INL/CON-24-77669-Revision-0

Performance Validation of a ThermallyIntegrated 50 kW High Temperature Electrolyzer System

May 2024

Changing the World's Energy Future

Amey Shigrekar, Temitayo Olayemi Olowu, Shaleena Jaison, Trina Marie McCormick, Micah Joel Casteel, Tyler L Westover

Idaho National Laboratory

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

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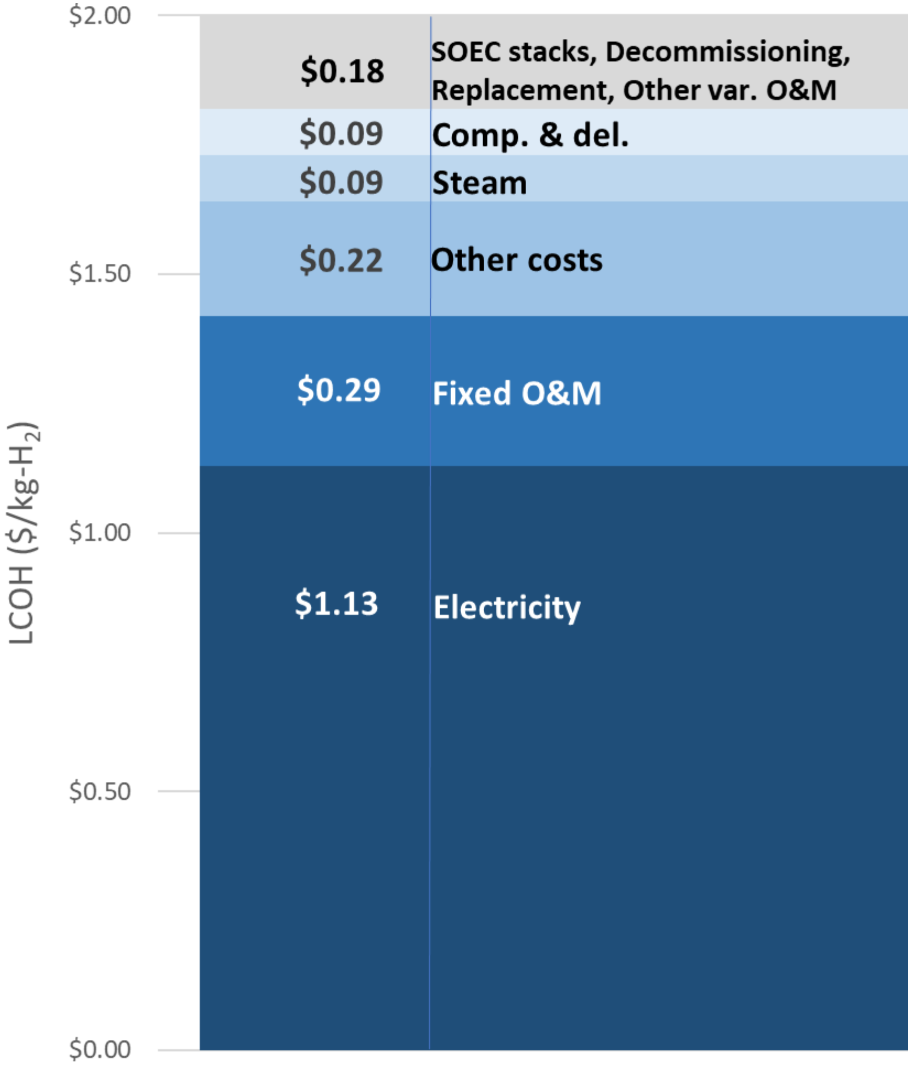
Performance Validation of a Thermally Integrated 50 kW High Temperature Electrolyzer System

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

Project Goals

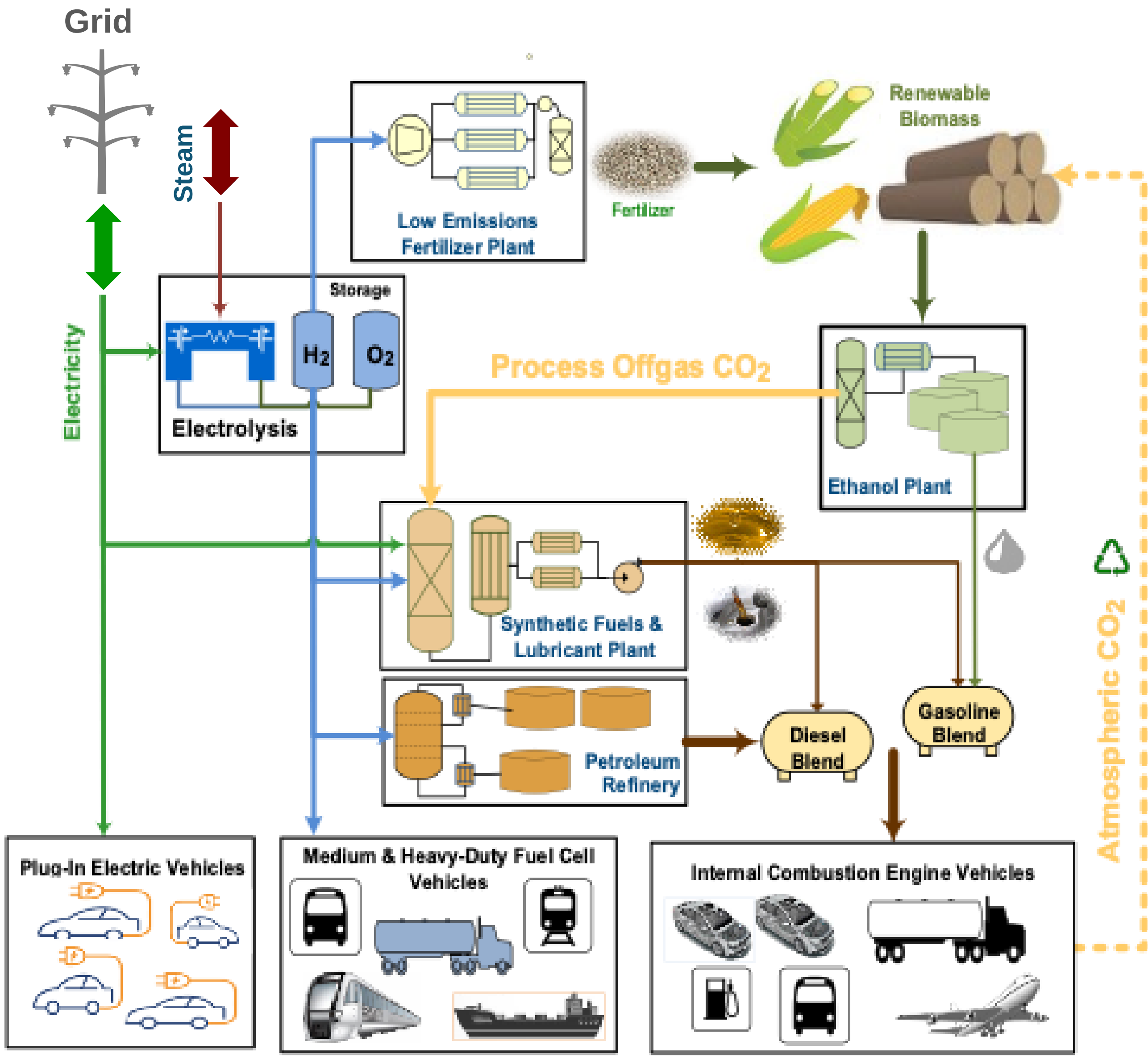
- Accumulate ~3,000 hrs operating a reversible solid oxide electrolysis (rSOC) system
  - A SOC system at INL will be modified for reversible operations:
    - 30-kW electrolysis mode/10-kW fuel cell mode
  - SOC stacks will incorporate improved catalyst in fuel electrode
  - Operation of rSOC system will be coupled to a steam generator programmed to mimic an industrial source of low-grade heat
- Thermodynamic analysis will demonstrate potential to achieve > 85% system efficiency in electrolysis mode
- Technoeconomic analysis (TEA) will demonstrate potential to produce hydrogen at a cost of $2/kg on a cost of electricity of $30/MWhr.



- Project Start Date: 10/01/2020
- Project End Date: 08/30/2024

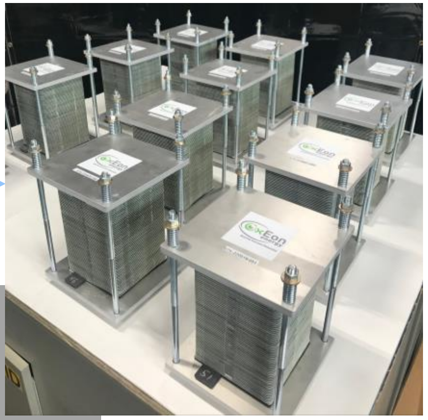
Relevance

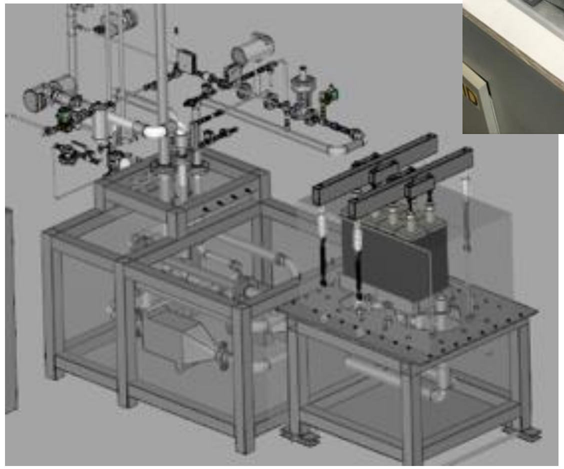
- **DE-FOA-0002300 AIO 2:**
  - Improving the cost, performance and reliability of reversible rSOC systems for clean hydrogen and clean power production
  - rSOC systems have opportunities to enter the marketplace but need proven system cost, performance, and reliability
  - rSOC systems can use the same system components (stacks, heat exchangers, piping, power converters, etc.) to reduce capital cost and maximize equipment capacity factor (% of time at maximum power)
  - 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

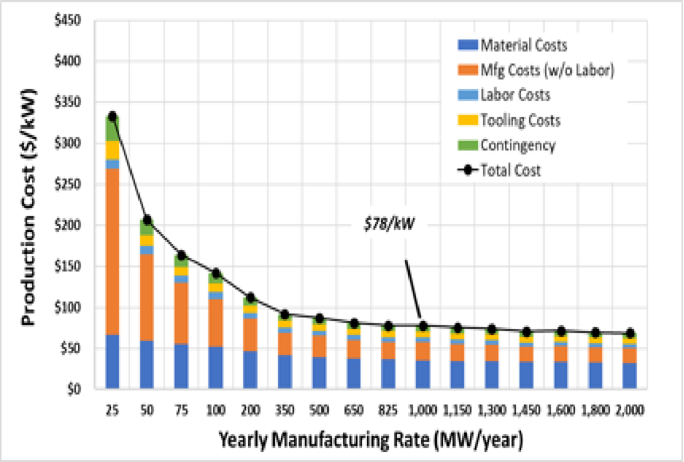


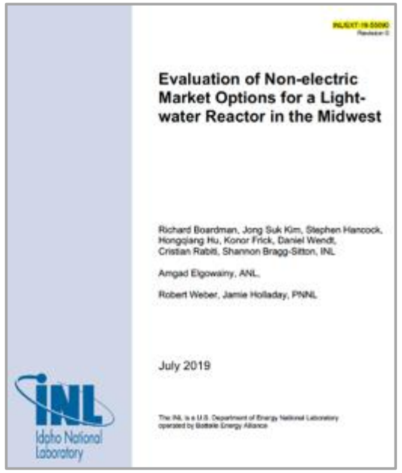
Approach

- **Task 1: Revise Project Management Plan**
- **Task 2: Stack manufacturing (OxEon)**
- **Task 3: e^2 Catalyst Development (MIT)**
- **Task 4: Reconfigure 50 kW SOC system**
- **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

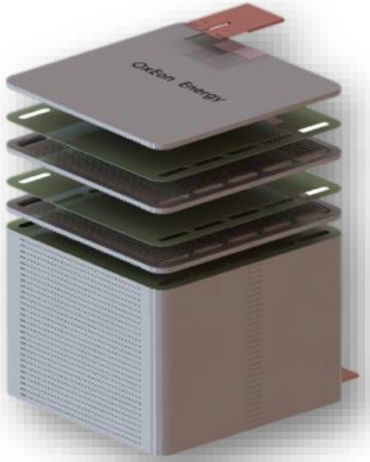
Idaho National Laboratory

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

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

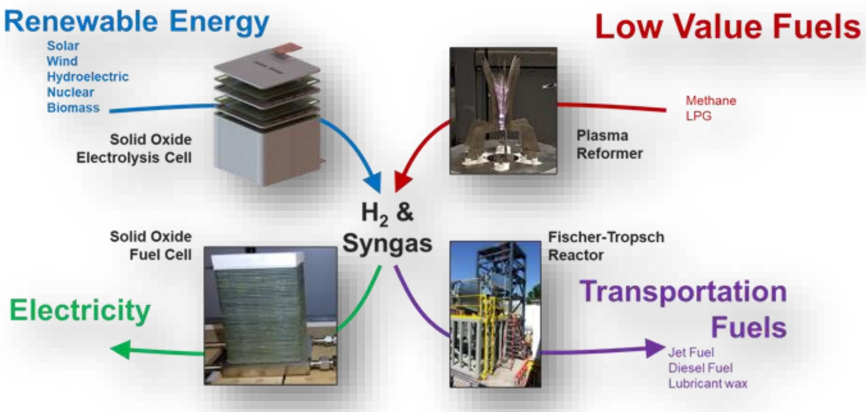


Solid Oxide Fuel Cell and Electrolysis Stacks

- 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

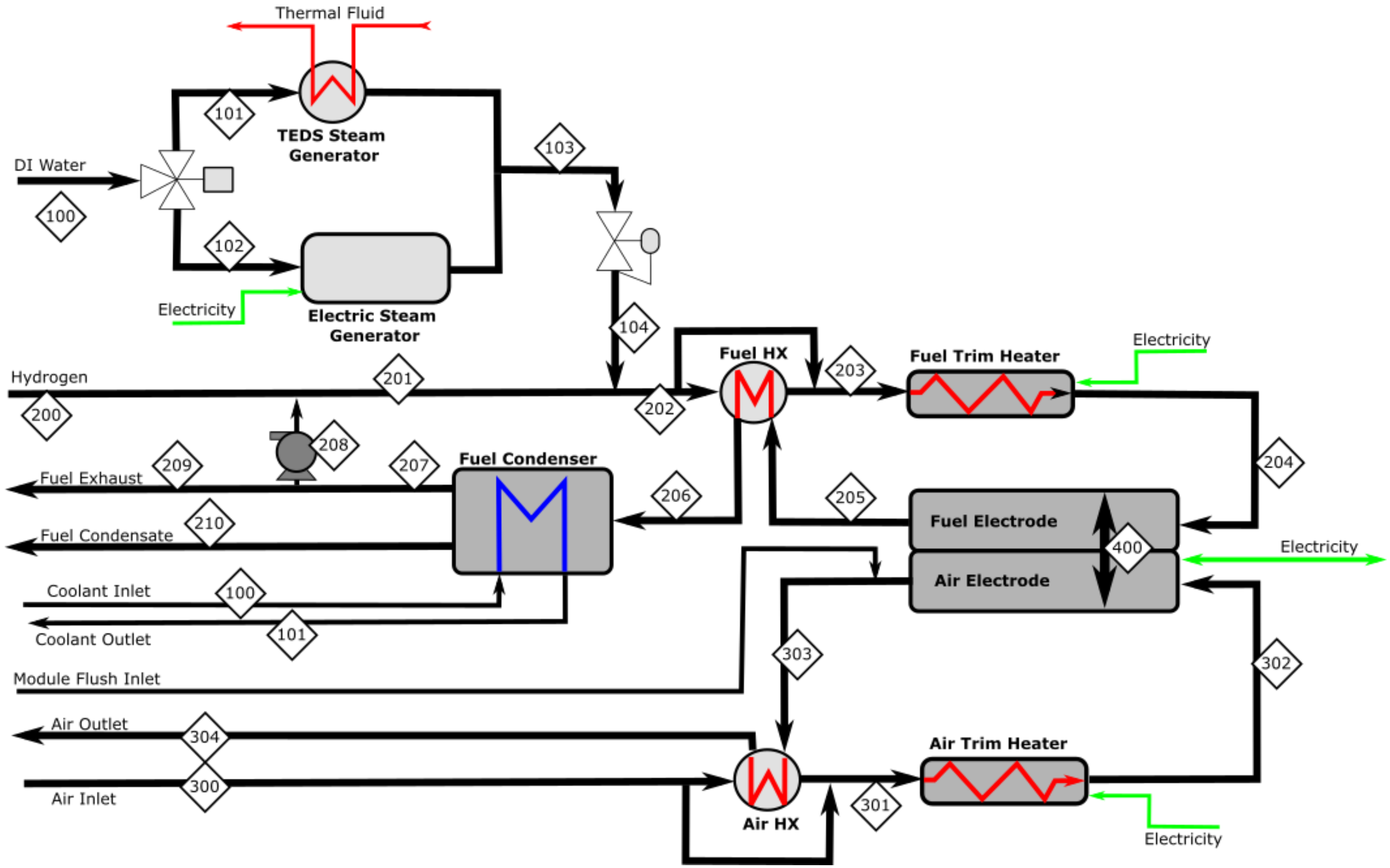
Fuel Reformation and Generation

- 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 and Integration

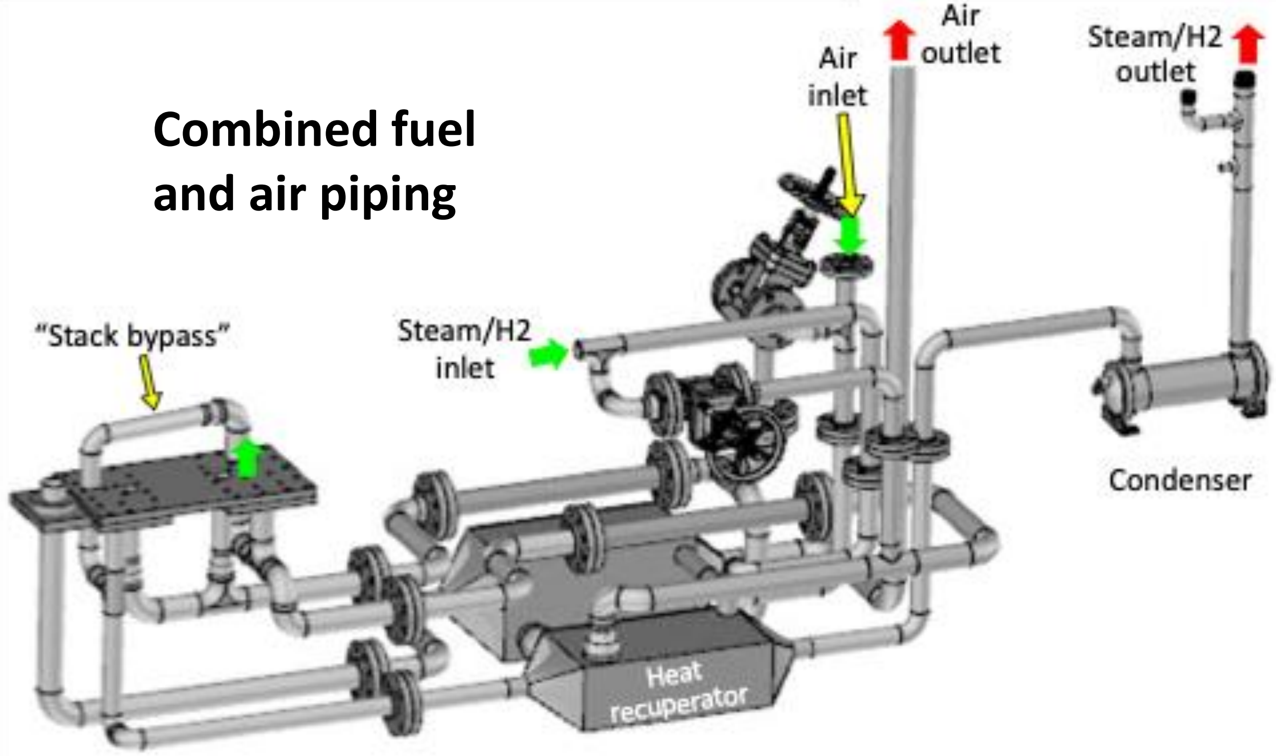
- Standard SOEC/SOFC design
  - High temperature heat exchangers (HXers) on fuel and air streams
  - HXer bypasses for incoming fuel and air streams in FC model
  - Trim heaters for EC mode
  - Fuel Condenser to separate water from product H2
  - H2 recycle loop with blower
- Steam from electric boiler or non-fired boiler



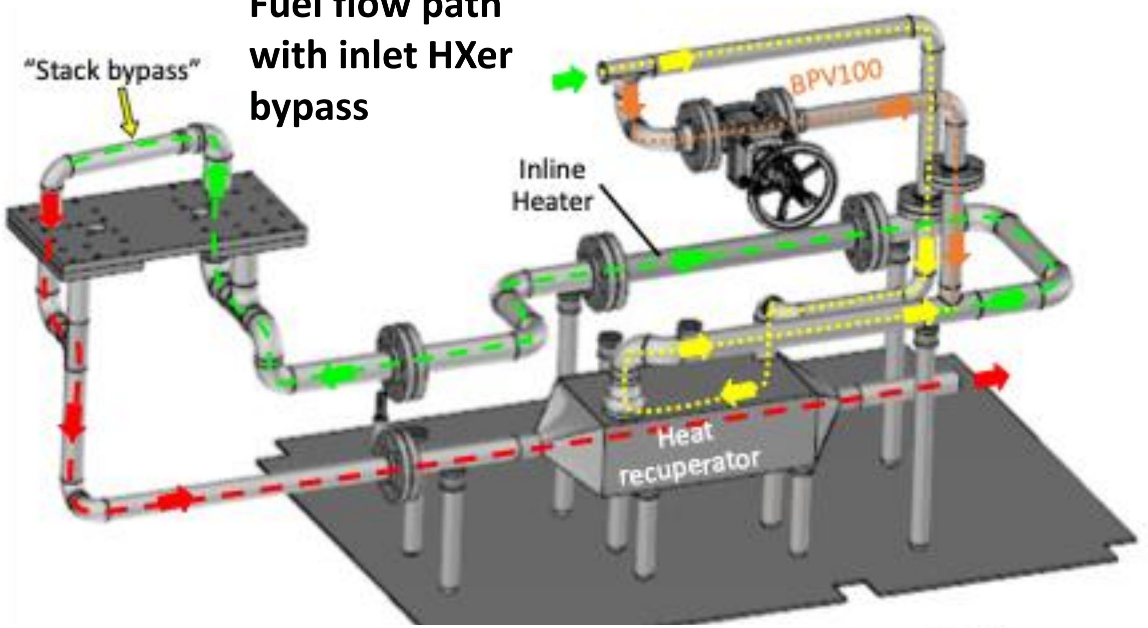
System Design & Integration

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

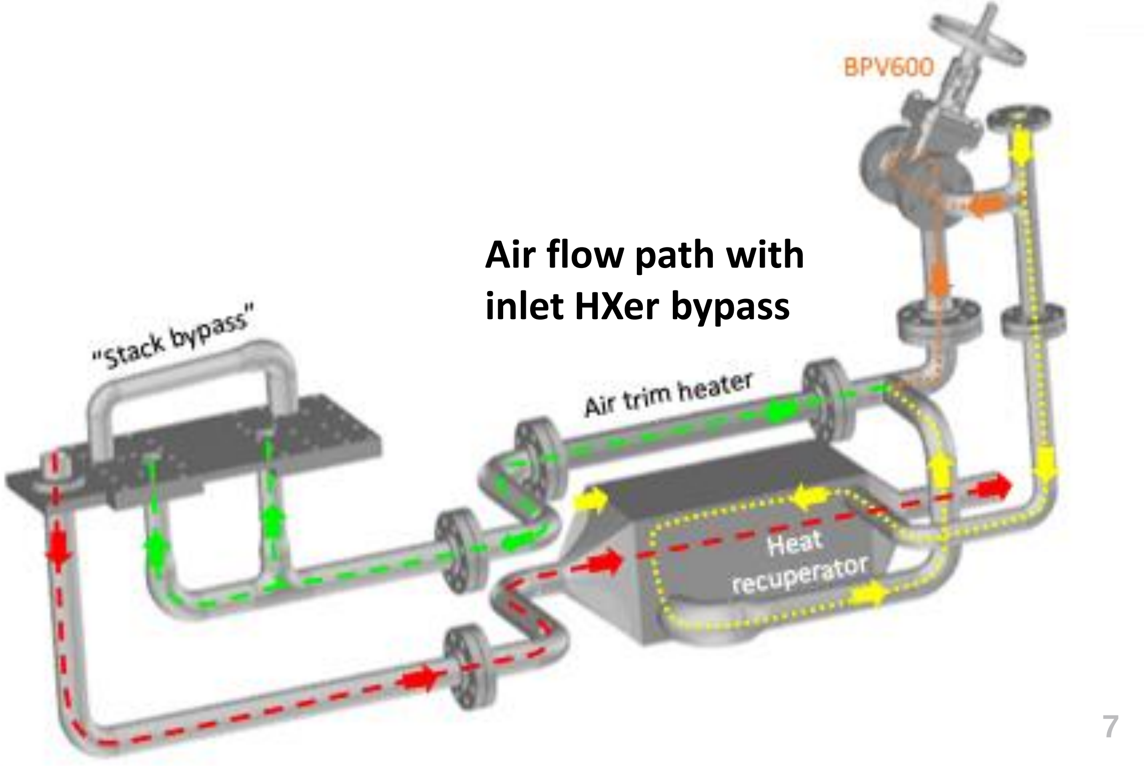
Combined fuel and air piping



Fuel flow path with inlet HXer bypass

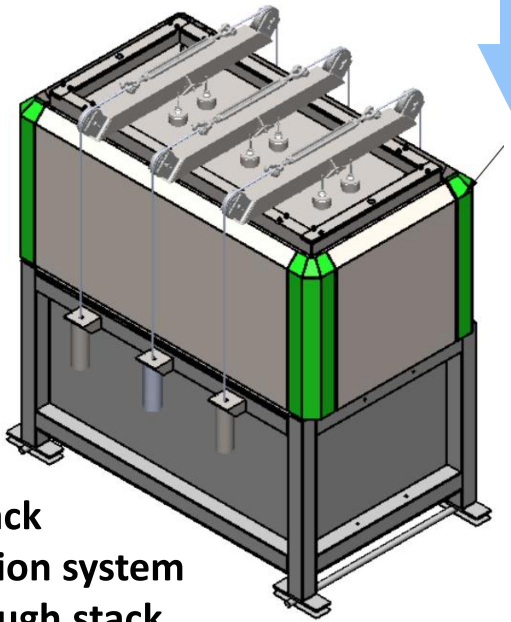


Air flow path with inlet HXer bypass

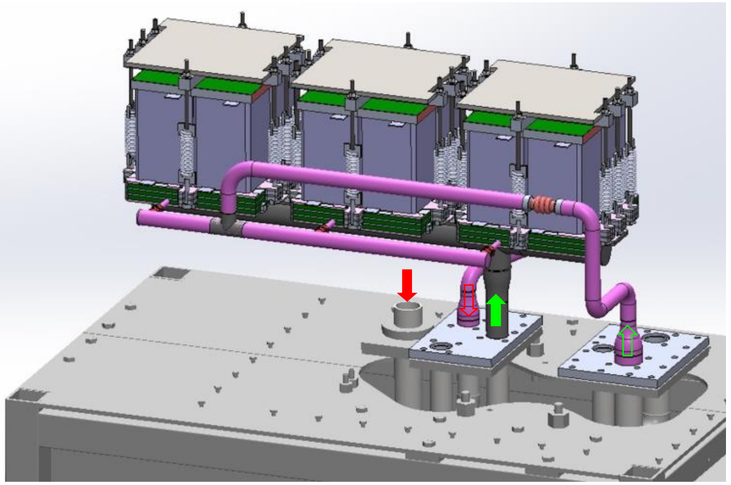


System Design & Integration

- 30 kW rSOC system located in custom 20 ft container with doors on three walls
- 12 OxEon SOEC stacks arranged in quad configurations on manifold

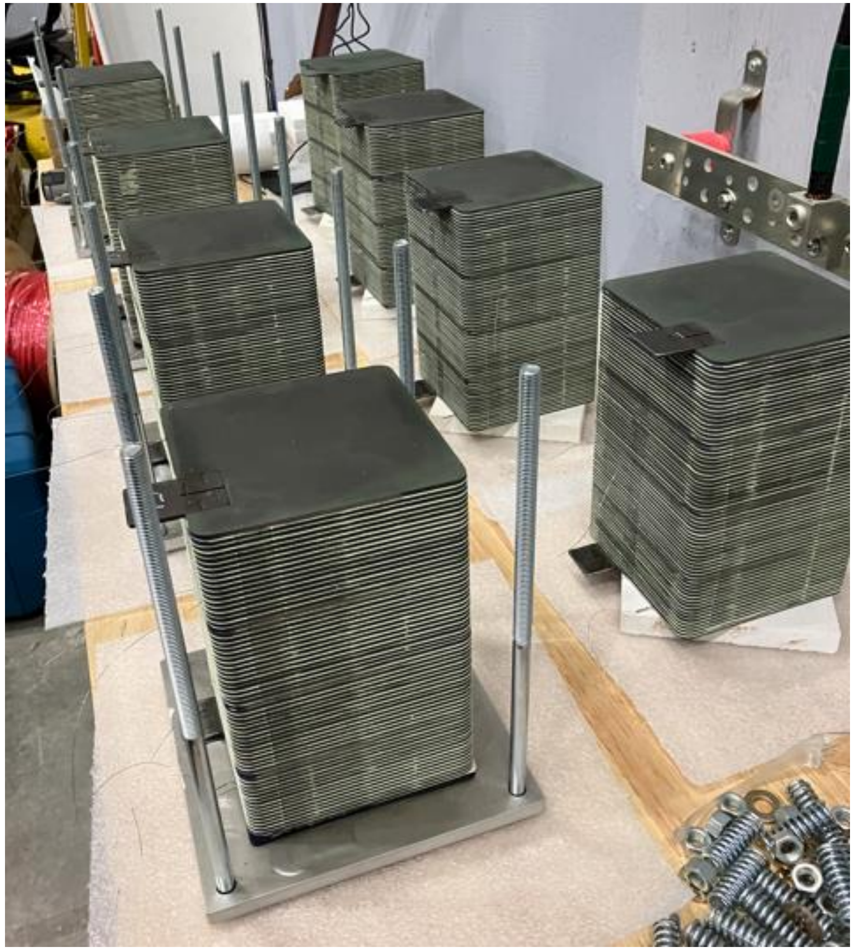


OxEon stack compression system (acts through stack module lid)



OxEon SOEC stacks on manifold

OxEon Stacks



Challenges and Barriers

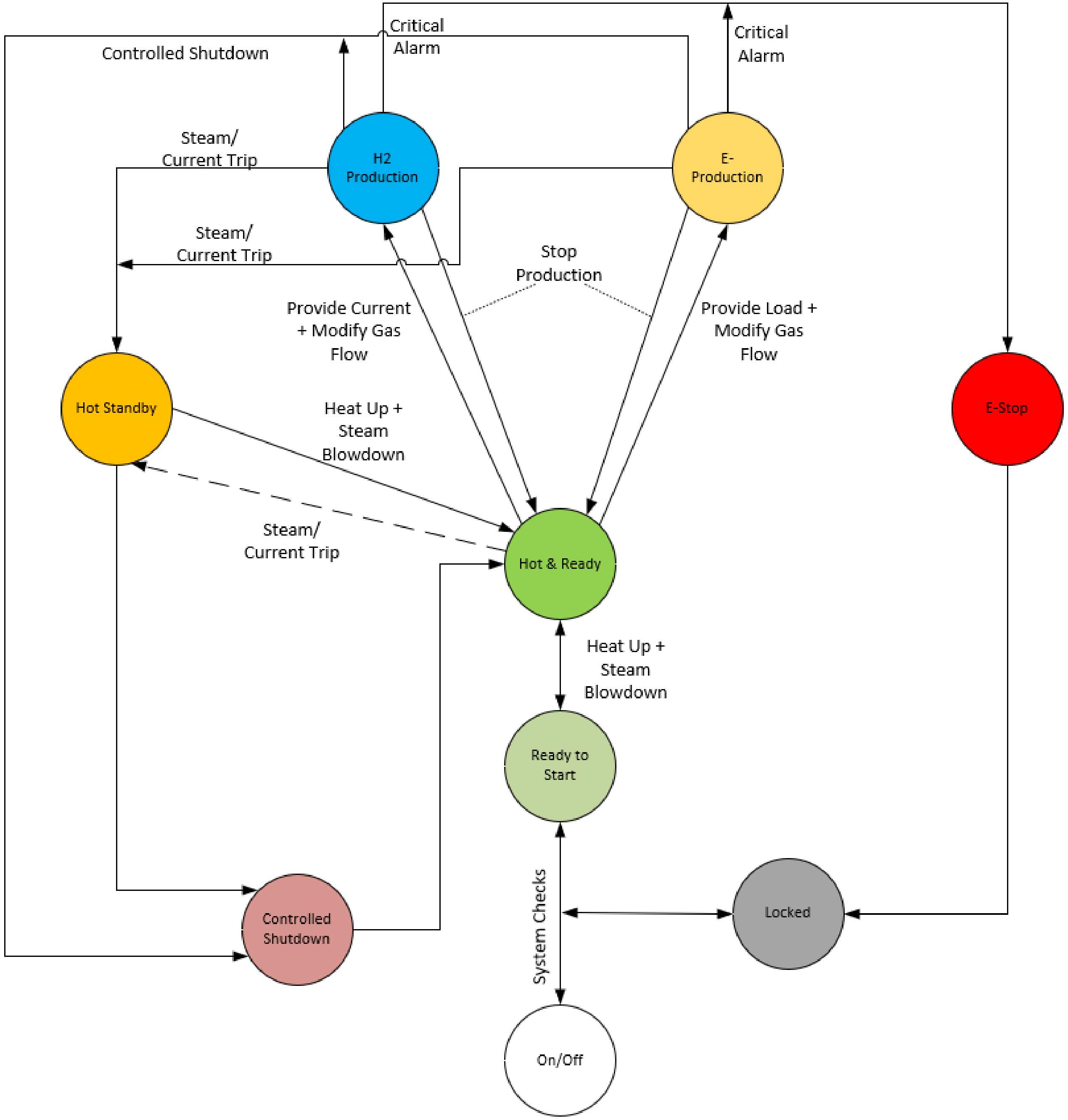
- Manufacturing delays
  - COVID-19 issues have slowed procurement
    - Some components have 18 – 30-week lead time.
  - Loss of critical personnel
  - Design issues
    - Excessive heat loss
    - Misalignment of the lid
    - Lack of recirculation

System Status 1

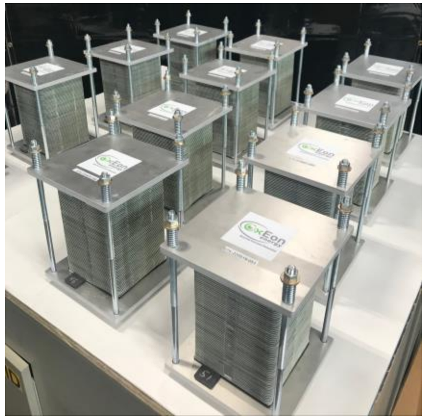
- Design build is complete
  - All the necessary components and instrumentation has been installed on the system
  - Instrumentation ring out with data acquisition is complete

System Status 2

- Subsystem tests have been performed to verify operation
  - Fuel, sweep air, electrical, thermal, safety, comms etc.
- Control strategy is 90% complete
  - Current focus is on state transition flow



Summary



- Task 2 – Stack manufacturing
  - Manufacturing by OxEon is complete
- Task 3 – e^2 Catalyst development
  - Catalyst development complete
- Task 4 – Reconfigure 50-kW SOEC system
  - Engineering complete
  - Last major item to be received is the high temperature piping system – expected ~ Nov. 8, 2002
- Task 5 – System integration and testing
  - System integration – expected ~ Dec. 15, 2022
  - System will be instrumented to measure thermodynamic performance
  - System will be operated for 3,000 hrs (Jan. – Jul. 2023)
- Task 6 – Technoeconomic & thermodynamic analysis (TEA)
  - Thermodynamic analysis will demonstrate potential to achieve > 85% system efficiency in SOEC mode
  - TEA will show potential to produce H_2 at $2/kg on a cost of electricity of $30/MWhr.

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