Project ID: ta064

Hydrogen Production, Grid Integration, and Scaling for the Future

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DOE Hydrogen Program
2024 Annual Merit Review and Peer Evaluation Meeting

Project Goal

The project will explore near and long-term visions towards the commercialization of grid integrated electrolysis systems to inform deployment across the planning, procurement, and operation stages of hydrogen production on the grid. It will leverage NREL's state-of-the-art 1.25 MW polymer electrolyte membrane (PEM) electrolyzer system to characterize system performance in relevant scenarios, also creating a digital twin for emulation in the Advanced Research on Integrated Energy Systems (ARIES) virtual environment and performing hardware-in-the-loop (HIL) testing of pilot scale, decentralized, and centralized hydrogen systems.

Overview

Timeline and Budget

- Project start date: 08/01/2022 (estimated)
- Project end date: 05/31/2025
- Total project budget: $1,653,170
  - DOE share: $1,157,219
  - Cost share: $165,317
  - In-Kind: $330,634
  - DOE funds spent: $197,910
  - Cost share funds spent: $32,464

Partners

- **NREL**, Sam Sprik (PI)
- Electric Power Research Institute (**EPRI**), Brittany Westlake

Barriers

- Lack of system performance understanding to guide commercial deployments of electrolyzers with renewables and the grid

Relevance/Potential Impact

- This project will provide insights into building a clean hydrogen energy infrastructure through multiple scenarios and hardware testing of a 1.25 MW electrolyzer and hydrogen support equipment. It will help stakeholders in decisions about deployments of clean hydrogen production with system characterization examples, multiple configurations, optimizations, suggested metering and custody transfer points.
- Hydrogen production from renewables is a clean source of fuel which is near zero for greenhouse gas emissions and criteria pollutants. The results from this project will inform entities looking to build clean energy projects that produce good paying jobs in manufacturing, installation, maintenance and operation of these facilities.

Approach: H2@Scale - Grid Integration of Hydrogen Produced via Electrolysis

Exploring H2@Scale concepts:

- Integrating water electrolysis with renewables and the grid.
- Vision towards deployments and commercialization.

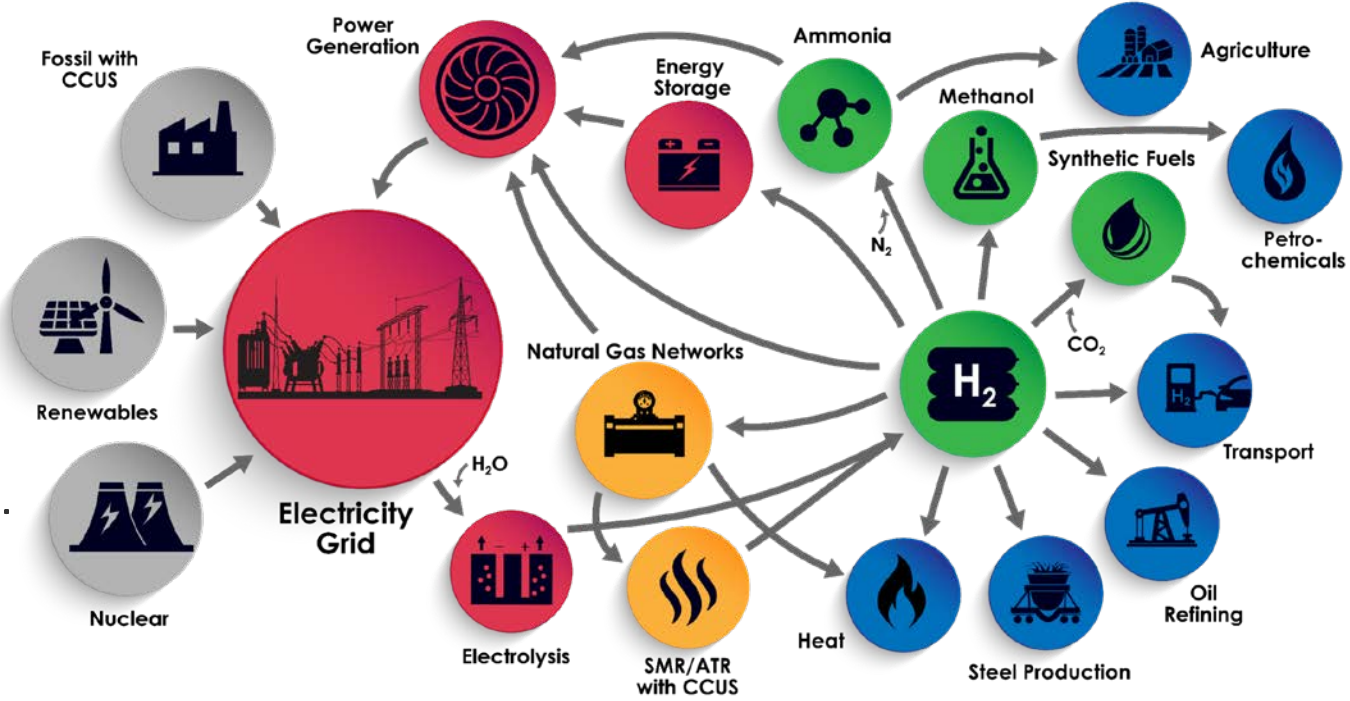


Figure Modified from DOE H2@Scale (EPRI).

Approach: Project Tasks

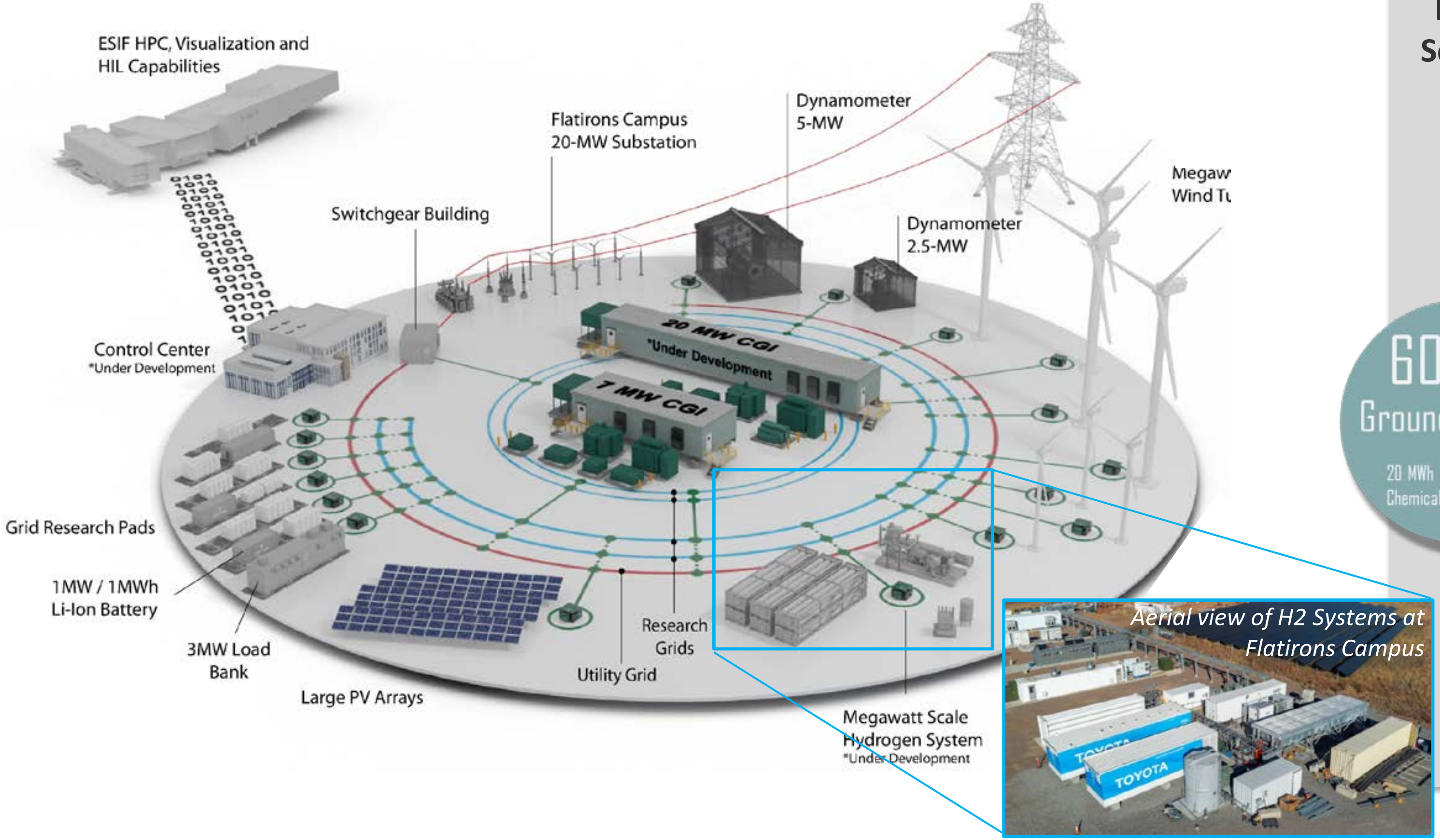
1. Determine system boundary and scenarios with grid, wind and solar.
    - Electrical custody transfer points: Grid connected, islanded, behind the meter with renewable energy mix, and power purchase agreement.
    - H2 custody transfer points: tube trailer, natural gas blending, hydrogen pipeline.
2. Metering and monitoring needs for research vs. commercial systems.
3. Prepare hydrogen system sizing and demand scenarios along with system testing and characterization procedures.
4. Hardware system characterization using demand profiles and test procedures from scenarios above.
5. Create scalable digital twin. Explore the advantage of shared balance-of-plant (BOP) opportunities, maintenance schedules, degradation characteristics, and best practices for modular systems.
6. Use the Renewable Energy Integration and Optimization (ReOpt) tool for short-, mid- and long-term scenarios for optimizing system sizes. Compressor efficiency and major electrical loads considered in optimization.

7-9 HIL testing along with emulation in the Advanced Research on Integrated Energy Systems (ARIES) virtual network for pilot scale, decentralized and centralized hydrogen production.

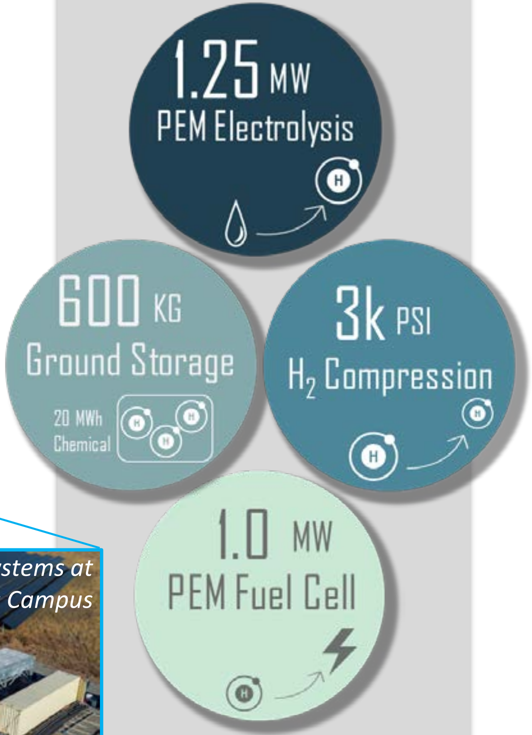
10. Interim reporting on tasks and final report.

Go/No-Go decision for Tasks 1–3 **6/30/2024**: Testing and Characterization of NREL 1.25MW Electrolyzer.

Approach: Utilize the MW Scale Hydrogen Systems Capabilities at NREL



Integrated Megawatt Scale Hydrogen System



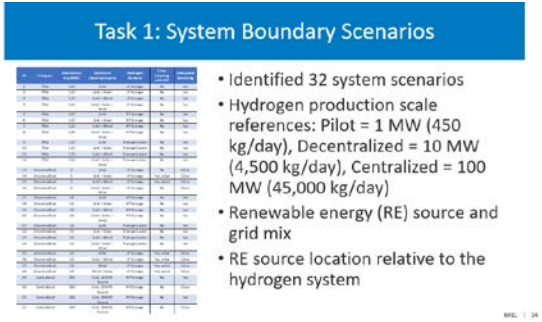
Approach: Safety Planning and Culture

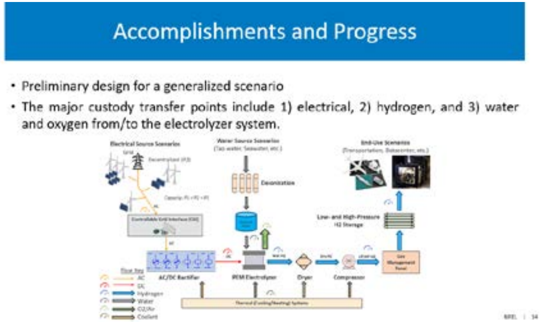
- Work for this project has been done in agreement with NREL's safety culture and Hazard Analysis Review procedures.
- Please visit Daniel Leighton's AMR presentation for more information: TA048 ARIES/Flatirons Facility – Hydrogen System Capability Buildout.

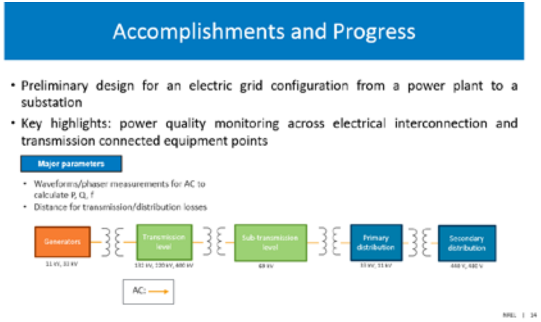
Accomplishments and Progress:
Response to Previous Year Reviewers’ Comments

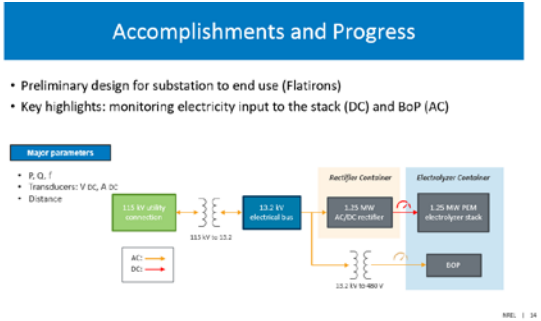
- This project has not been reviewed.

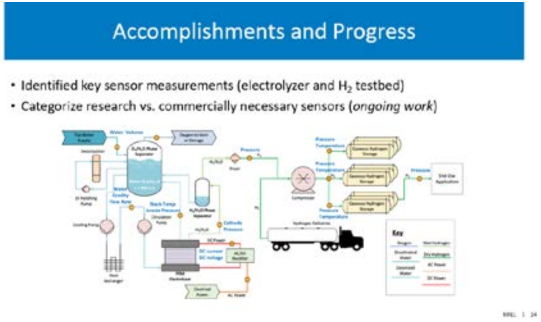
2023 Accomplishments

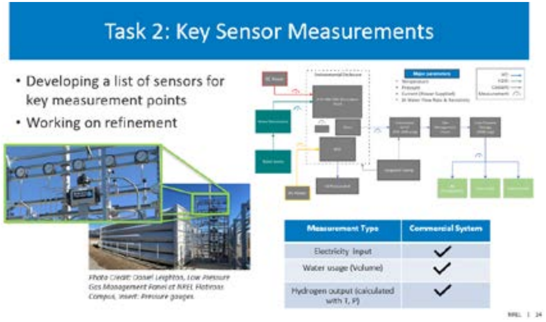












For more details, please reference the 2023 AMR poster.

Accomplishments and Progress

For Task 1, the following work was initiated:

- Preliminary design for a generalized scenario
- Power plant to substation
- Substation to end use (NREL Flatirons)

For Task 2, the following work was initiated:

- Identified key sensor measurements (electrolyzer and H_2 testbed)
- Ongoing efforts to refine research vs. safety sensors

For Task 3:

- Currently preparing hydrogen system sizing and demand scenarios along with **system testing and characterization procedures**.
- Initial electrolyzer system shakedown experiments have been conducted towards Go/No-Go decision milestone work, excluding the compressor/storage tanks.

PEM Electrolysis System Shakedown Experimental Timeline

Monday 2/26/2024

- Cold-start operation
- 100% power
- Polarization curves
- 30 sec holds
- 5-minute holds

Tuesday 2/27/2024

- Cold-start operation
- 100% power
- Issues with alarms
- Installed MFM hardware

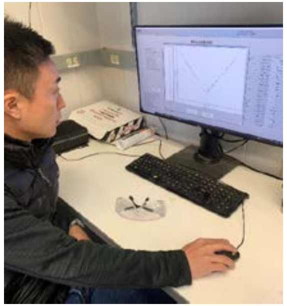
MFM – Mass Flow Meter

Monday 3/4/2024

- Cold-start operation
- 75% power
- H_2 dew point < 5 ppm (SAE J2719) to change from "vent" to "product" mode
- MFM data collected

Thursday 3/7/2024

- Cold-start operation
- 100% power
- MFM data collected



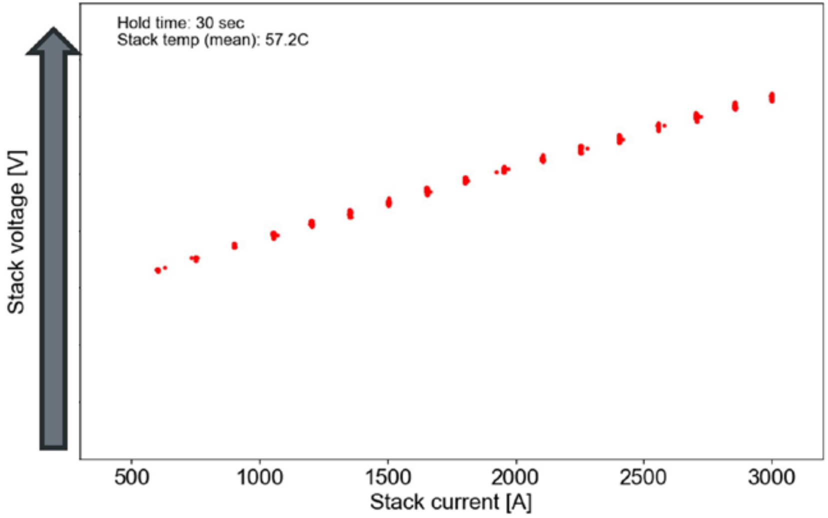
Tuesday 3/12/2024

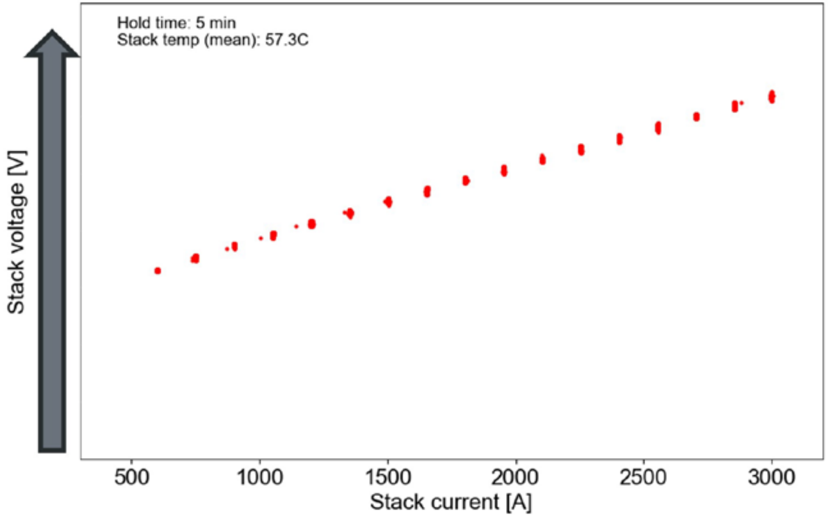
- Cold-start operation
- 100% power
- 25% power
- MFM data collected ~4 hrs

Goal: To identify any potential issues & gain experience to determine the best workflow plans.

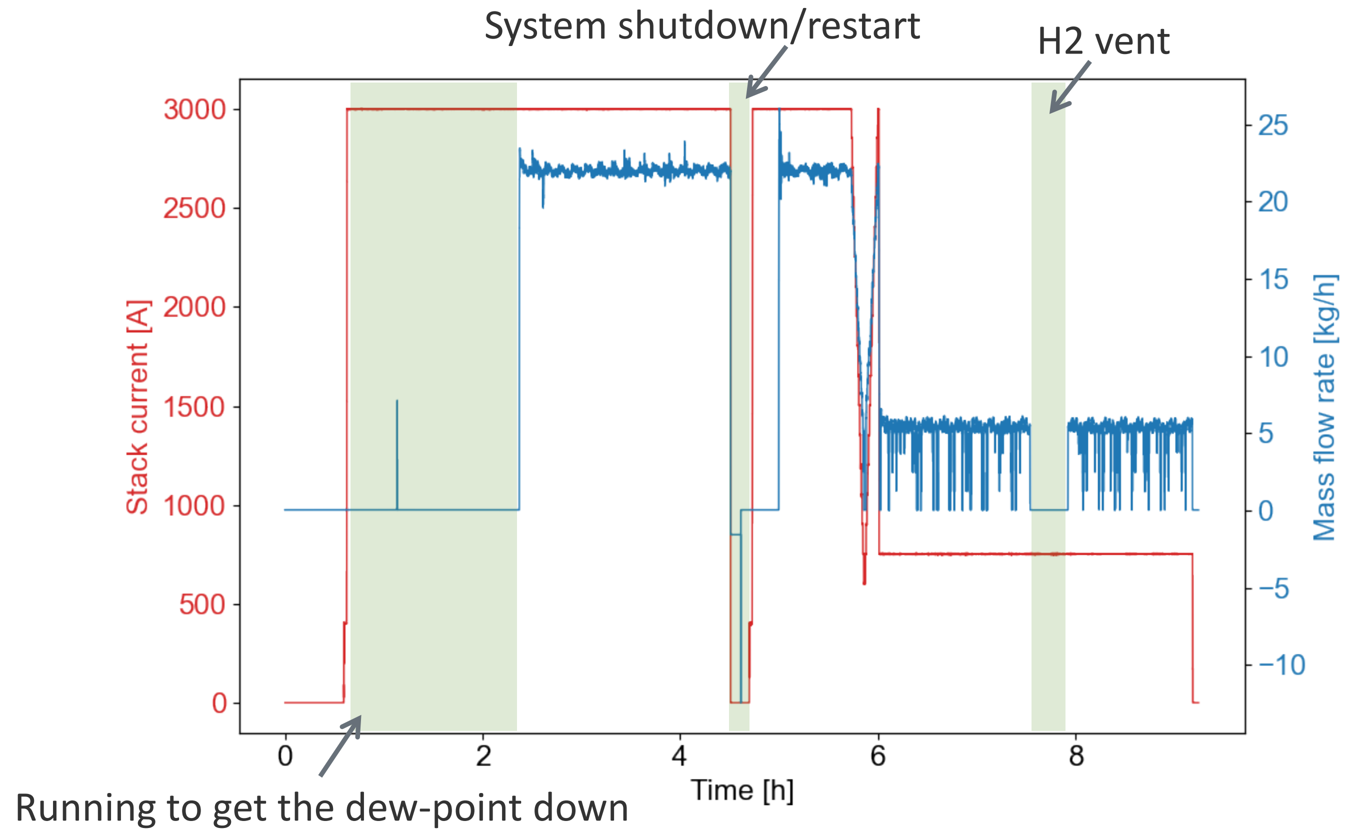
Milestone Preliminary System Test Results

- Towards 40 hours steady state operation to examine stack efficiency at various power levels (25%-100%) for ~10 hours
- Step-up/down profile from 100% to 20% (5 min hold)
- A series of preliminary tests with 30 sec and 5 min holds have been performed to examine the system response rate and stack efficiency.





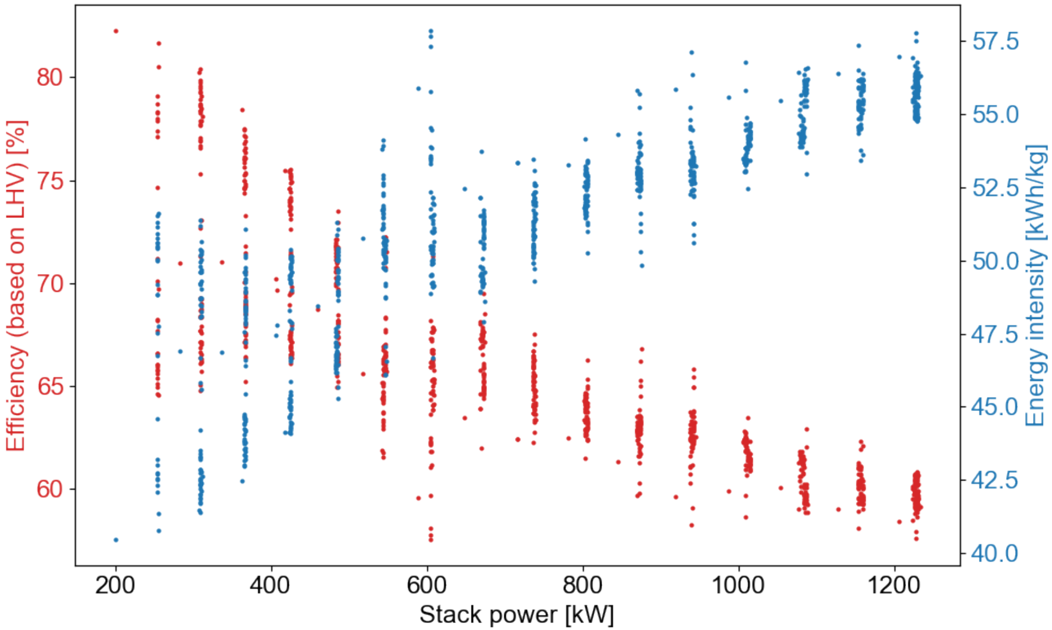
Milestone Preliminary System Test Results

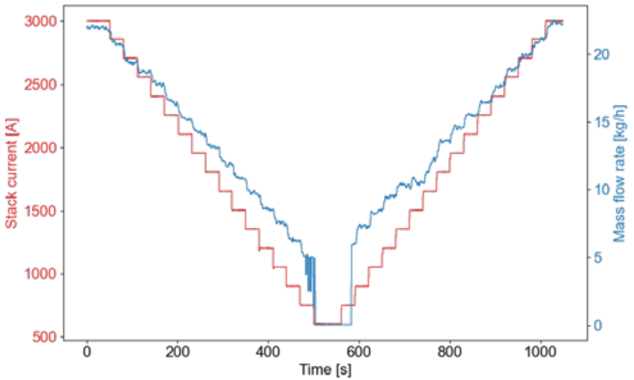


- 100% setpoint, polarization curve, and then 25% setpoint
- MFM values fluctuate when operating low current applied due to lower H_2 production rate/H_2 outlet pressure

Milestone Preliminary Stack Test Results

Data filtered between 40 kWh/kg and 60 kWh/kg
Data vary due to fluctuated MFM data, especially lower stack current/power region (ref. 30-sec hold polarization curve)





Stats	Efficiency (based on LHV) [%]	Energy intensity [kWh/kg]
Mean	65.2	51.4
Min	57.5	40.5
Median	64.2	51.9
Max	82.3	57.9
Std	5.0	3.7

Collaboration and Coordination

Organization	Type	Roles
National Renewable Energy Lab (**NREL)**	National Lab	Project lead, testing, modeling, optimization, reporting.
Electric Power Research Institute (**EPRI**)	Research Institute	Cost share, stakeholder feedback, reporting, scenarios, reviews.
Low-Carbon Resources Initiative (**LCRI**)	EPRI and Gas Technology Institute (**GTI**) Technical Subcommittee	Feedback on system testing, performance verification and scenarios that may likely occur at commercial deployments.

Proposed Future Work

- Revise scenarios and system coupling with renewable boundaries.
- Revise test plans for future experiments now that the electrolyzer system is fully commissioned at the NREL Flatirons site.
- Finalize the Report from previous tasks.
- Go/No-Go decision 6/30/2024: Testing and Characterization of NREL 1.25MW Electrolyzer.
- Complete the tasks listed on the Approach: Project Task slide
  - Test procedure development, system scaling, optimizing, HIL testing with renewables, digital twin model

Any proposed future work is subject to change based on funding levels

Remaining Challenges and Barriers

Challenges and barriers:

- Delayed commissioning of the electrolyzer system (3/2024).

Next steps:

- Metering and monitoring suggestions for research vs. commercial systems.
- Preparing hydrogen system sizing and demand scenarios along with system testing and characterization procedures.
- Hardware system characterization using demand profiles and test procedures from scenarios above.
- Creating scalable digital twin for modeling and analysis.
- System optimization with Renewable Energy Integration and Optimization (ReOpt) tool.
- HIL testing along with emulation in the Advanced Research on Integrated Energy Systems (ARIES) virtual network for pilot scale, decentralized and centralized hydrogen production.
- Reporting results.

Summary

- This 3-year project is in beginning stage.
- It will explore several scenarios for hydrogen demand and production from grid, wind, and solar in pilot scale, distributed, and central production.
- NREL's 1.25 MW electrolyzer and hydrogen hardware will be used for performance characterization and testing scenarios along with emulation.
- Results will provide insights into hydrogen production configurations, metering, performance characterization, and integration with the grid and renewables.
- Hardware testing has begun with initial system performance and production measured using a mass flow meter during initial shakedown testing. The planning for future testing is underway and will lead towards a test procedure that other systems could benefit from.

Thank You

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NREL/PR-5700-89514

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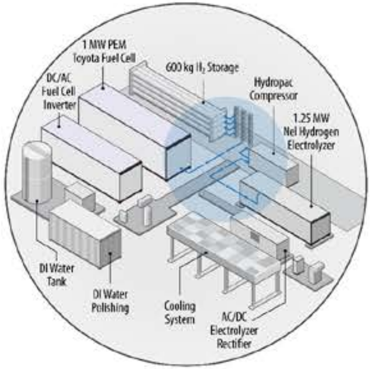
Technical Backup and Additional Information

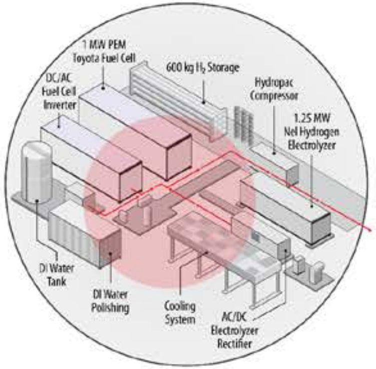
Technology Transfer Activities

- **No technology transfer activities as this project is just getting started.**
- **Development of standard test procedure for electrolyzer system characterization.**

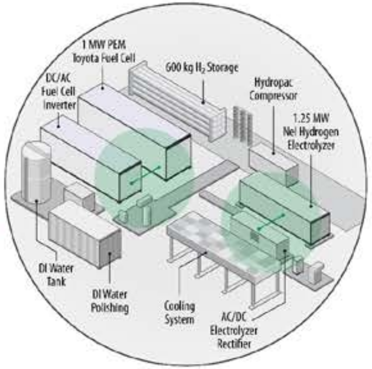
Technical Backup Slide: Systems Integration



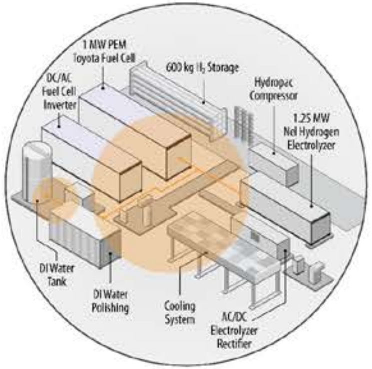
Hydrogen Connections



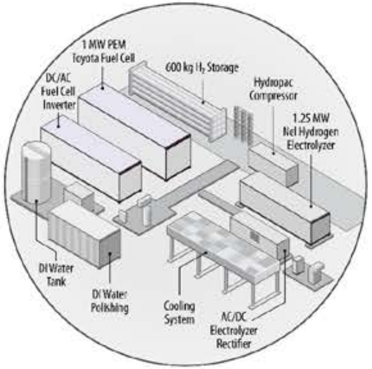
13.2 kW Grid Connections



DC Connections



DI Water Connections



System Map

Publications and Presentations

Public report from Task 1 in preparation.

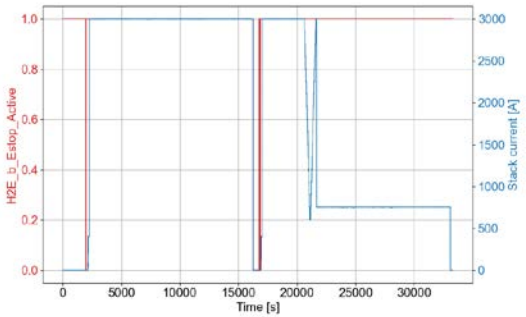
Reviewer Only

Unplanned E-Stop

On 3/12/2024 during our experiment while both the electrolyzer and fuel cell were operating the EPO button was accidentally bumped by a worker.

This unplanned E-Stop verified the immediate and complete system shut-down when running at full power.

H2E_b_Estop_Active plot



The EPO button near the electrolyzer.