DOE HFTO H2IQ Hour: NREL ARIES Flatirons Campus MW-Scale Hydrogen System Research

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July 25, 2024

Photo by Dennis Schroeder, NREL 55200

NREL at a Glance

3,915 Workforce, including:

- 2,913 regular/limited term
- 531 contingent workers
- 223 postdoctoral researchers
- 155 graduate student interns
- 93 undergraduate student interns

—as of 5/15/2024

World-class research expertise in:

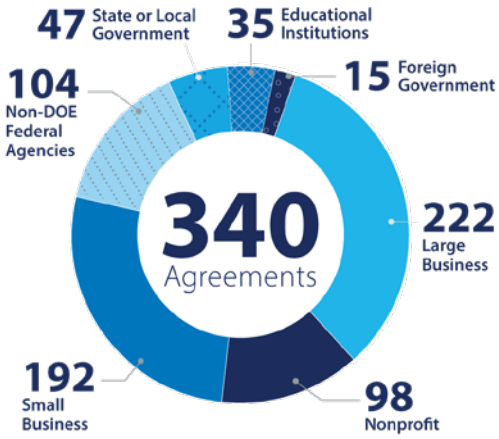
- Renewable Energy
- Sustainable Transportation & Fuels
- Buildings and Industry
- Energy Systems Integration

Partnerships with:

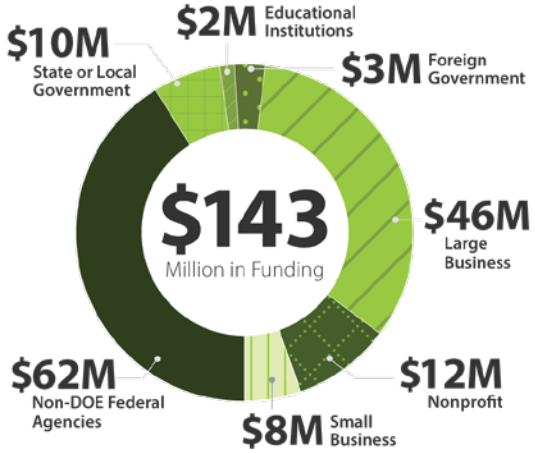
- Industry
- Academia
- Government

4 Campuses operate as living laboratories

More Than 1,100 Active Partnerships in FY 2023

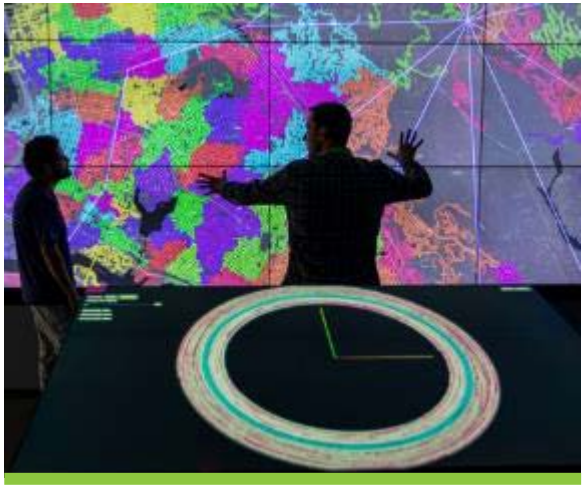


Agreements by Business Type



Funding by Business Type

Integrated Energy Pathways



Electrons to Molecules

Circular Economy for Energy Materials

NREL's Vision:

A Clean Energy Future for the World

Three critical research areas respond to today's energy challenges and provide tomorrow's solutions

NREL Brings Distinct Capabilities

Foundational Science | Accelerated Technology Scale-Up | Systems | Markets

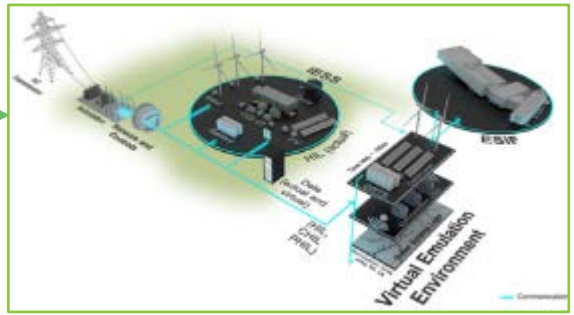
Bench-scale- discovery | Scaling R&D and Process Engineering | R&D with Industry Partners

Solar Energy Research Facility
Science and Technology Facility
Field Test Laboratory Building

Energy Materials and Processing at Scale (Completion 2025)

Energy Systems Integration Facility

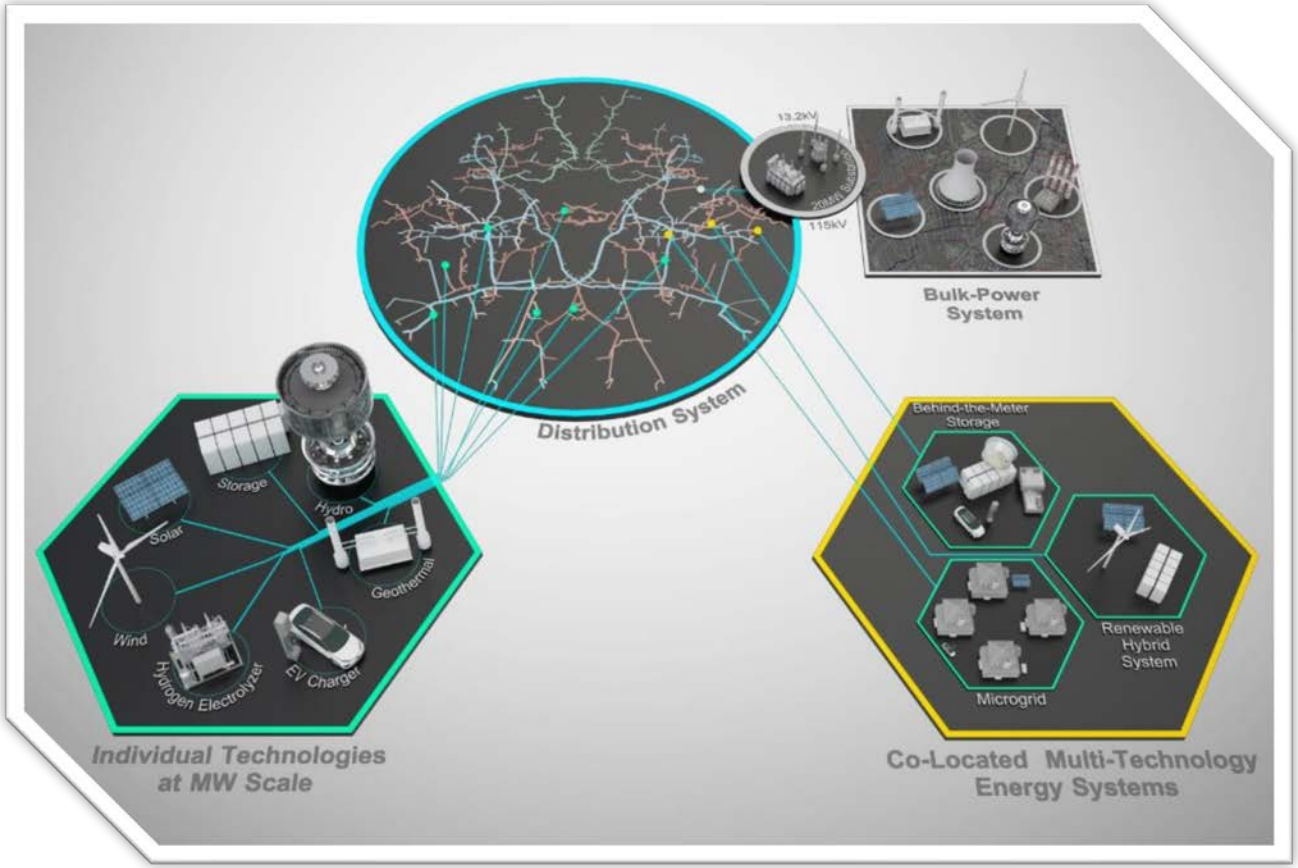
- Carbon-free H2
- Products from electrochemical processes and CO2
- Advanced Batteries
- PV, Wind, Water Power, Geothermal
- New Buildings and Industrial Materials, Manufacturing and Systems
- Grid and security tech



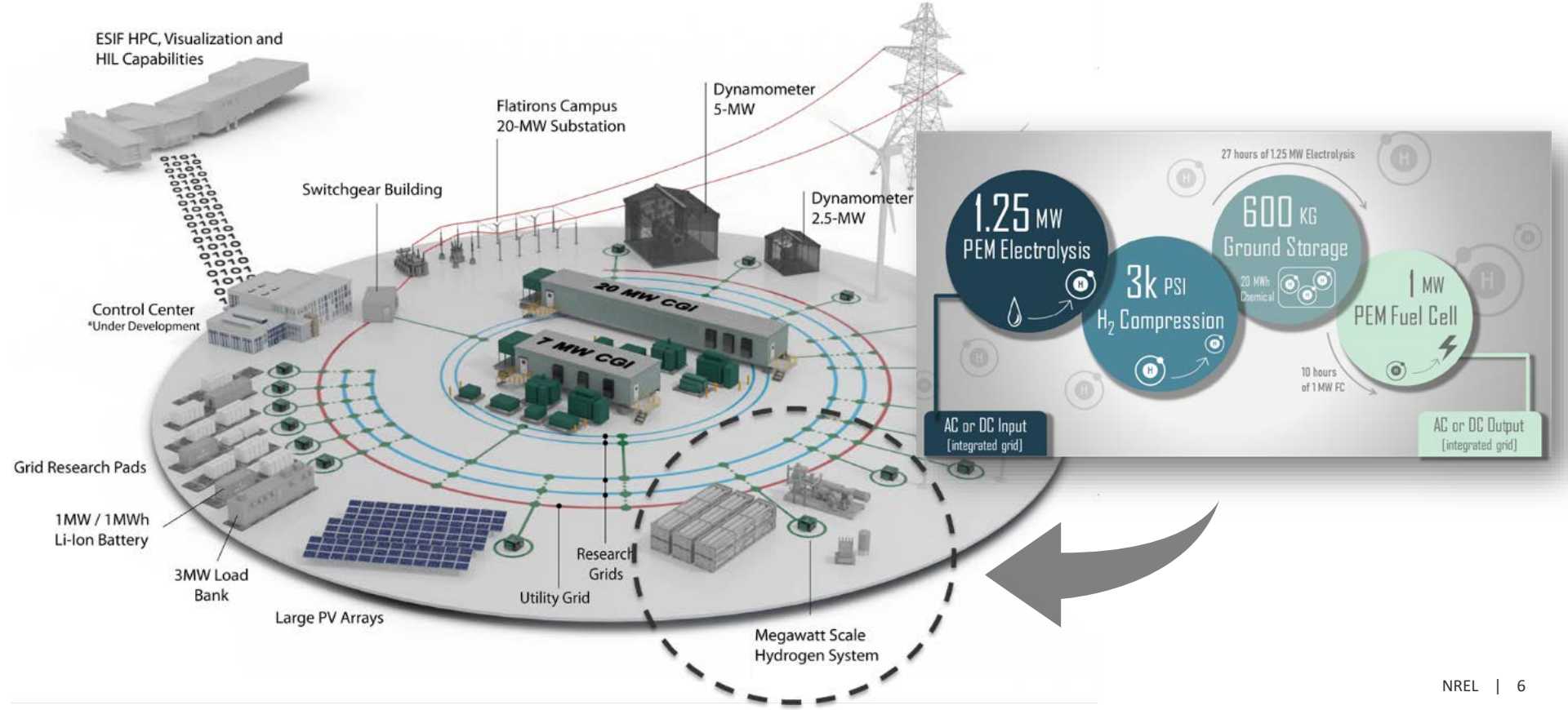
Advanced Research on Integrated Energy Systems

High-Performance Computing, Simulation, and Visualization

Advanced Research on Integrated Energy Systems (ARIES) Vision

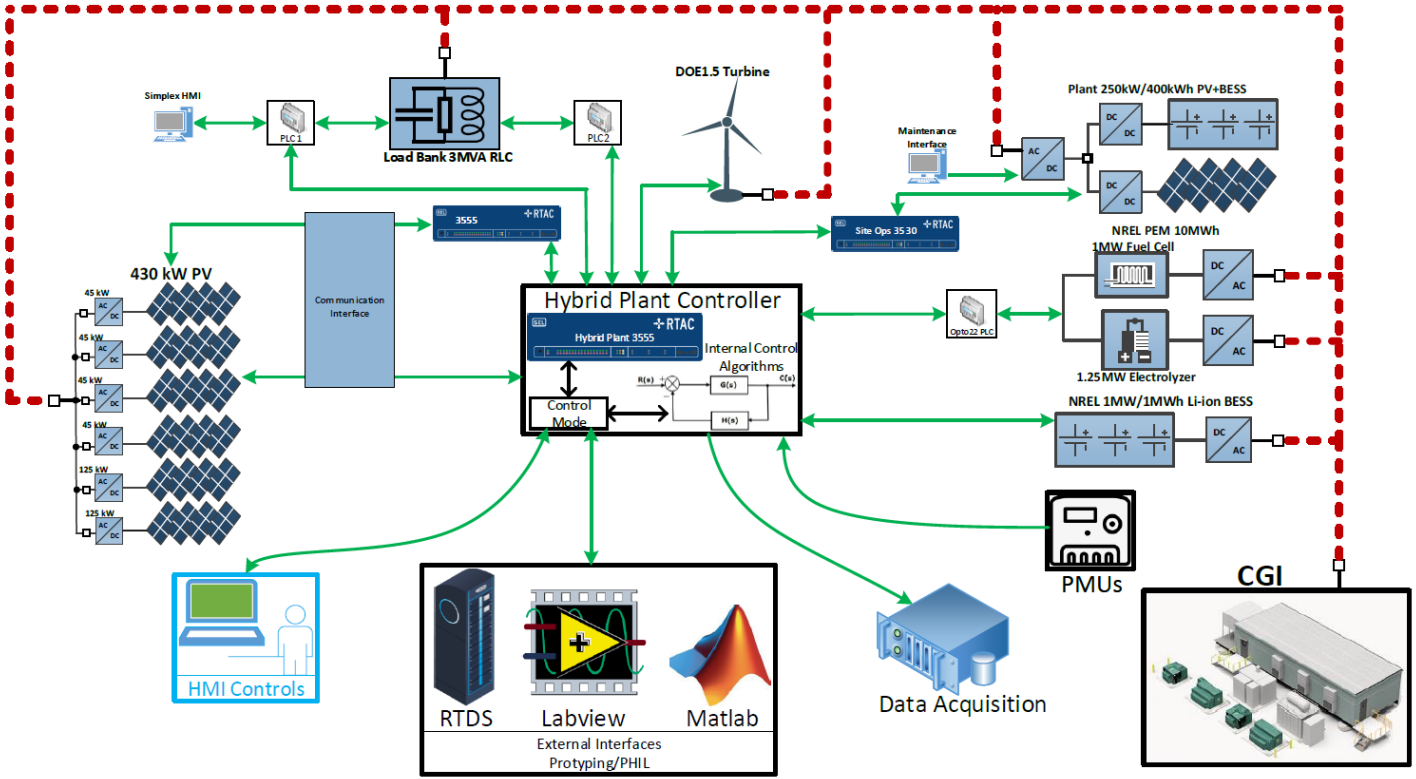


ARIES Flatirons Campus Grid Equipment



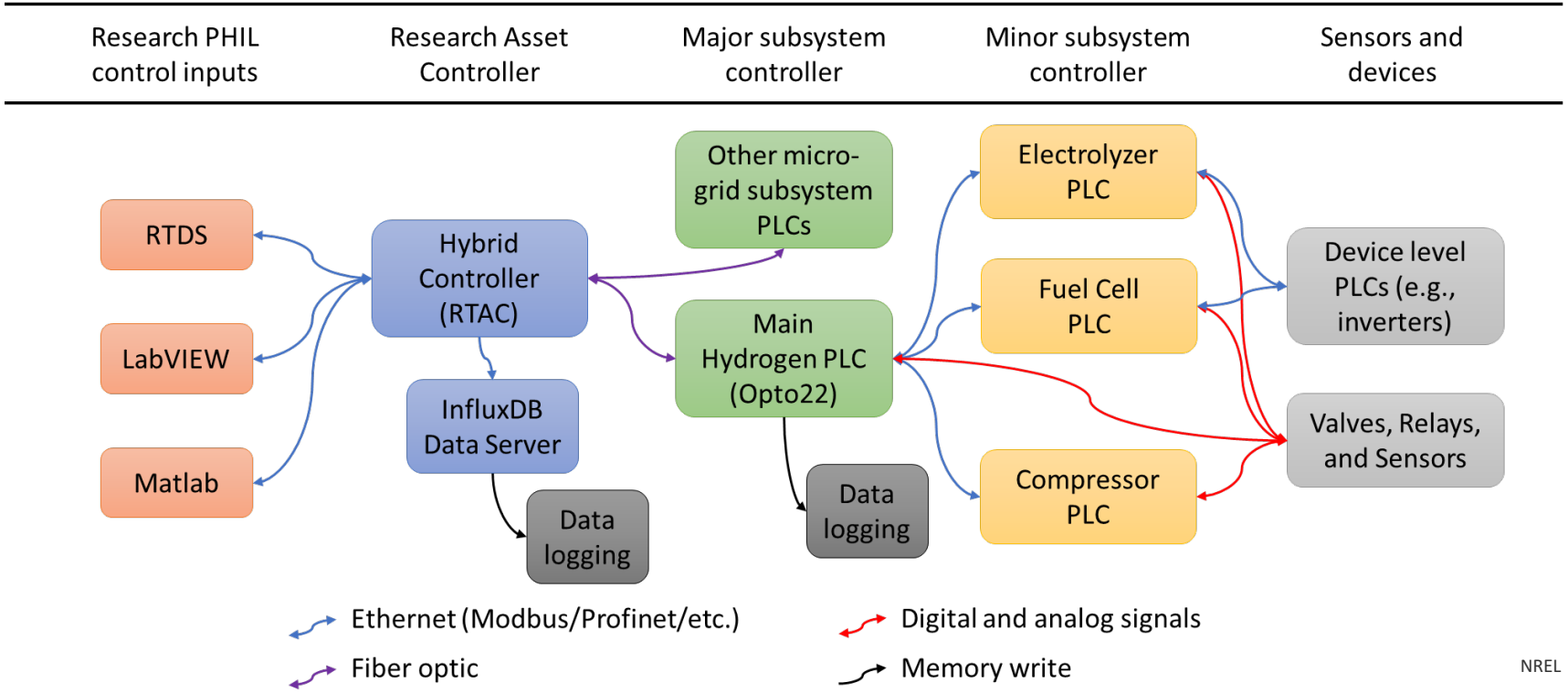
Medium Voltage Grid Hybrid Controller

Hybrid Controls Map

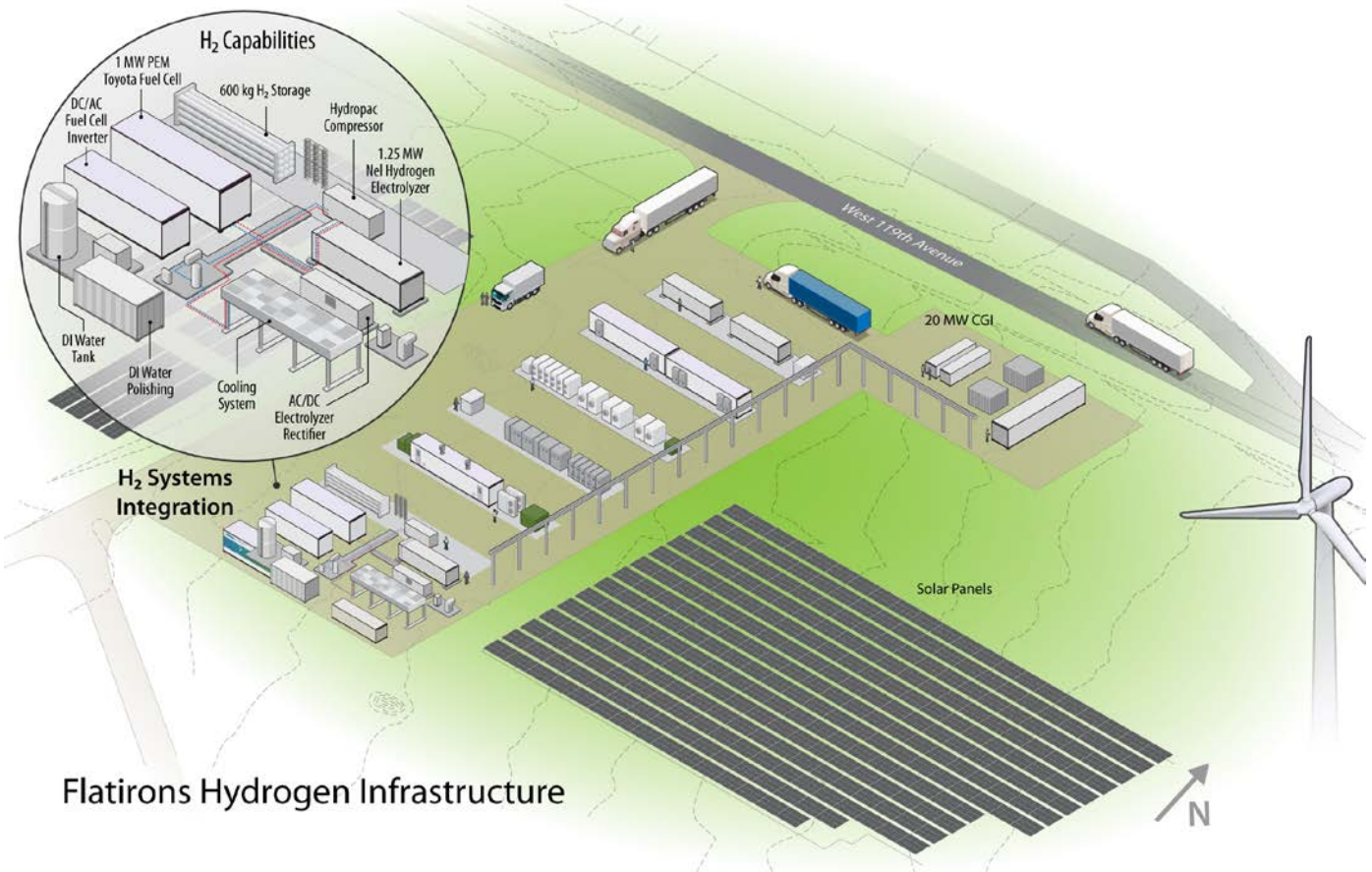


Controls Architecture

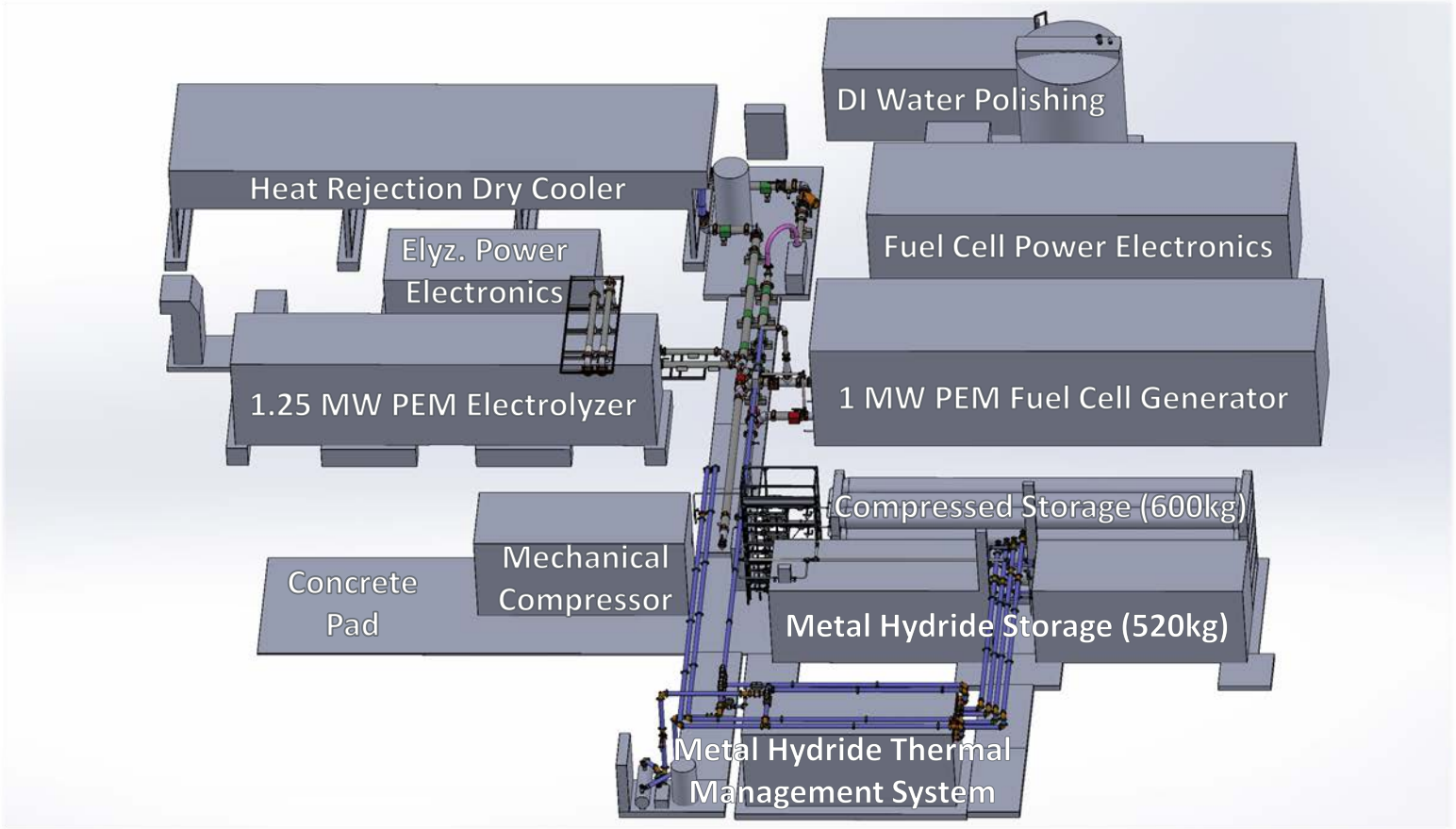
Hydrogen System Signal Flow



Flatirons Campus Site



Existing Flatirons Campus Hydrogen System Layout



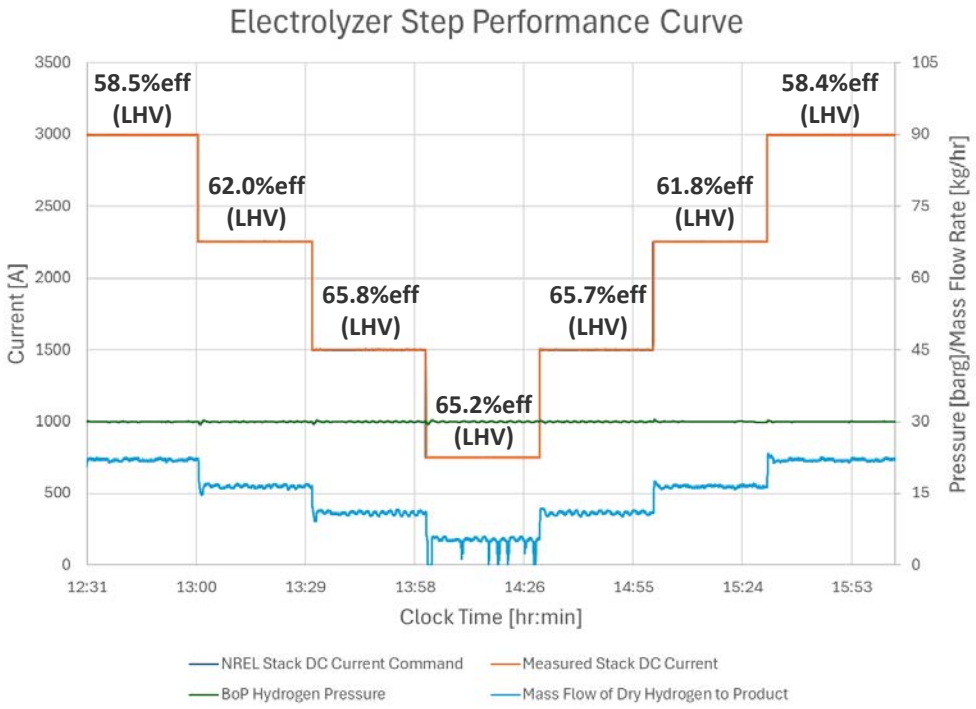
Flatirons Campus Hydrogen System Today

Photo by Joshua Bauer, NREL

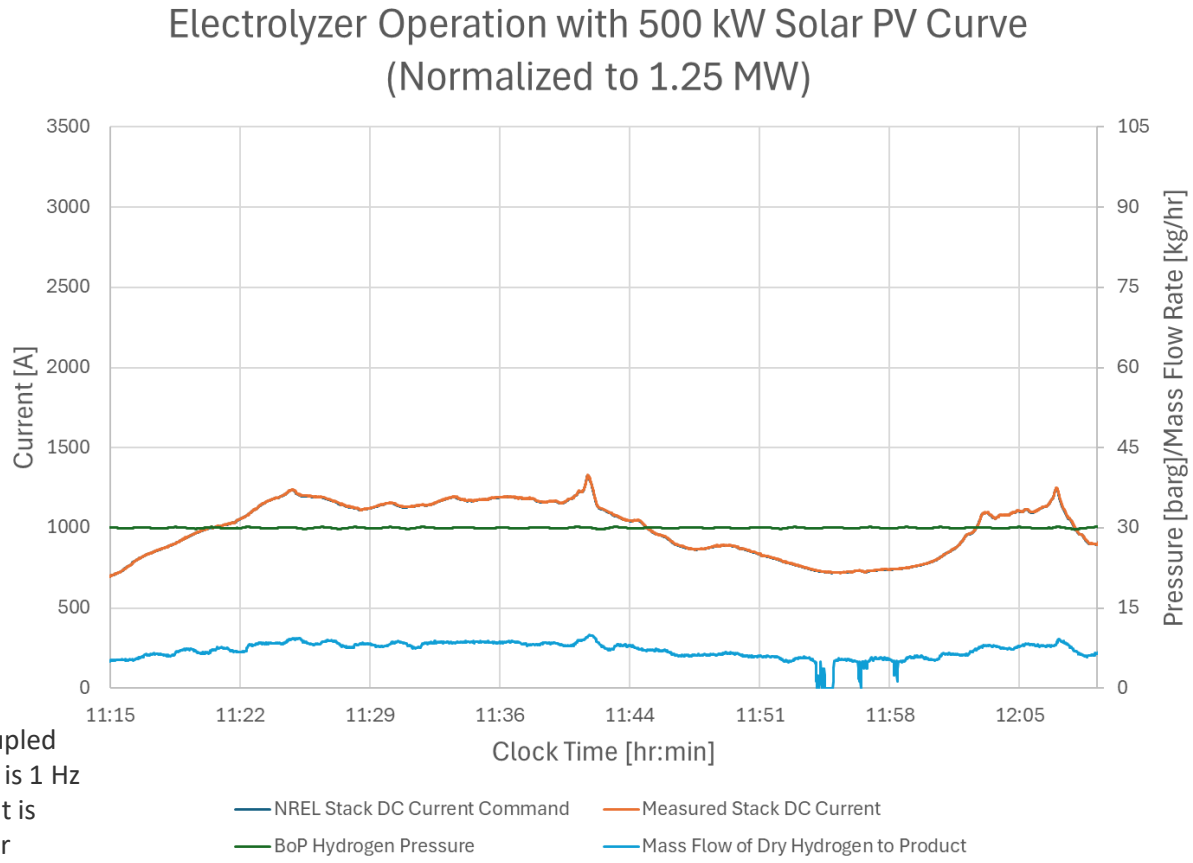
Future Hydrogen Site Construction (inc. MMW LTE)

Electrolyzer Steady State Efficiency

*Note: Efficiencies calculated as measured dry mass of hydrogen output as product times lower heating value (LHV) of hydrogen divided by DC power to stack (NO parasitic balance of plant power included)



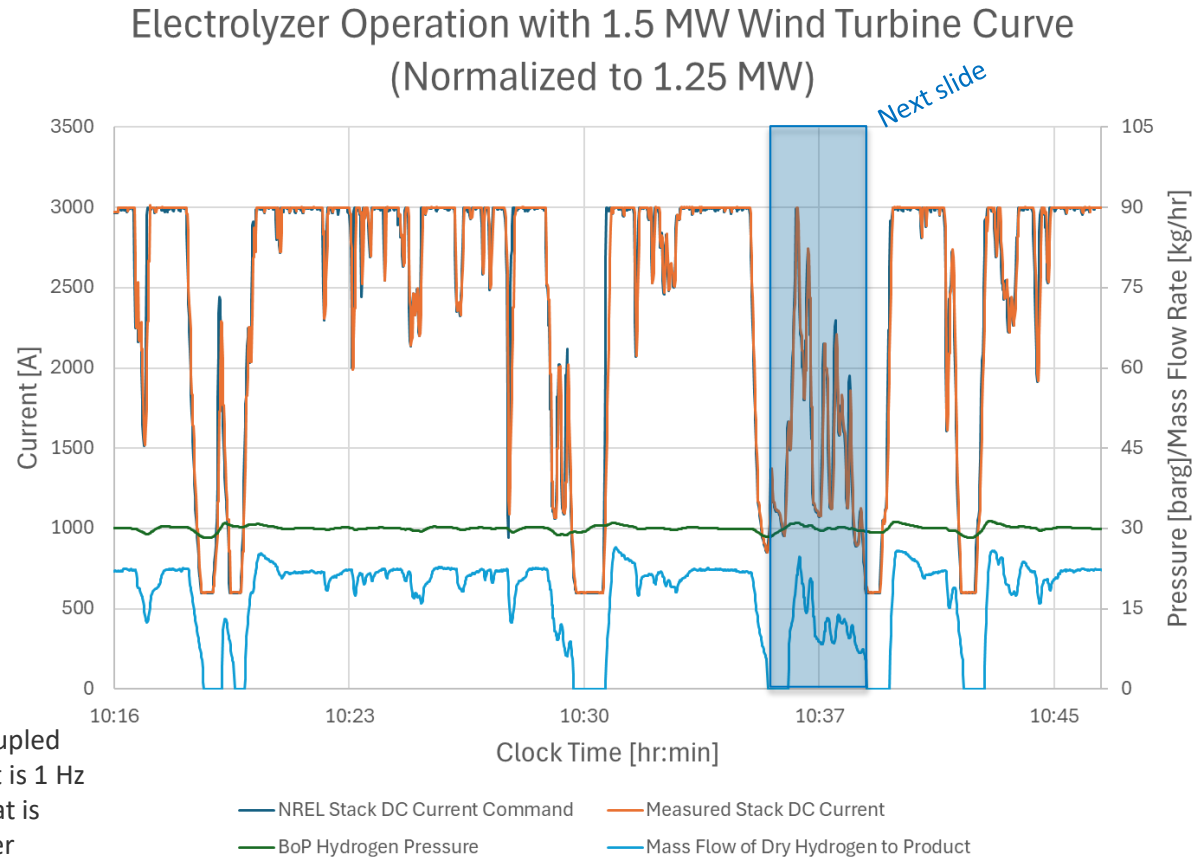
Electrolyzer Operated on Solar PV Profile



- 67.0% efficiency (LHV)
- Highly variable (high gain/slew rate) data used from single PV field (near worst case)

*Note: This is NOT direct coupled real time solar production, it is 1 Hz data recorded previously that is prescribed to the electrolyzer

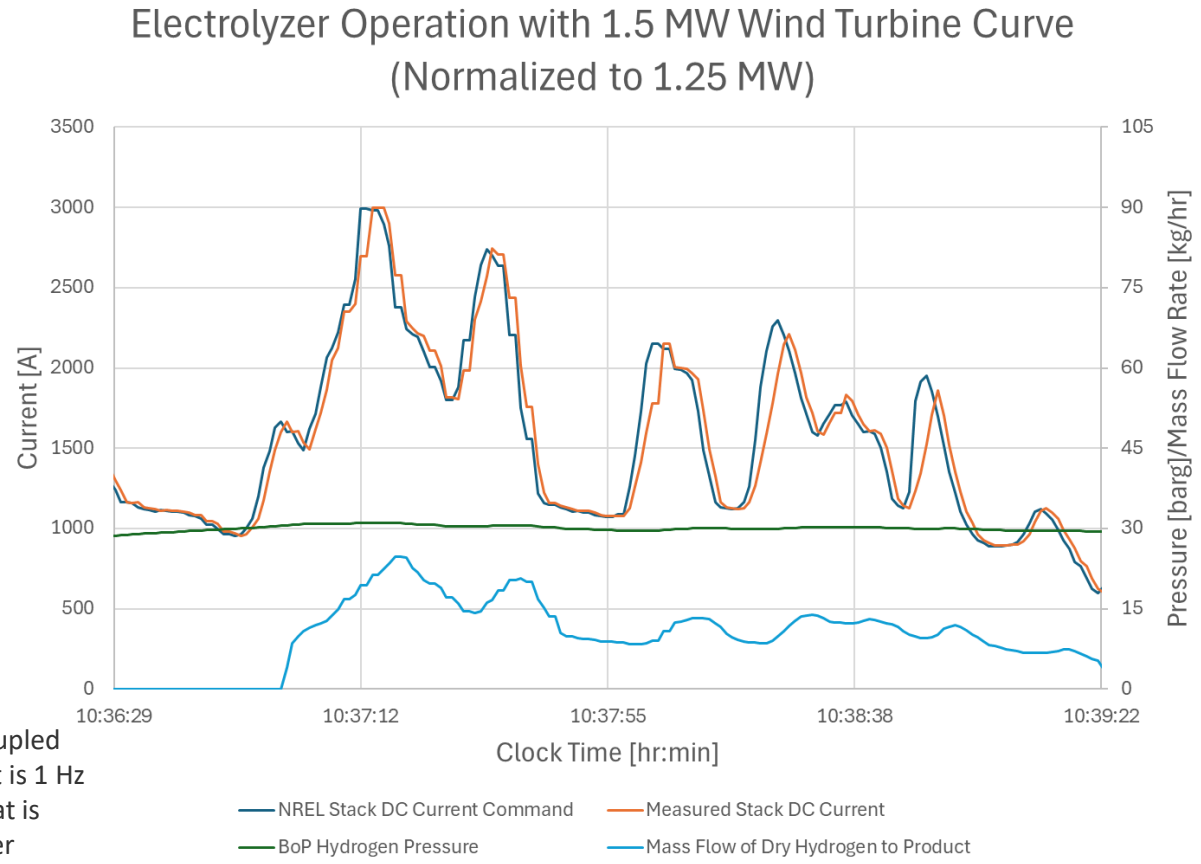
Electrolyzer Operated on Wind Turbine Profile



- 58.4% efficiency (LHV)
- Highly variable (high gain/slew rate) data used from single turbine (near worst case)

*Note: This is NOT direct coupled real time wind production, it is 1 Hz data recorded previously that is prescribed to the electrolyzer

Electrolyzer Operated on Wind Turbine Profile



- Up to 573A offset during gain period (~3 seconds)
- Up to 250A offset during slew period (~1 second)

*Note: This is NOT direct coupled real time wind production, it is 1 Hz data recorded previously that is prescribed to the electrolyzer

Fuel Cell Generator Performance

- 48.7% efficiency at 100 kW-AC
- 52.4% efficiency at 250 kW-AC
- 48.4% efficiency at 1 MW-AC

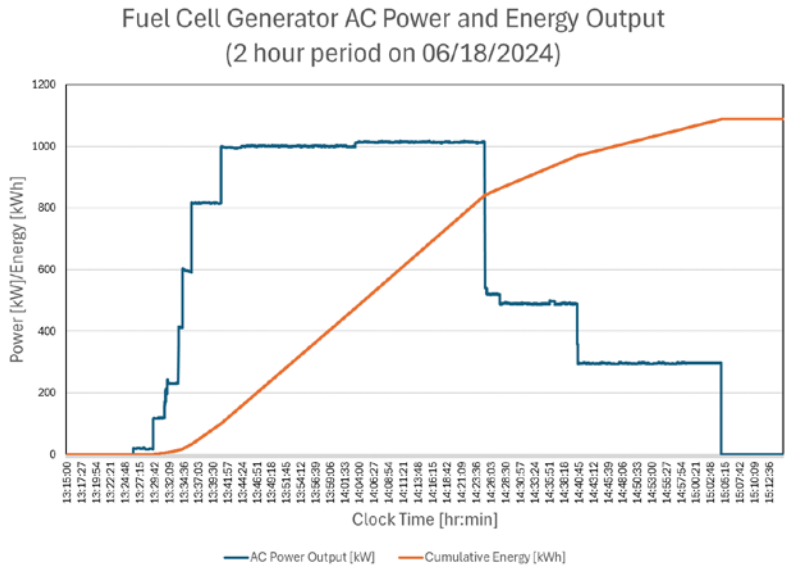
*Note: These are NOT stack efficiency numbers, but are instead complete generator efficiencies calculated as AC power output from inverter divided by dry mass of hydrogen discharged from tanks times lower heating value (LHV) of hydrogen. They include ALL parasitic balance of plant loads such as compressor, pump, fan, lighting, and control power, as well as conversion losses

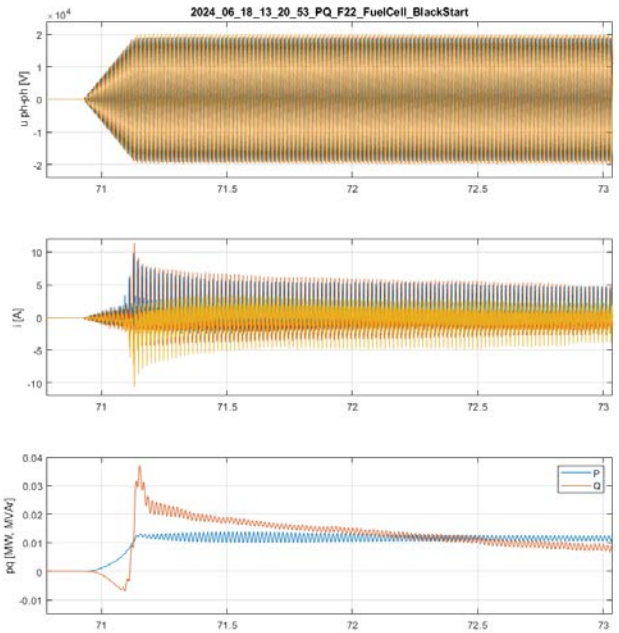
Photo by Daniel Leighton, NREL

- 28.3% round trip energy storage efficiency at full power (electrons to electrolysis molecule production, molecular storage, back to grid electrons via fuel cell generator)
- 35.1% round trip energy storage efficiency at low power (solar PV electrolysis case and 25% fuel cell)

Fuel Cell Generator Black Start/Grid Forming

- 6+ MVA of transformers black started on 13.2kV grid in 200 ms with maximum inrush current of 12 A
- Peak output power of 1.016 MWe-AC, with 1.088 MWhe-AC of energy produced
- 64.4 kg of hydrogen consumed, which is 50.7% AC-LHV efficiency
- Maximum Frequency/Power (F/P) droop of 1.4% during step changes





MV Grid 50 kHz data of black start voltage, current, real and reactive power (from top to bottom) versus time in seconds – Courtesy of: Przemyslaw Koralewicz

ARIES Research Projects Underway

We're collecting data with industry partners to answer questions on the suitability of current commercial PEM electrolysis and fuel cell technology for larger scale deployments

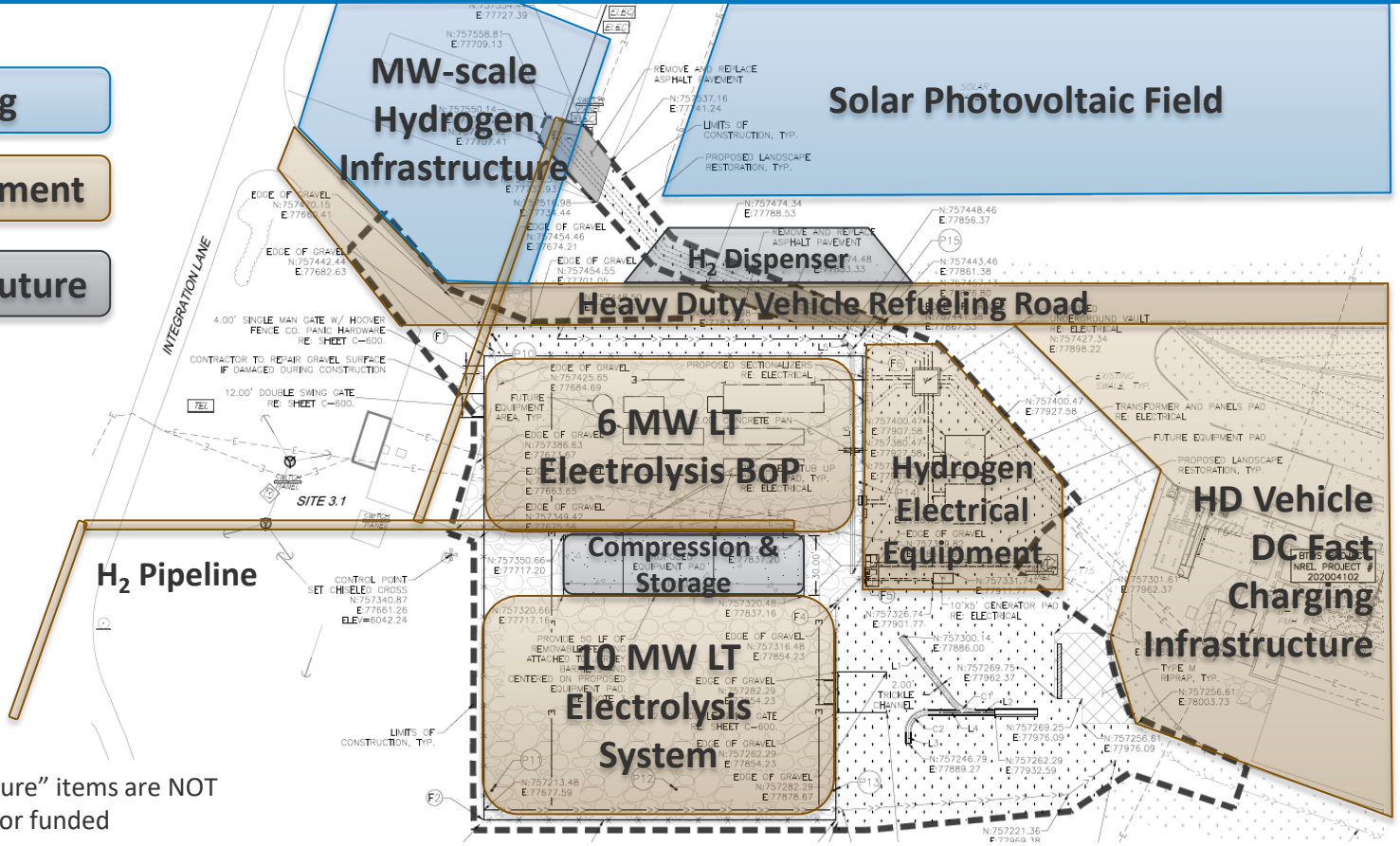
- **GKN & SoCalGas CRADA:** High Efficacy Validation of Hydride Mega Tanks at the ARIES Lab
- **EPRI CRADA:** Hydrogen Production, Grid Integration, and Scaling for the Future
- **GE & Nel Hydrogen CRADA:** Optimal Wind Turbine Design for H2 Production
- **EPRI/GTI (et al.) CRADA:** Next Generation Hydrogen Leak Detection--Smart Distributed Monitoring for Unintended Hydrogen Releases
- Multiple other DOE funded projects (Flexpower, Leak Rate Quantification, etc.)
- Multiple direct-funded industry projects

Site Infrastructure Plans: Existing, Funded, and Proposed

Existing

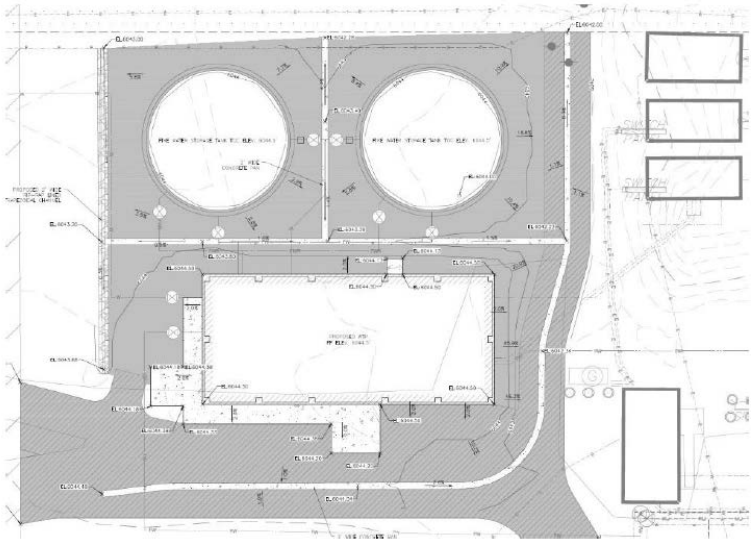
In development

Potential Future



*Note: "Potential Future" items are NOT currently committed or funded

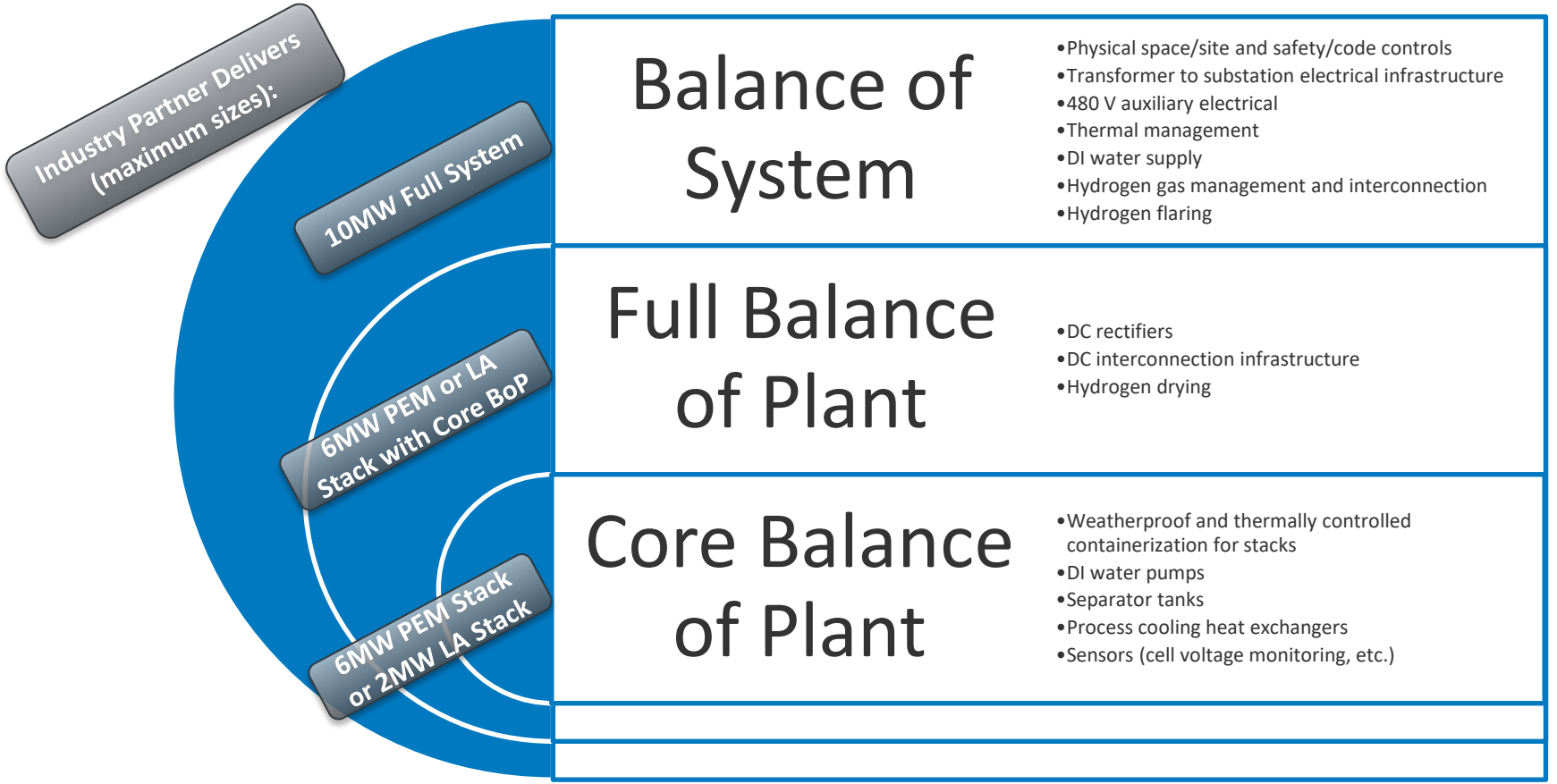
Campus Water Supply Infrastructure Upgrades



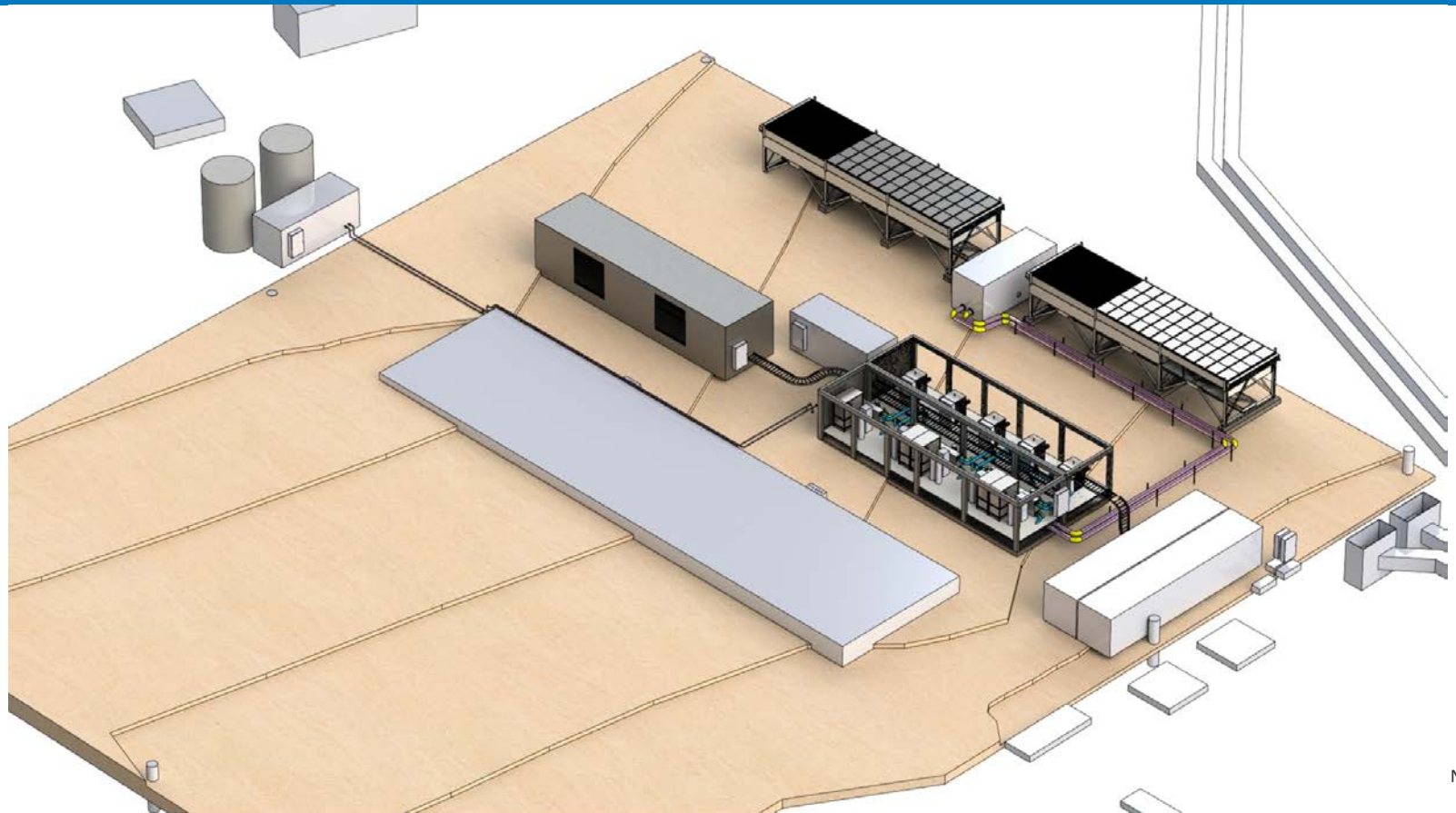
Planned water tanks and treatment plant locations

- Infrastructure investment being made to develop water main from reservoir, treatment facility, storage system, and supply lines to equipment (including hydrogen site)
- Design complete
- Awaiting Colorado State approval of water treatment process to proceed with construction bidding

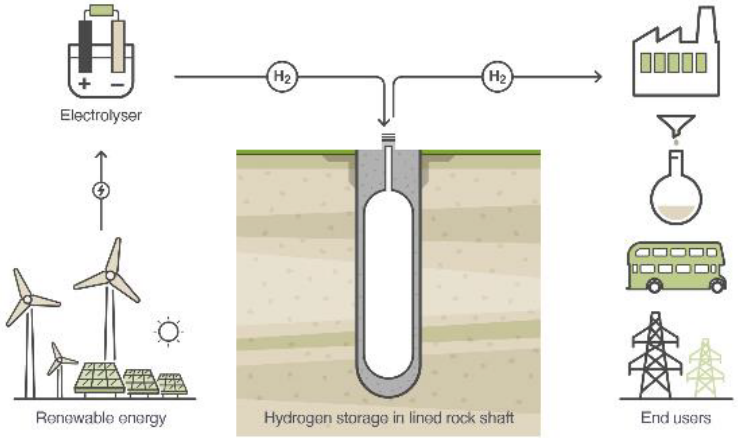
MMW LTE Research Capability

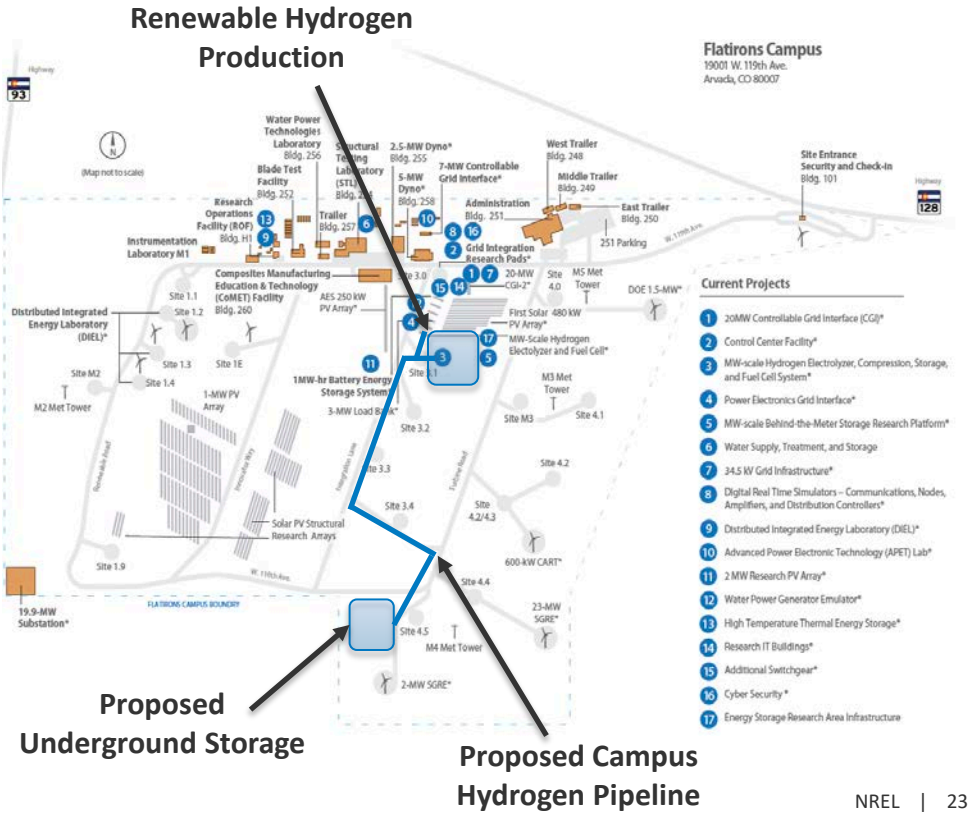


Future MMW LTE Site Layout



10-ton Underground H_2 Storage Capability





Potential Future Capabilities

- Heavy-duty vehicle fueling station
- H_2 power systems (fuel cells, engines, turbines)
- Molecule building (ammonia, green steel, methanol, etc.)
- Direct DC integration of H_2 technologies with renewables
- Liquefaction and/or liquid hydrogen storage
- Natural gas blending

Thank You

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NREL/PR-5700-90601

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Hydrogen and Fuel Cell Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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