Hydrogen Production, Grid Integration, and Scaling for the Future

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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 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: $80,393
  - Cost share funds spent: $3,400

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

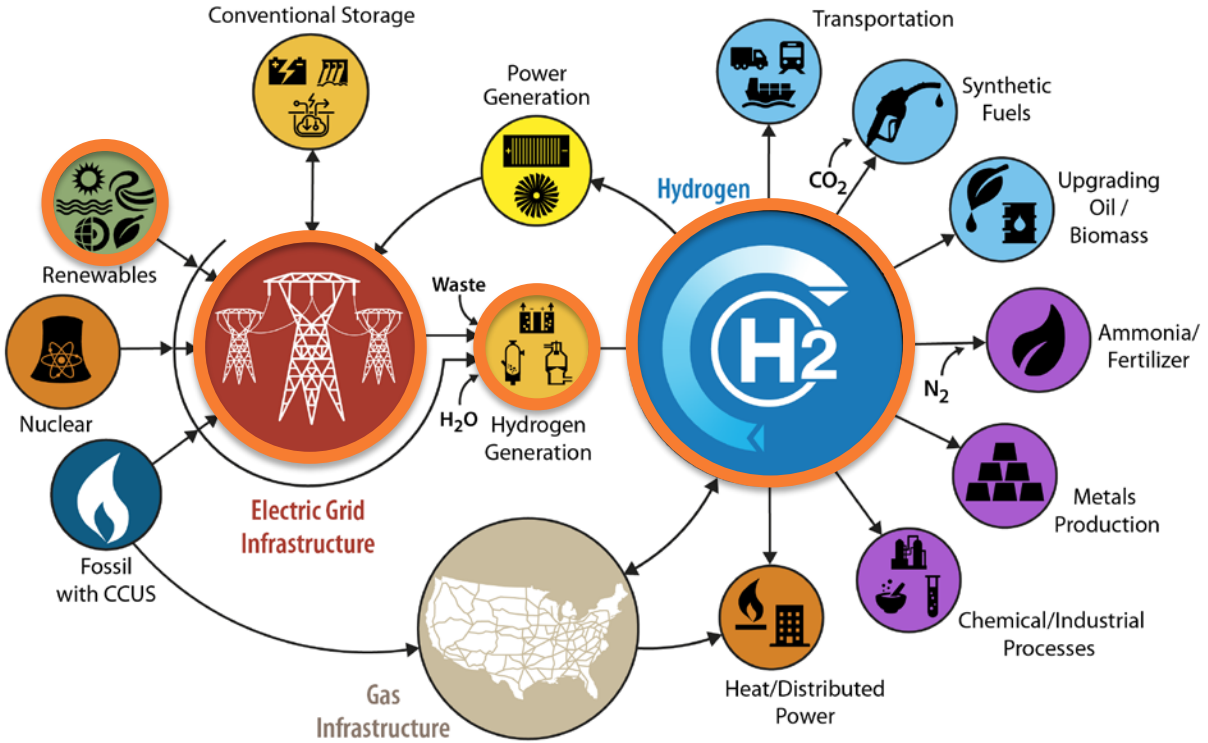
Relevance/Potential Impact

- 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 Electrolysis

Exploring H2@Scale concepts:

- Integrating hydrogen electrolysis with renewables and the grids.
- Vision towards deployments and commercialization.



Approach: Project Tasks

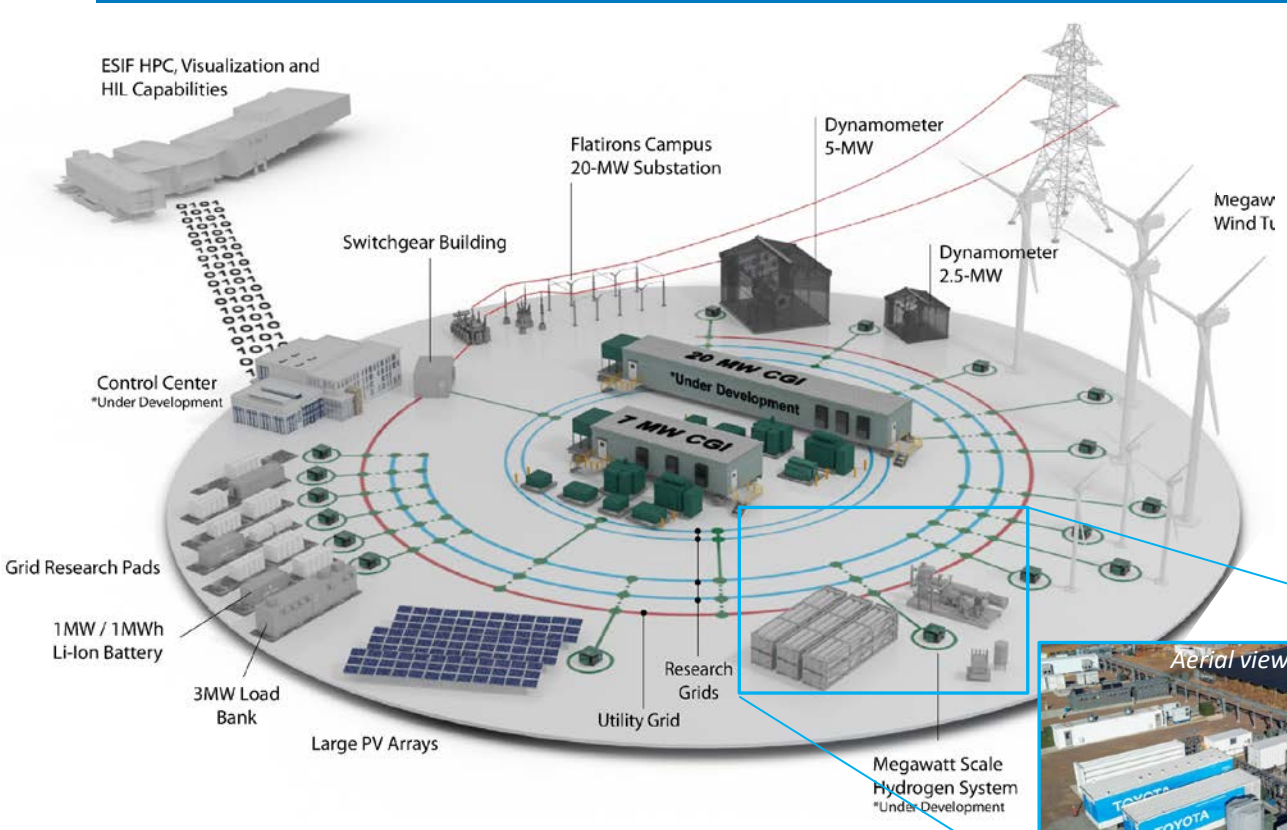
1. Determine system boundary and scenarios with grid, wind and solar.
    - Electrical custody transfer points: Grid connected, islanded, behind the meter with renewable energy mix, and power purchase agreement.
    - H2 custody transfer points: tube trailer, natural gas blending, hydrogen pipeline.
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.

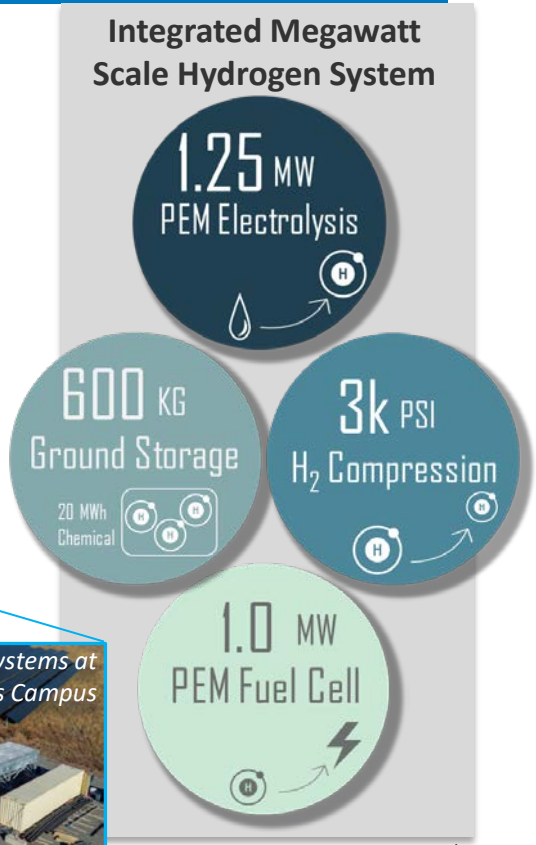
7-9 HIL testing along with emulation in the Advanced Research in Integrated Energy Systems (ARIES) virtual network for pilot scale, decentralized and centralized hydrogen production.

10. Interim reporting on tasks and final report.

Go/NoGo decision 3/30/2023: Testing and Characterization of NREL 1.25MW Electrolyzer. (*Pending system commissioning: May*)

Approach: Utilize the MW Scale Hydrogen Systems Capabilities at NREL





Accomplishments and Progress

- Determined system boundary scenarios related to electricity supply (Grid/Solar/Wind)
- Determined system boundary scenarios related to hydrogen production scale (pilot, distributed, and centralized production)
- Determined system boundary scenarios related to end-use (hydrogen pipeline, hydrogen blending with natural gas pipeline, transportation via tube trailer, storage via tanks)
- Determined potential custody transfer points for electricity and hydrogen

For Task 1, the following work was initiated:

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

For Task 2, the following work was initiated:

- Identified key sensor measurements (electrolyzer and H_2 testbed)

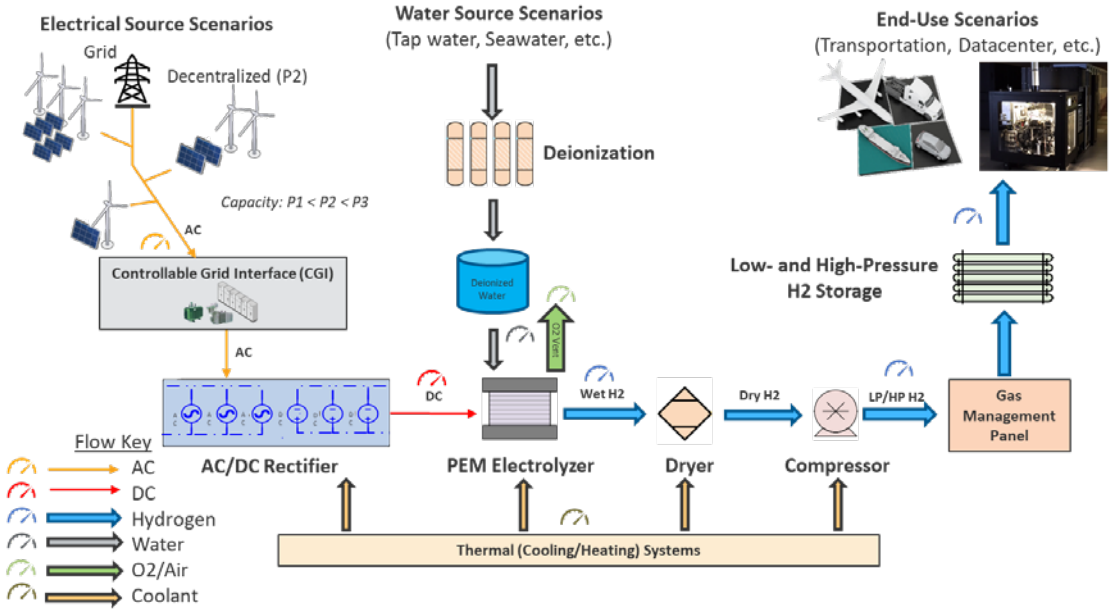
Task 1: System Boundary Scenarios

ID	Category	Electrolyzer Size (MW)	Dominant Electrical Source	Hydrogen Demand	Close Coupling with RE?	Geospatial Balancing
1	Pilot	1.25	Grid	LP Storage	No	Far
2	Pilot	1.25	Grid + Solar	LP Storage	No	Far
3	Pilot	1.25	Grid + Wind	LP Storage	No	Far
4	Pilot	1.25	Grid + Solar + Wind	LP Storage	No	Far
5	Pilot	1.25	Grid	HP Storage	No	Far
6	Pilot	1.25	Grid + Solar	HP Storage	No	Far
7	Pilot	1.25	Grid + Wind	HP Storage	No	Far
8	Pilot	1.25	Grid + Solar + Wind	HP Storage	No	Far
9	Pilot	1.25	Grid	Transportation	No	Far
10	Pilot	1.25	Grid + Solar	Transportation	No	Far
11	Pilot	1.25	Grid + Wind	Transportation	No	Far
12	Pilot	1.25	Grid + Solar + Wind	Transportation	No	Far
13	Decentralized	5	Grid	LP Storage	No	Close
14	Decentralized	5	Grid + Solar	LP Storage	Yes, solar	Close
15	Decentralized	5	Grid + Wind	LP Storage	Yes, wind	Close
16	Decentralized	5	Grid + Solar + Wind	LP Storage	No	Close
17	Decentralized	10	Grid	HP Storage	No	Far
18	Decentralized	10	Grid + Solar	HP Storage	No	Far
19	Decentralized	10	Grid + Wind	HP Storage	No	Far
20	Decentralized	10	Grid + Solar + Wind	HP Storage	No	Far
21	Decentralized	10	Grid	Transportation	No	Far
22	Decentralized	10	Grid + Solar	Transportation	No	Far
23	Decentralized	10	Grid + Wind	Transportation	No	Far
24	Decentralized	10	Grid + Solar + Wind	Transportation	No	Far
25	Decentralized	10	Solar	LP Storage	Yes, solar	Close
26	Decentralized	10	Solar + Wind	LP Storage	Yes, solar	Close
27	Decentralized	10	Wind	LP Storage	Yes, wind	Close
28	Decentralized	10	Wind + Solar	LP Storage	Yes, wind	Close
29	Centralized	100	Grid, 25% RE Source	HP Storage	No	Far
30	Centralized	100	Grid, 25% RE Source	HP Storage	No	Close
31	Centralized	100	Grid, 50% RE Source	HP Storage	No	Far
32	Centralized	100	Grid, 50% RE Source	HP Storage	No	Close

- Identified 32 system scenarios
- Hydrogen production scale references: Pilot = 1 MW (450 kg/day), Decentralized = 10 MW (4,500 kg/day), Centralized = 100 MW (45,000 kg/day)
- Renewable energy (RE) source and grid mix
- RE source location relative to the hydrogen system

Accomplishments and Progress

- Preliminary design for a generalized scenario
- The major custody transfer points include 1) electrical, 2) hydrogen, and 3) water and oxygen from/to the electrolyzer system.

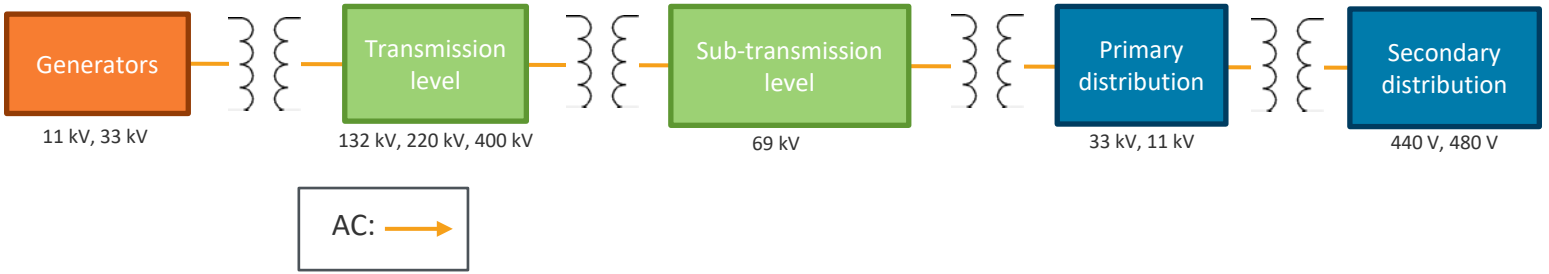


Accomplishments and Progress

- Preliminary design for an electric grid configuration from a power plant to a substation
- Key highlights: power quality monitoring across electrical interconnection and transmission connected equipment points

Major parameters

- Waveforms/phaser measurements for AC to calculate P, Q, f
- Distance for transmission/distribution losses

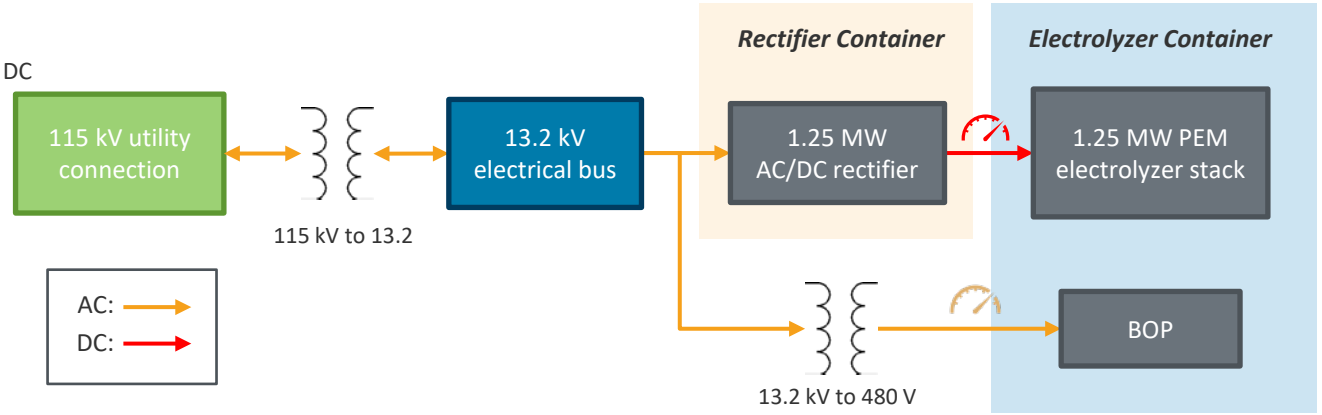


Accomplishments and Progress

- Preliminary design for substation to end use (Flatirons)
- Key highlights: monitoring electricity input to the stack (DC) and BoP (AC)

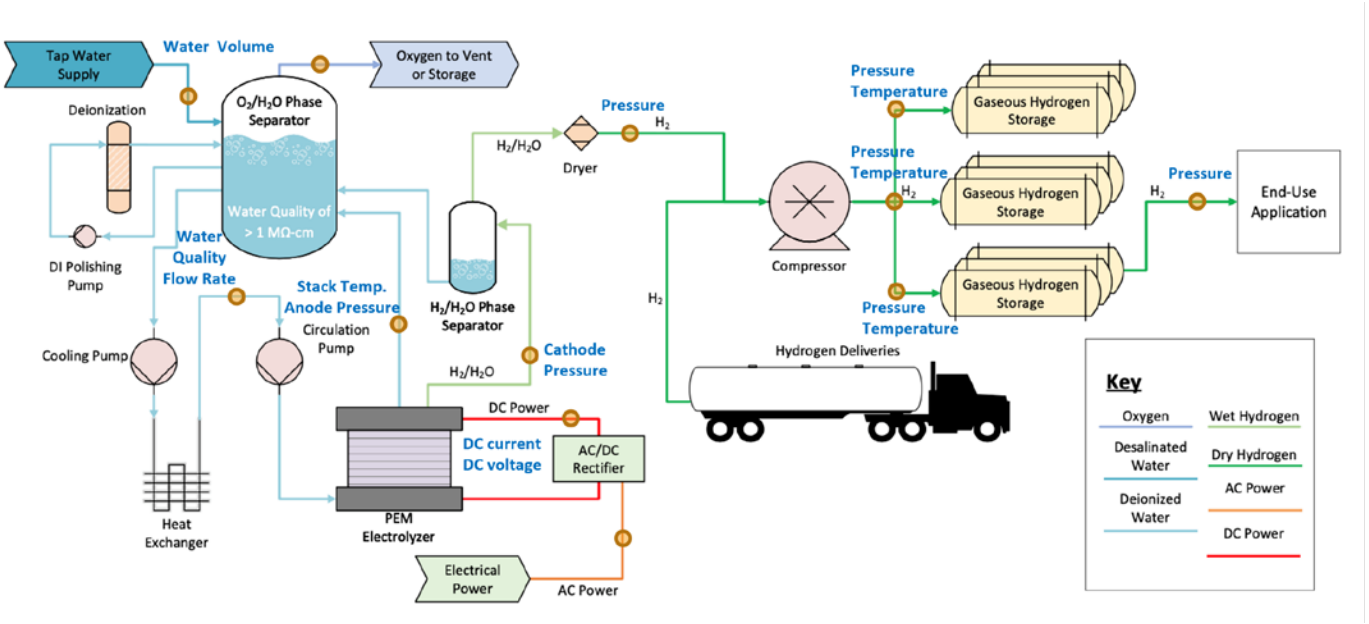
Major parameters

- P, Q, f
- Transducers: V DC, A DC
- Distance



Accomplishments and Progress

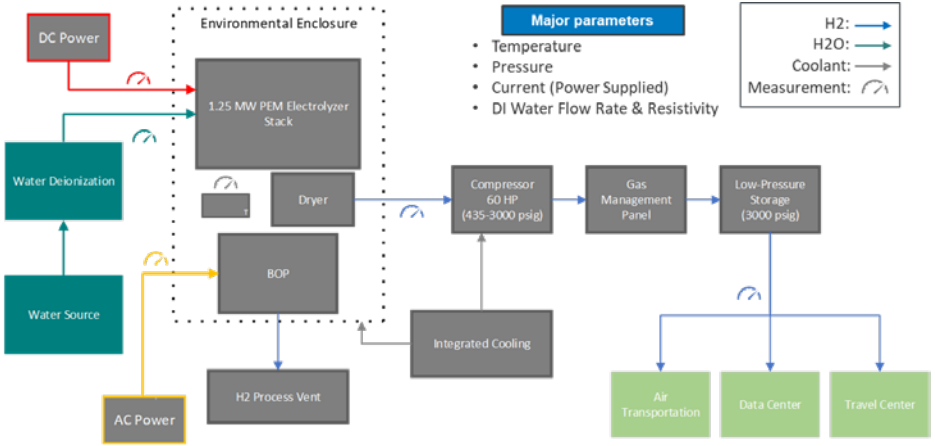
- Identified key sensor measurements (electrolyzer and H_2 testbed)
- Categorize research vs. commercially necessary sensors (*ongoing work*)



Task 2: Key Sensor Measurements

- Developing a list of sensors for key measurement points
- Working on refinement

Photo Credit: Daniel Leighton, Low Pressure Gas Management Panel at NREL Flatirons Campus, Insert: Pressure gauges.



Measurement Type	Commercial System
Electricity input	✓
Water usage (Volume)	✓
Hydrogen output (calculated with T, P)	✓

Accomplishments and Progress:
Response to Previous Year Reviewers' Comments

- This project has not been reviewed.

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.

Remaining Challenges and Barriers

Challenges and barriers:

- Delayed commissioning of the electrolyzer system (currently Expected for May 2023)

Next steps:

- Metering and monitoring needs 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 in Integrated Energy Systems (ARIES) virtual network for pilot scale, decentralized and centralized hydrogen production.
- Reporting results.

Proposed Future Work

- Revise scenarios and system coupling with renewable boundaries.
- Publish the results from Task 1.
- Prepare testing plans for future experiments once the electrolyzer system is fully commissioned at the Flatirons site.

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

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.

Thank You

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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.**