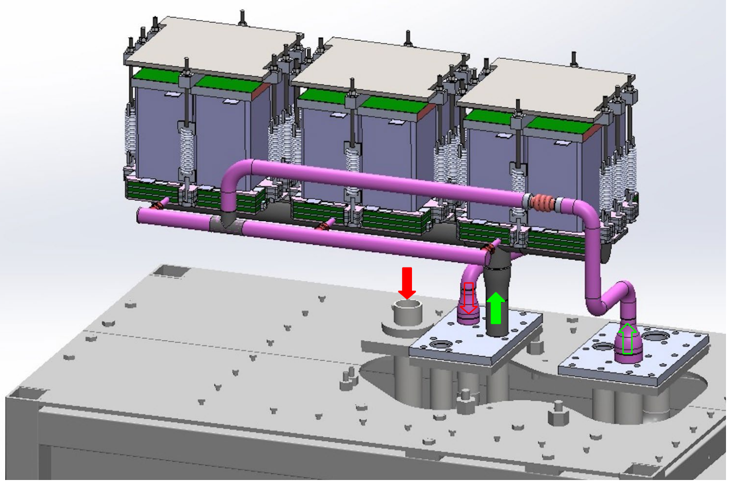


2. Air flow path with inlet HXer bypass

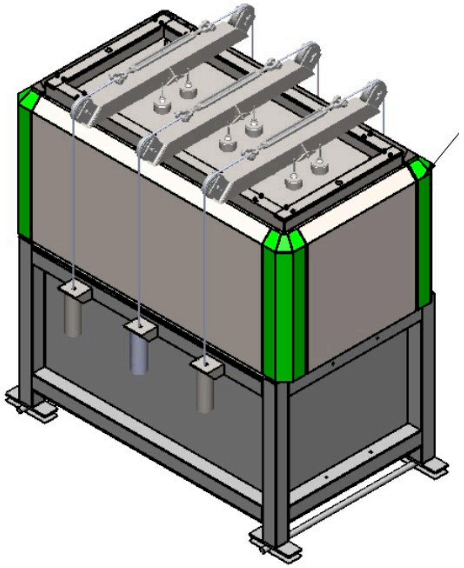


System Design & Integration (3/4)

- 12 OxEon SOC stacks arranged in quad configurations on manifold.
- External hotbox with compression assembly encloses the stacks.
- The rSOC system is located within custom 20 ft container with doors on three walls.



OxEon SOEC stacks on manifold



OxEon stack compression system (acts through stack module lid)

System Design & Integration (4/4)

- A total of 12 stacks with 65 cells per stack. Each stacks is ~2.5 kW therefore a total capacity of 30 kW.

- Stacks connected to fuel flow manifolds, with current conductors and voltage taps in place.

OxEon stacks being prepped for installation

OxEon stacks with voltage taps and current conductors

Challenges and Barriers

- Manufacturing & Supply Chain Issues
  - COVID-19 issues had slowed procurement
    - For example, >10-month delay in obtaining heat exchangers.
    - Other data acquisition instruments had about 18 – 30 week lead time.
- Loss of critical personnel.
- Design issues
  - Inadequate thermal insulation & need for greater thermal overhead.
  - Complications with compression assembly system.
  - Complications with air flow return impacting HXer performance.
  - Need for improved instrumentation.

System Status (1/2)

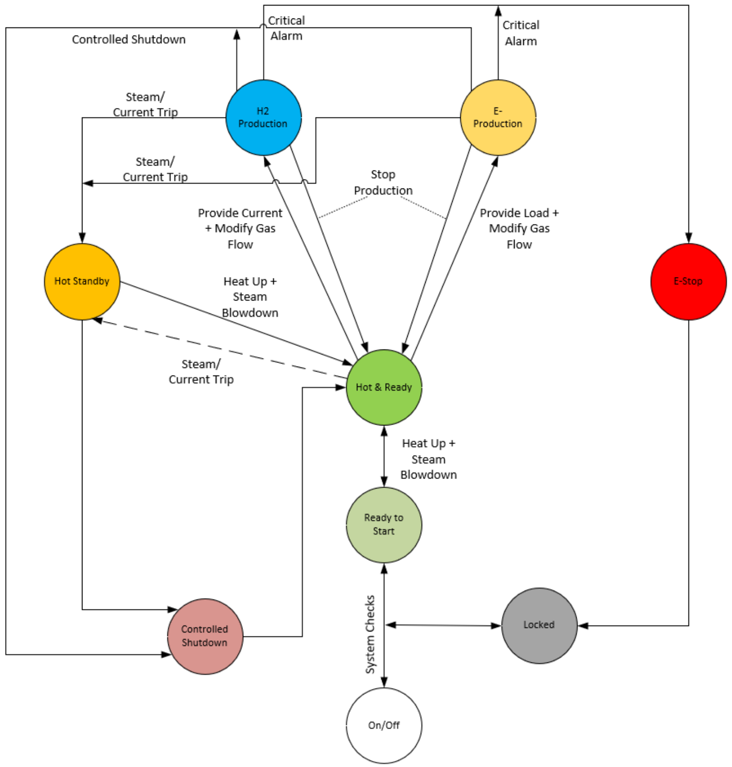
- Design build is complete!
  - All necessary design modifications have been completed.
  - All necessary components and instrumentation have been installed on the system.
- Solutions to design issues
  - Additional insulation has been added to minimize heat loss and heaters with higher wattage are being used.
  - Compression assembly has been modified for better alignment.
  - Secondary air blower used to force circulation of air through HXer.
  - Additional instrumentation has been installed throughout the system.
- System testing requirement has been increased by additional 2,000 hours to a total of 3,000 hours.

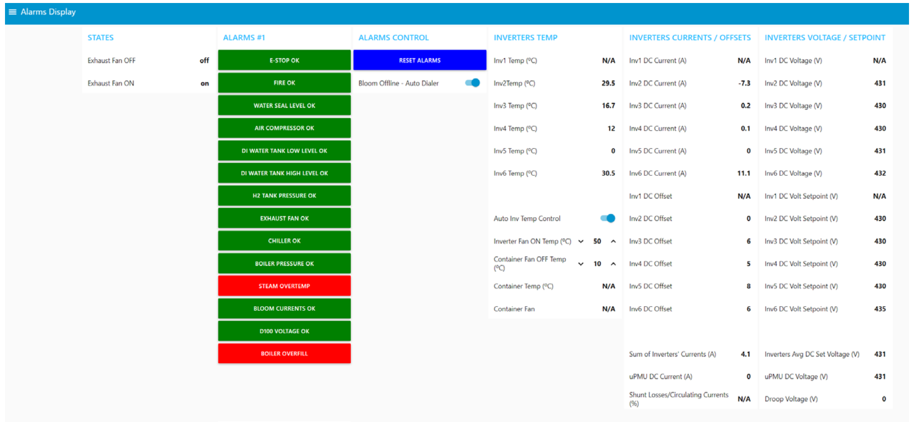
System Status (2/2)

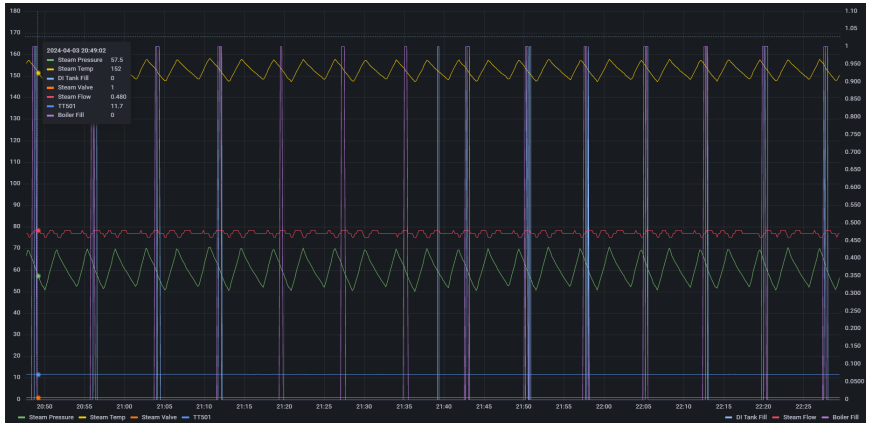
- Control strategy is 90% complete
  - Current focus is on state transition flow
  - Tuning of controllers is currently underway and should be completed by end of April.

- Appropriate alarms are being developed using information from safety systems and system state conditions to notify system operators when needed.

- Graphical User Interface is being developed to provide more intuitive user experience for system operators.







Summary

Current Work

- Task 4 – Reconfigure 50-kW SOEC test stand
  - Engineering design is complete.
  - All major components have been received and system build is complete.

- Task 5 – System integration and testing
  - Subsystem testing and control strategy-based operation is expected to be completed by April 30th, 2024.
  - System will be operated for 3,000 hrs (May. – Aug. 2024).

Future Work

- Task 7 & 8 – Data Analysis and Final Report
  - The data collected during Task 5 will be used to perform system performance analysis to demonstrate the potential of achieving > 85% (HHV) system efficiency in SOEC mode.
  - Final reporting on system performance, successes, failures and lessons learned.

Idaho National Laboratory

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