ARIES / Flatirons Facility - Hydrogen System Capability Buildout

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Project Goal

- Under the “Advanced Research on Integrated Energy Systems” (ARIES) initiative, hydrogen system capabilities including a MW-scale electrolyzer, storage system, and MW-scale fuel cell generator will be designed and commissioned at NREL’s Flatirons Campus
- This hydrogen infrastructure will support H2@Scale goals by enabling integrated systems R&D to study the science of scaling for hydrogen energy systems
- The system is designed with flexibility to provide a testbed to demonstrate systems integration, grid services, energy storage, direct renewable hydrogen production, and innovative end use applications (e.g. HD transportation, natural gas blending, etc.)

Overview

Timeline and Budget

- Project start date: 05/06/2020
- FY21 DOE funding: $408,587
- FY22 planned DOE funding: $200,000
- Total DOE funds received to date*: $4,080,145

  * Since the project started

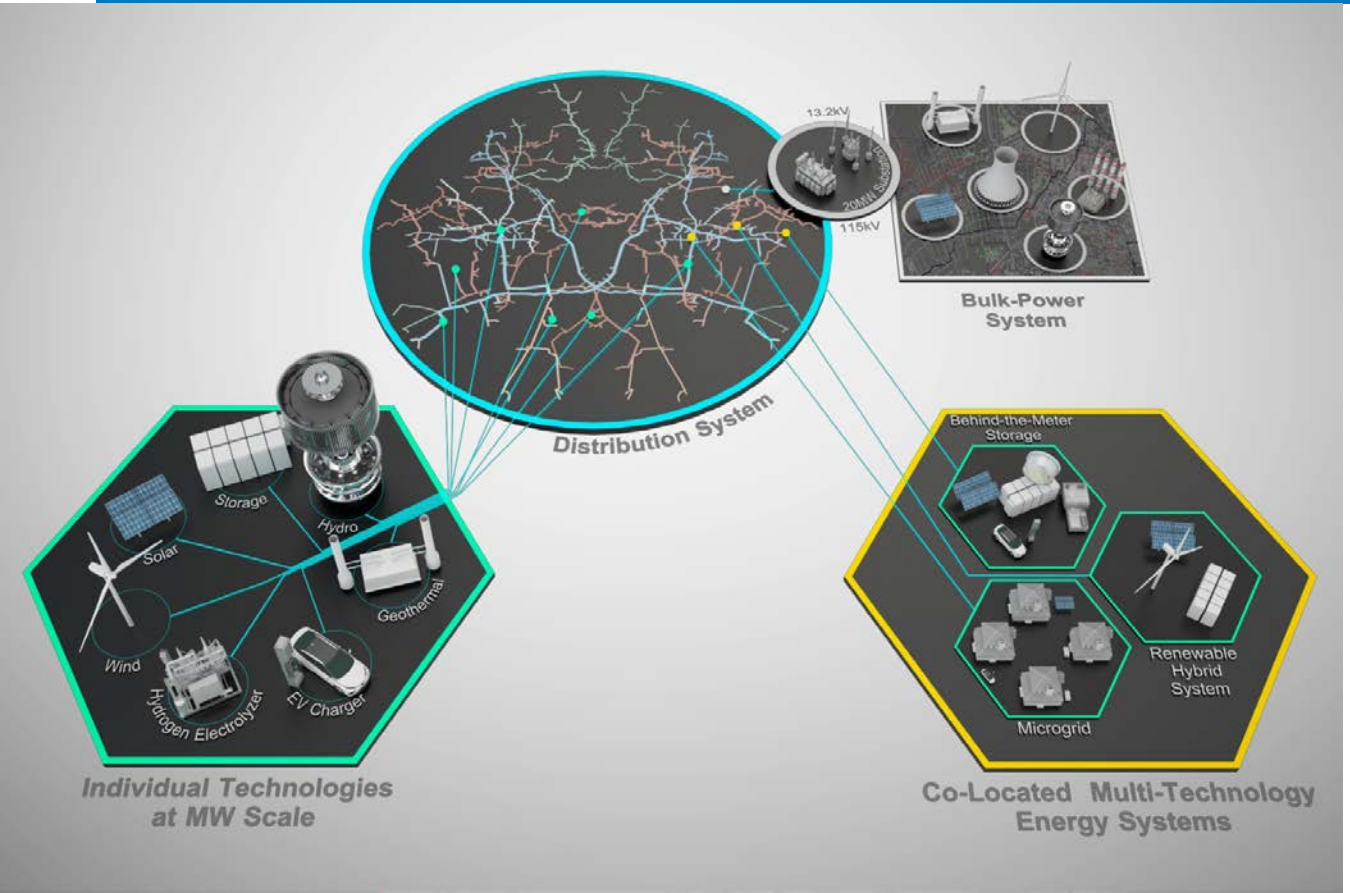
Partners

- Project lead: NREL
- PI: Daniel Leighton

Relevance/Potential Impact

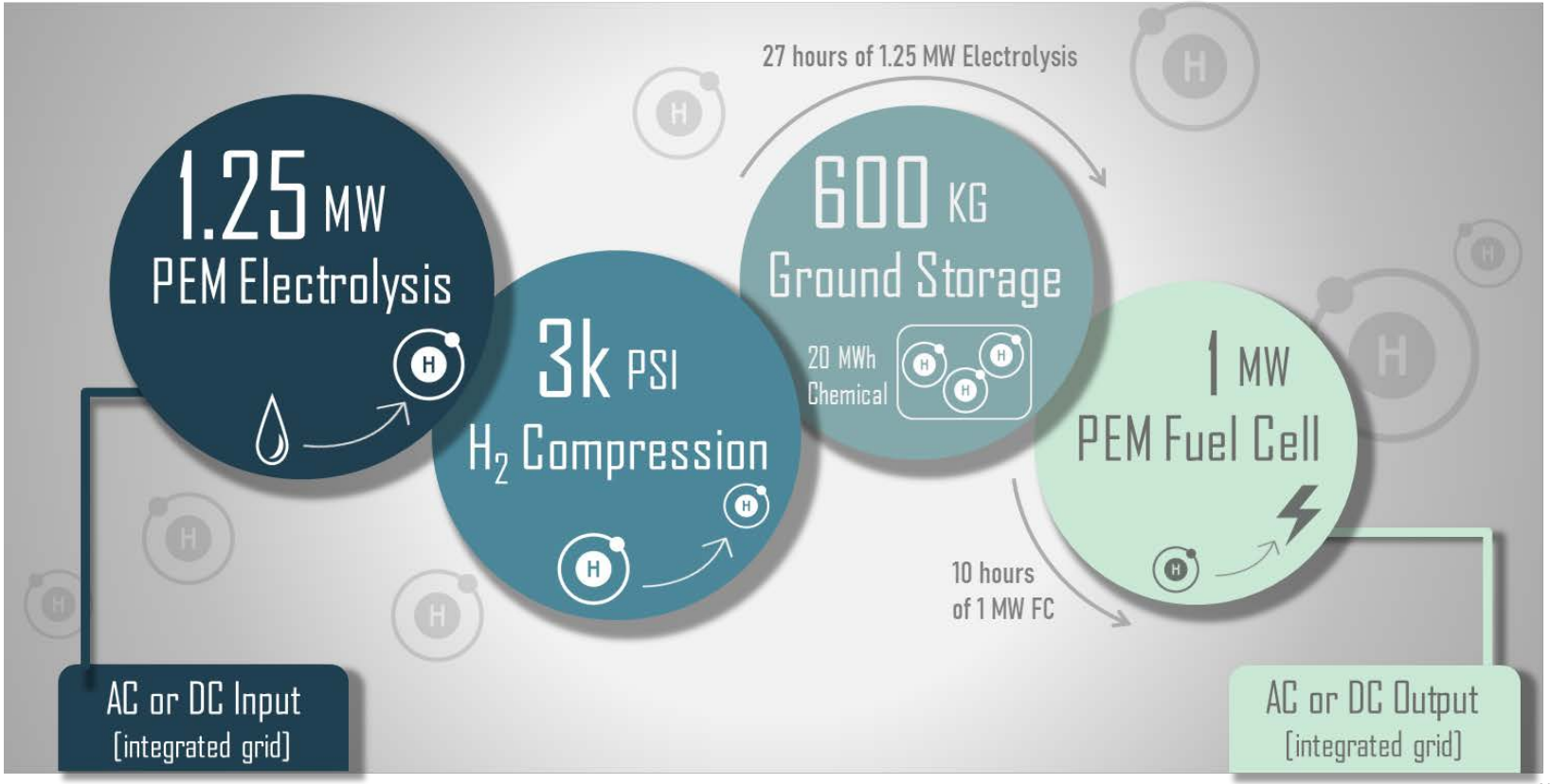
- This work is a **research capability** for future projects to conduct MW-scale research in the areas of hydrogen generation, energy storage, end-use distribution, and power production
  - Proving technologies and addressing integration challenges at scale is a critical precursor to deployment and investment nation-wide to reduce green house gas emissions through the construction of clean U.S. energy infrastructure
  - Key to this is integration of hydrogen as an energy carrying molecule coupled to other technology areas such as wind, solar, energy systems (grid), etc.
- This capability will also support additional technology areas relevant to H2@Scale as they mature and need to be evaluated with an integrated MW-scale platform
  - Molecule building, blending with natural gas, heavy-duty vehicle fueling, etc.
  - Supports efforts within the hydrogen industry and other integrated EERE areas

Approach: ARIES Vision

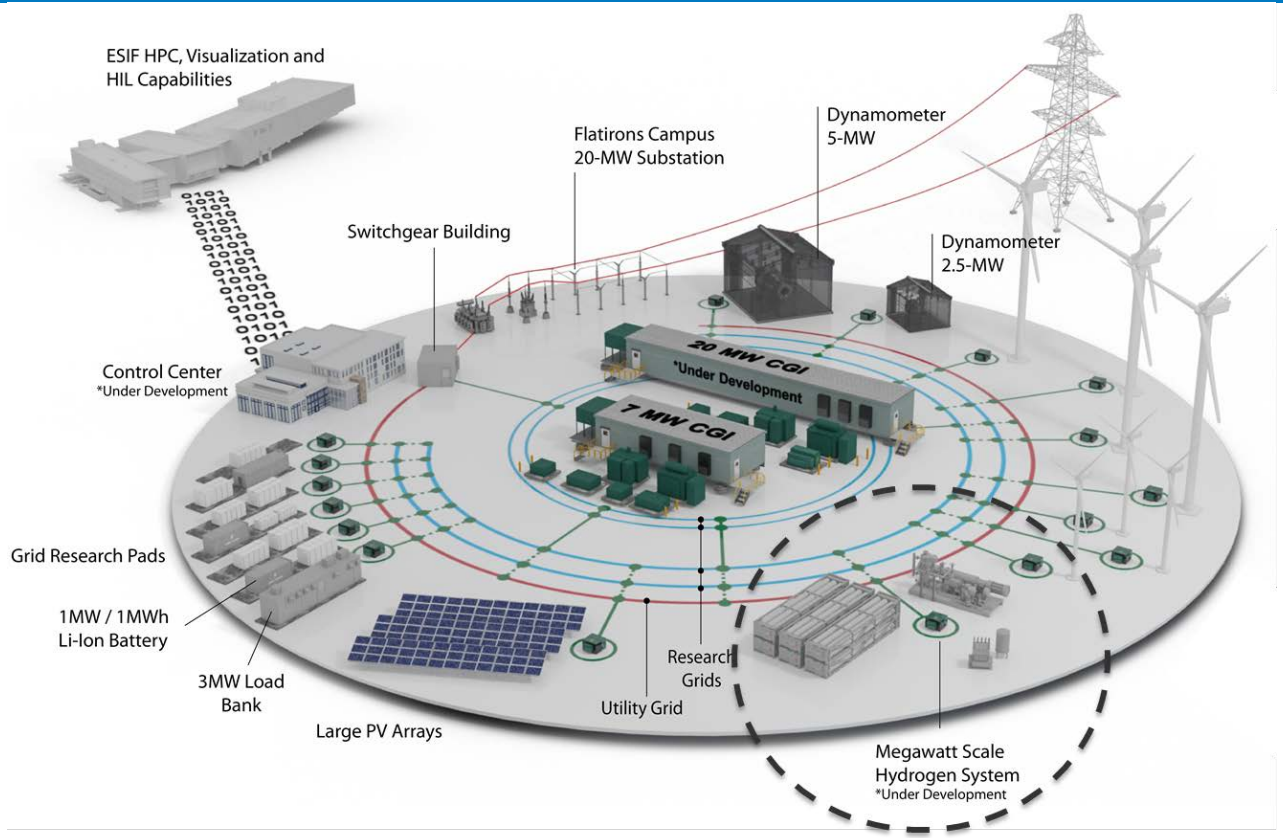


- Highly integrated and configurable
- Integrated energy research with analysis, modeling, and hardware experiments
- Varies in scale (devices, types, sizes up to 20 MW, and beyond virtually)
- Provide a collaborative hands-on experience

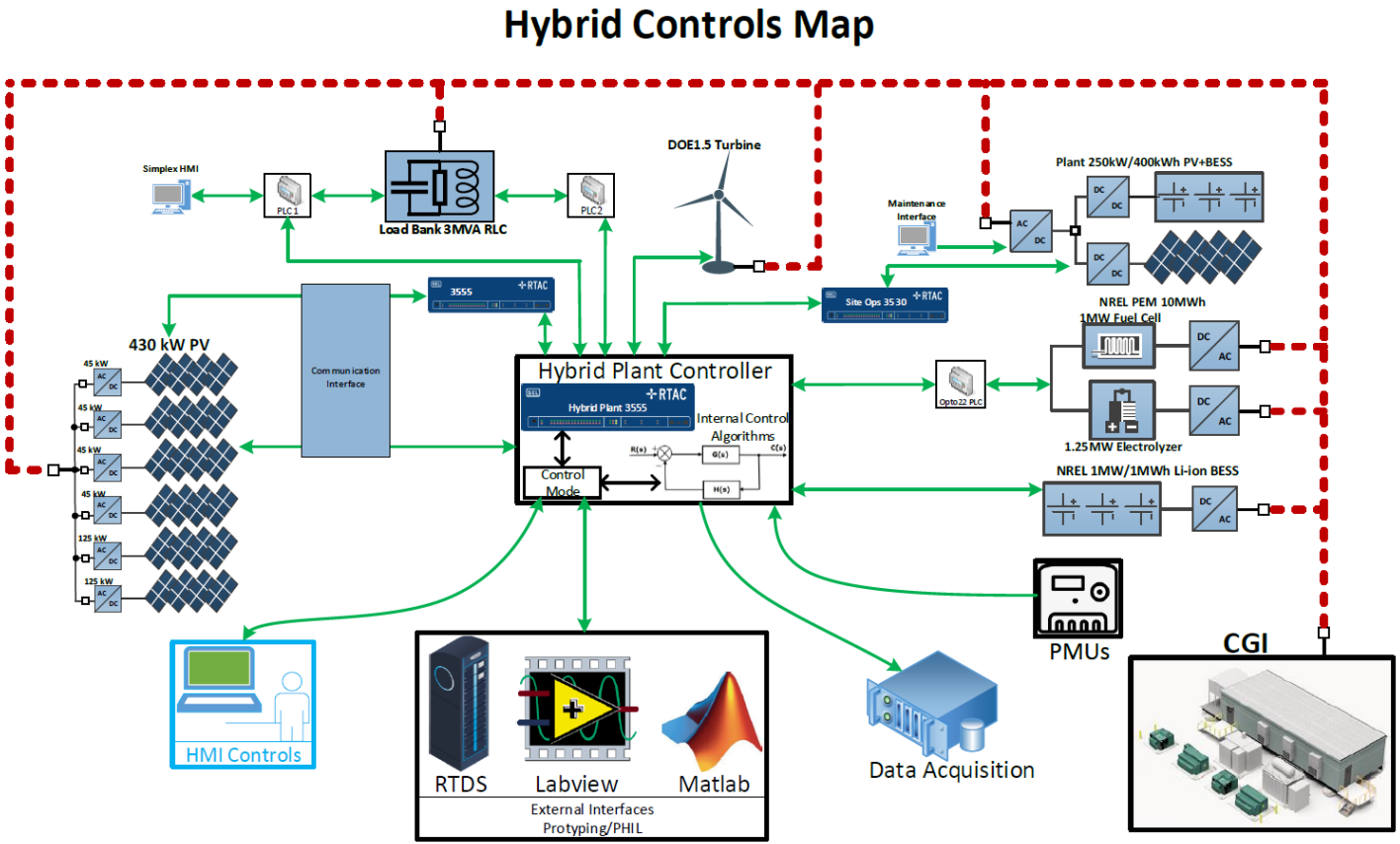
Approach: Hydrogen System



Approach: ARIES Grid Equipment



Approach: Hybrid Controller



Approach: Flatirons Site

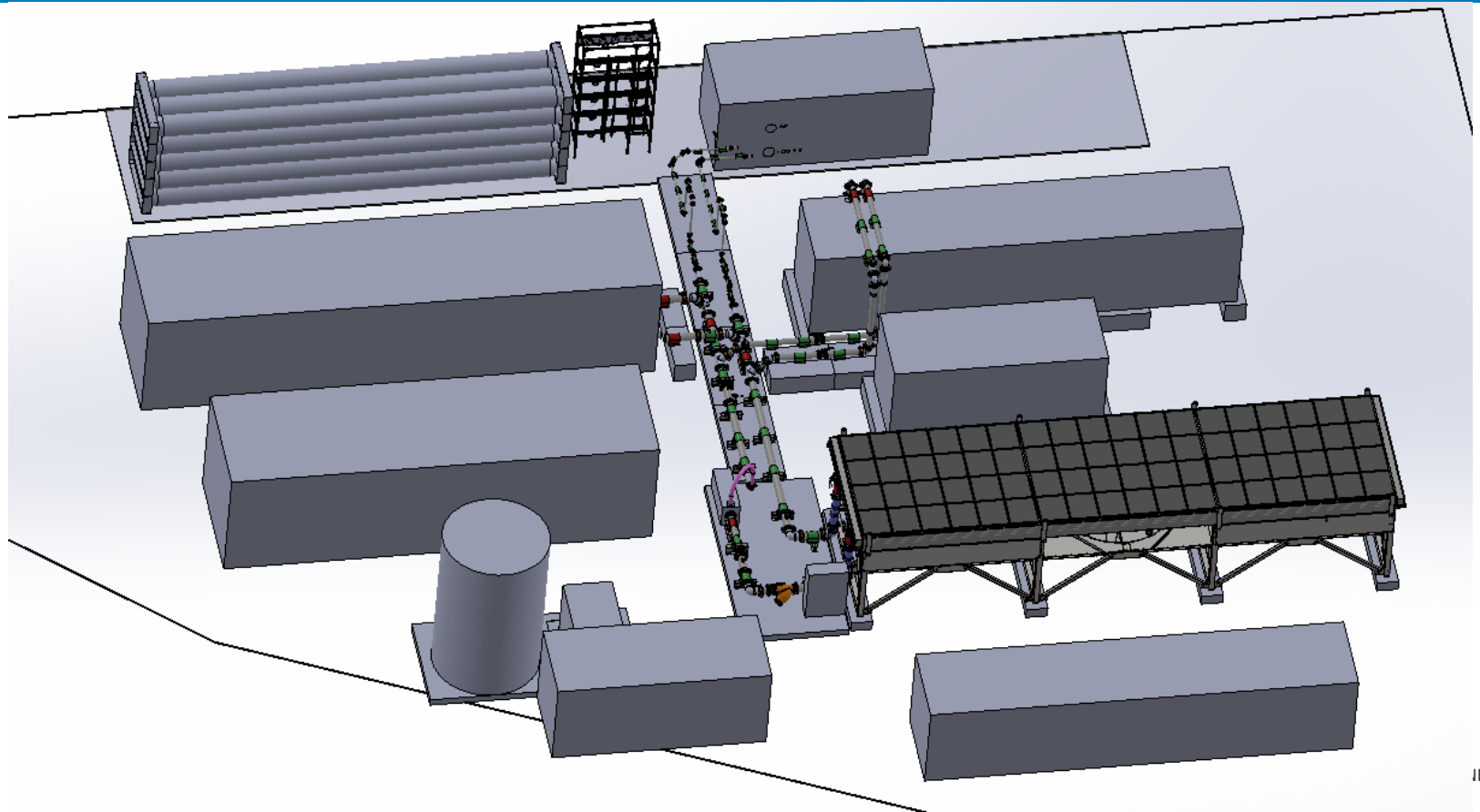
EXISTING

1. Multi-MW Wind Turbines
2. 0.5 MW Solar PV
3. 6.3 MW Controllable Grid
4. 1 MWh Battery

IN PROGRESS

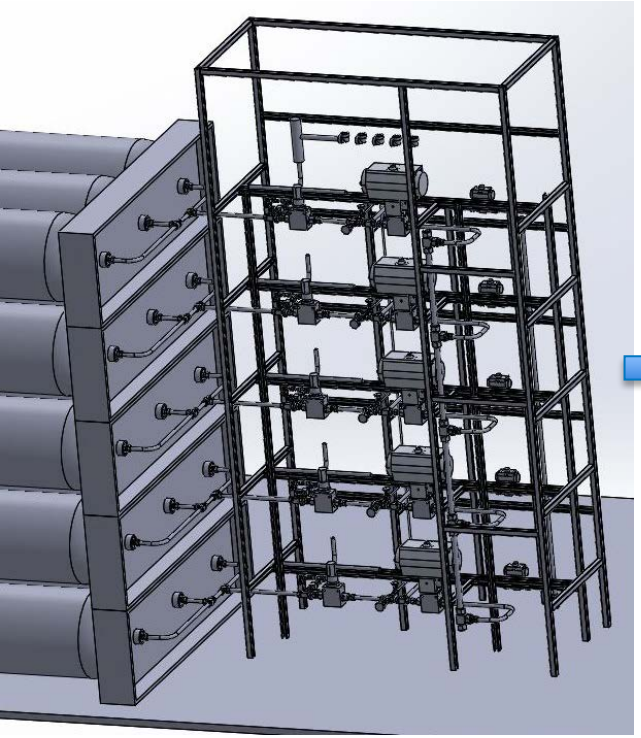
5. 20 MW Controllable Grid
6. Temporary Hydrogen Site (MW-Scale Hydrogen Production, Storage, & Power System)
7. Permanent Hydrogen Site (NG/H_2 Blending, HD Vehicle Fueling, etc.)
8. MW-Scale DC Fast-Charging

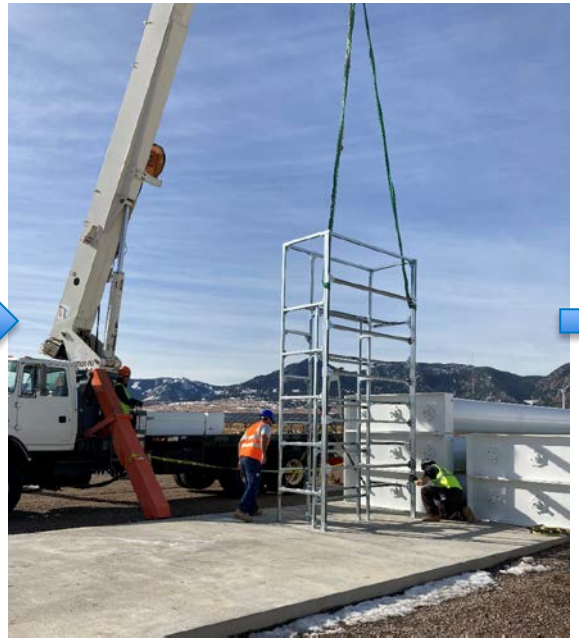
Accomplishments and Progress: Site Design



Accomplishments and Progress: Storage Tanks

Accomplishments and Progress: Gas Management Panel





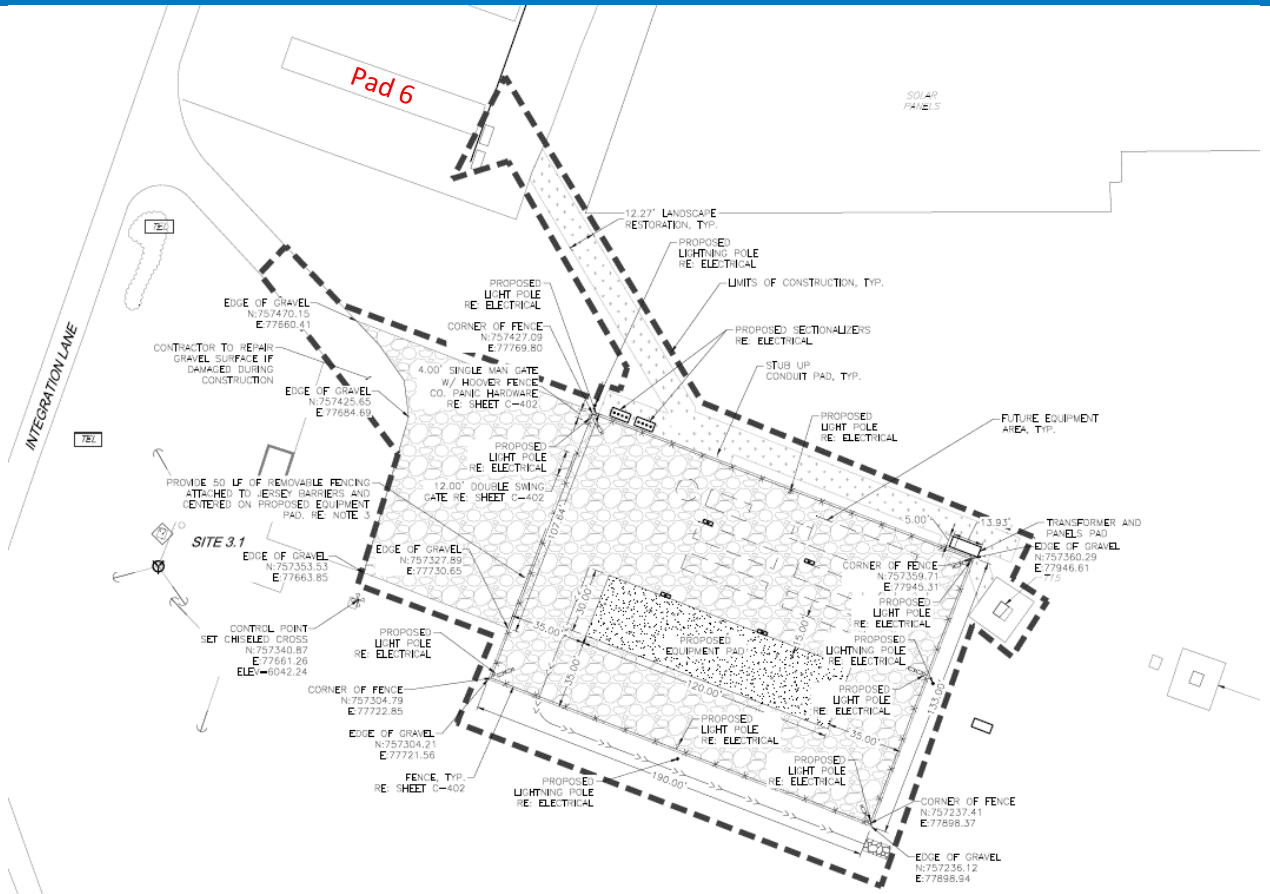
Accomplishments and Progress: Gas Management Panel

Accomplishments and Progress: Electrolyzer

Accomplishments and Progress: Dry Cooler

Accomplishments and Progress: Significant Sub-system Deliveries

Accomplishments and Progress: 100% Permanent Site Design



Accomplishments and Progress: Summary

- Design:
  - **Completed previous year:** Hydrogen system P&ID, site layout (including setback distances and fire code requirements), high-level electrical system, process hazard analysis (PHA) safety evaluation of storage system, compressor, and gas management panel
  - Completed this year: Integrated cooling system, water storage and supply system, gas management panel, detailed electrical infrastructure, controlled grid interface integration, electrolyzer system PHA, and 100% design drawings for permanent construction
- Major sub-system procurement:
  - Delivered: High-flow gas management panel valves and components
  - Delivered: PEM electrolyzer (1.25 MW producing ~22 kg/hr)
  - Delivered: Type I ground storage vessels (600 kg at 3,000 psig)
  - Delivered: Integrated cooling system heat exchanger, pump, piping, and components
  - Manufacturing: Compressor (electrolyzer output to 3,000 psig storage) – delivery expected early-May
  - Manufacturing: Deionized water storage and delivery system – delivery expected early-May
  - Manufacturing: PEM fuel cell generator (1 MW net output) – delivery expected mid-June

Accomplishments and Progress: Summary

- Build:
  - LP GMP fully fabricated, installed, and ready for connection with other sub-systems
  - Storage tanks structurally installed in final location
  - Electrolyzer structurally installed in final location
  - Dry cooler structurally installed in final location
  - Fabrication of electrical, controls, integrated cooling system, and de-ionized water infrastructure in progress

Response to Previous Year Reviewers' Comments

- *Numerous comments on a weakness being a lack of onsite water and the drawbacks of trucking in deionized water.*
  - Agreements have been secured for water rights in a reservoir several miles away, and there are infrastructure investments planned for a water pipeline and treatment facility for the campus. The electrolyzer already has a deionization system installed to make use of this future water source. Operability of this water supply is several years out, but the hydrogen system demands are being factored into the future campus needs.
- *The external collaboration is weak. Only Nel Hydrogen is listed as a collaborator. The future plans need to include more details for such a big project.*
  - This project is an infrastructure installation project and doesn't include research itself, but rather supports future research. There are now six funded projects (with nine unique industry participants) that will use this infrastructure once it is commissioned, and many more projects with additional partners are currently under negotiation.
- *There are limitations for longer-term hydrogen production (projects) due to hydrogen storage system size.*
  - There are projects and plans in the works, both funded and not funded yet, to expand to >1,500 kg storage capacity onsite. Additional space is available to expand further as needed for research.
- *It would be great if solar or wind could be integrated in the system so the intermittency of renewable energy could be studied.*
  - Both solar and wind are being directly integrated and several future research projects currently planned will study the intermittency of renewable energy for hydrogen production.
- *The end use of the hydrogen was a bit unclear. It is unclear whether it can be sold or used for other downstream applications.*
  - The current end use for the hydrogen is the 1 MW fuel cell for research and power export. NREL cannot sell hydrogen on the market. There are several additional end uses being planned for the hydrogen, including HD vehicle fueling.

Collaboration and Coordination

- For the electrolyzer we have been working closely with the industry supplier, Nel Hydrogen, on a near first-of-its-kind unit for them
- For the fuel cell generator we have signed a CRADA with an industry partner to build and test their first-of-its-kind unit
- A portion of the additional follow-on research that is funded includes:
  - EPRI: CRADA for hydrogen production, grid integration, and scaling for the future
  - GE and Nel Hydrogen: CRADA for optimization of wind turbines for hydrogen electrolysis
  - GKN and SoCal Gas: CRADA for metal hydride tank R&D coupled with electrolysis and fuel cell systems
  - Nel Hydrogen: FOA for high-throughput compressor R&D for heavy-duty truck fueling applications

Remaining Challenges and Barriers

- COVID-19 related supply chain issues have caused **significant** unanticipated delays across the board for both major sub-systems and the smallest and simplest of components (as well as cost increases)
  - Almost all of the major equipment and integration components are either on-site or will arrive soon, but significant work is still needed to complete the physical integration between the sub-systems, complete safety reviews, and commission the system
- Permanent site infrastructure construction is behind schedule and over budget due significantly to supply chain issues
  - Temporary installation location will allow hydrogen system build, commissioning, and operation for research to continue in parallel to the long-term site construction

Proposed Future Work

- Finish build and integration work of all hydrogen sub-systems
- Complete safety reviews and commission system
- Produce, compress, and store >50kg of hydrogen using on-site wind power by September 30th, 2022 (annual milestone)
- Issue construction sub-contract for permanent site
- Transition hydrogen capabilities into multiple research projects within the ARIES platform

Summary

- *By the end of FY22 NREL plans to have an operational 1.25 MW PEM electrolyzer, compressor, 600 kg ground storage, and 1 MW PEM AC/DC output fuel cell generator system at the Flatirons campus*
- By the end of FY23 NREL plans to have a permanent hydrogen site installed at the Flatirons campus with infrastructure in place and ready for future research expansion
- This infrastructure will support future research projects under the ARIES umbrella, specifically in the areas of energy storage, direct hydrogen production coupling with renewables, grid stabilization, electrons to molecules, heavy duty transportation, and other innovative end uses

Thank You

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Technical Backup and Additional Information

Technology Transfer Activities

- No patent, licensing, or technology transfer is planned as a part of this funded work
- The work funded is creating a capability that supports multiple future collaborative research projects with industry, academia, and other national laboratories