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The #H2IQ Hour

Today's Topic:

Overview of Electrolyzer Operation at Nine Mile Point Nuclear Station

This presentation is part of the monthly H2IQ hour to highlight hydrogen and fuel cell research, development, and demonstration (RD&D) activities including projects funded by U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office (HFTO) within the Office of Energy Efficiency and Renewable Energy (EERE).

Housekeeping

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Questions?

- There will be a Q&A session at the end of the presentation
- To submit a question, please type it into the Q&A box; **do not** add questions to the Chat

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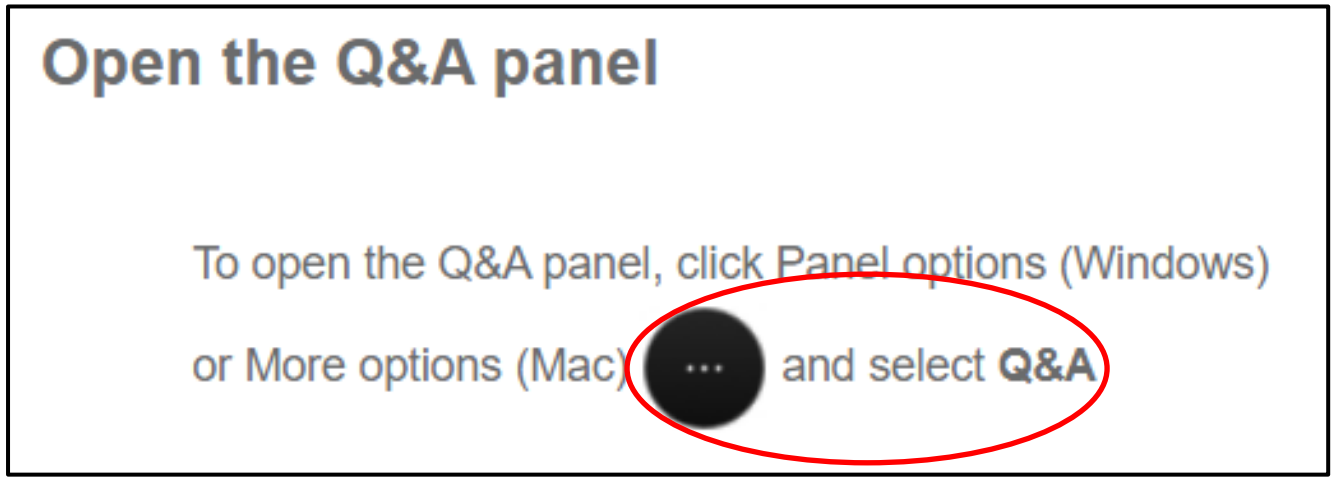
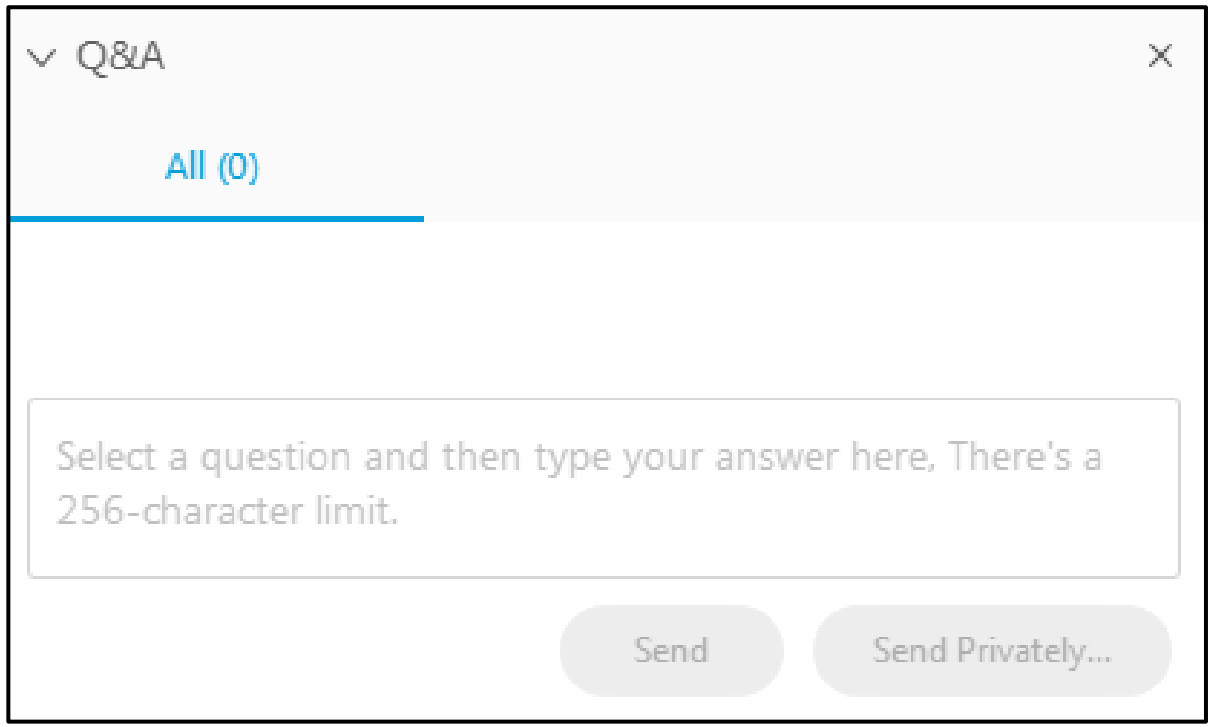
The #H2IQ Hour Q&A

Please type your questions into the Q&A Box





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June 2023 H2IQ Hour Presentation

Demonstration of electrolyzer operation at a nuclear plant to allow for dynamic participation in an organized electricity market and in-house hydrogen supply

Bob Beaumont, Project Manager, Constellation 6/28/2023

Project ID
TA028

Project Goals and scope

Goals/Objectives

- Install a 1MW Polymer Electrolyte Membrane (PEM) electrolyzer and supporting infrastructure at an Constellation nuclear power plant
- Provide economic supply of in-house hydrogen consumption at the plant
- Simulate a scale-up operation of a larger electrolyzer participation in power markets

Timeline and budget

- Conditional award: 10/01/2019
- Removal of condition: 04/01/2020
- Go/No-Go decision made: 07/30/2021
- Project End Date: 10/01/2023
- Total Project Forecast: $14.4M

Questions, challenges

- Site Selection
  - What are the criteria for site selection?
- Regulatory
  - What are the relevant regulations that affect nuclear H2 production?
- Market-related
  - What is the effective electricity price that the electrolyzer pays?

Partners

- Constellation Energy Corporation
- Idaho National Laboratory
- National Renewable Energy Laboratory
- Argonne National Laboratory
- Nel Hydrogen

Exelon

INL Idaho National Laboratory 70 YEARS OF SCIENCE & INNOVATION

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Argonne NATIONAL LABORATORY

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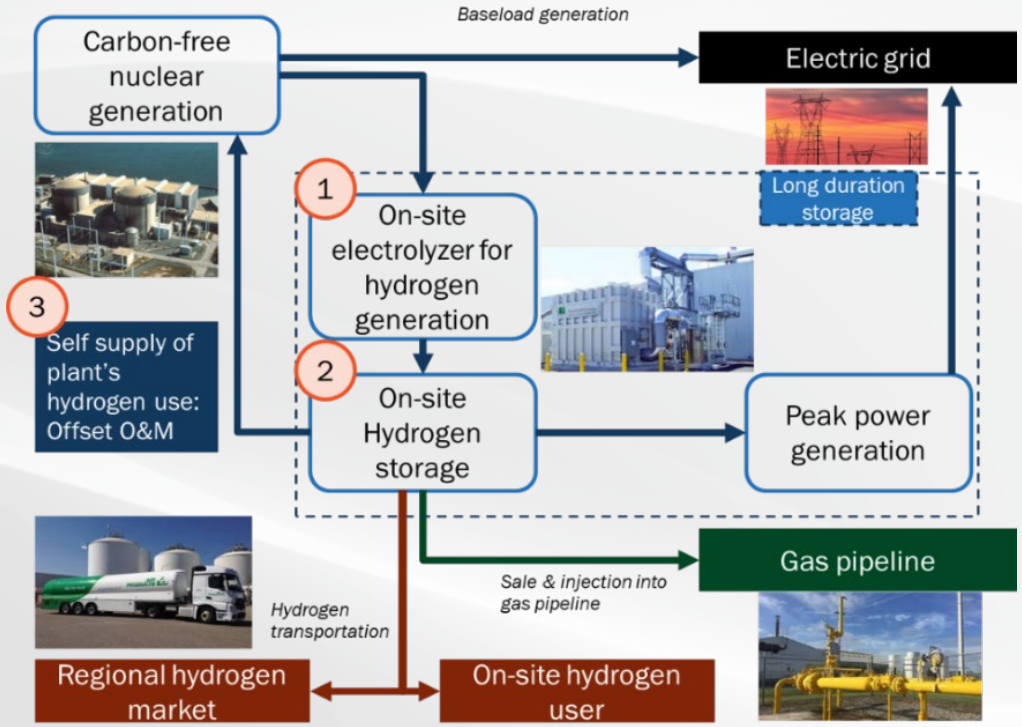
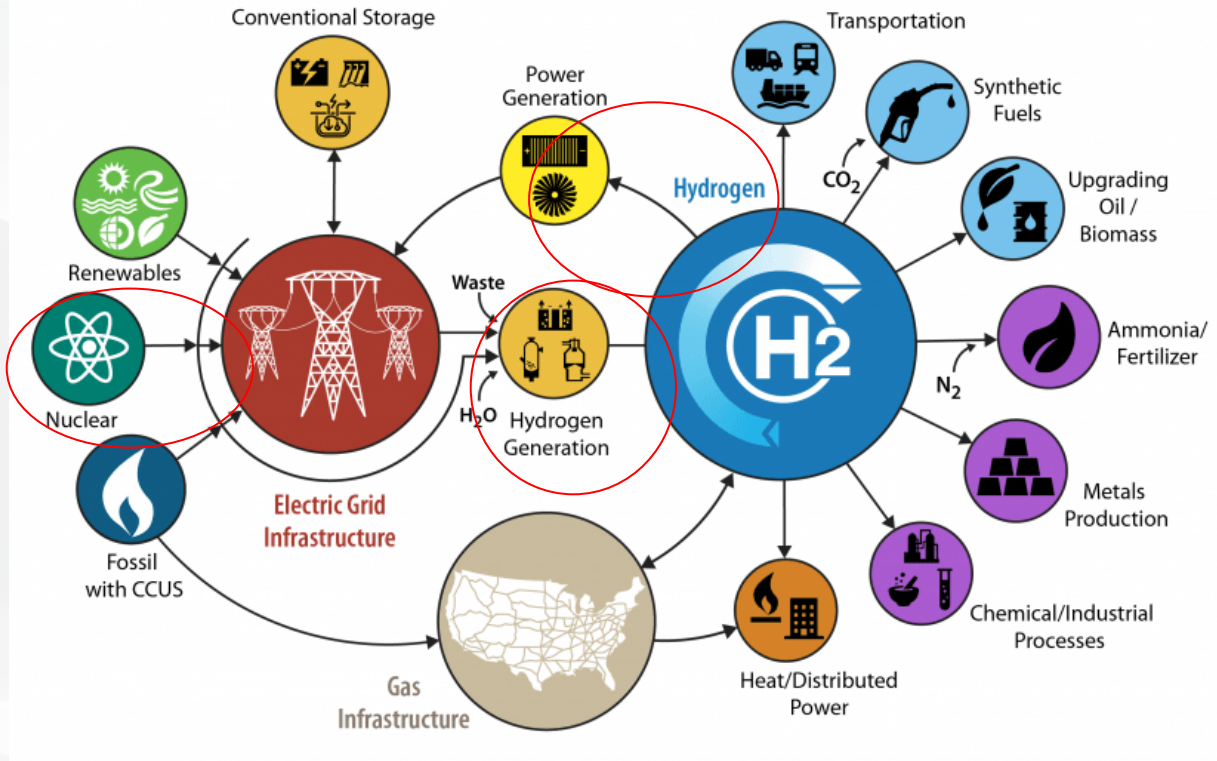
Relevance: The project demonstrates nuclear hydrogen pathway described in H2@scale vision

Technical Goals and Objectives

- Install a 1MW PEM electrolyzer and supporting infrastructure at an Constellation NPP
- Provide economic supply of in-house hydrogen consumption at the plant
- Simulate a scale-up operation of a larger electrolyzer participation in power markets





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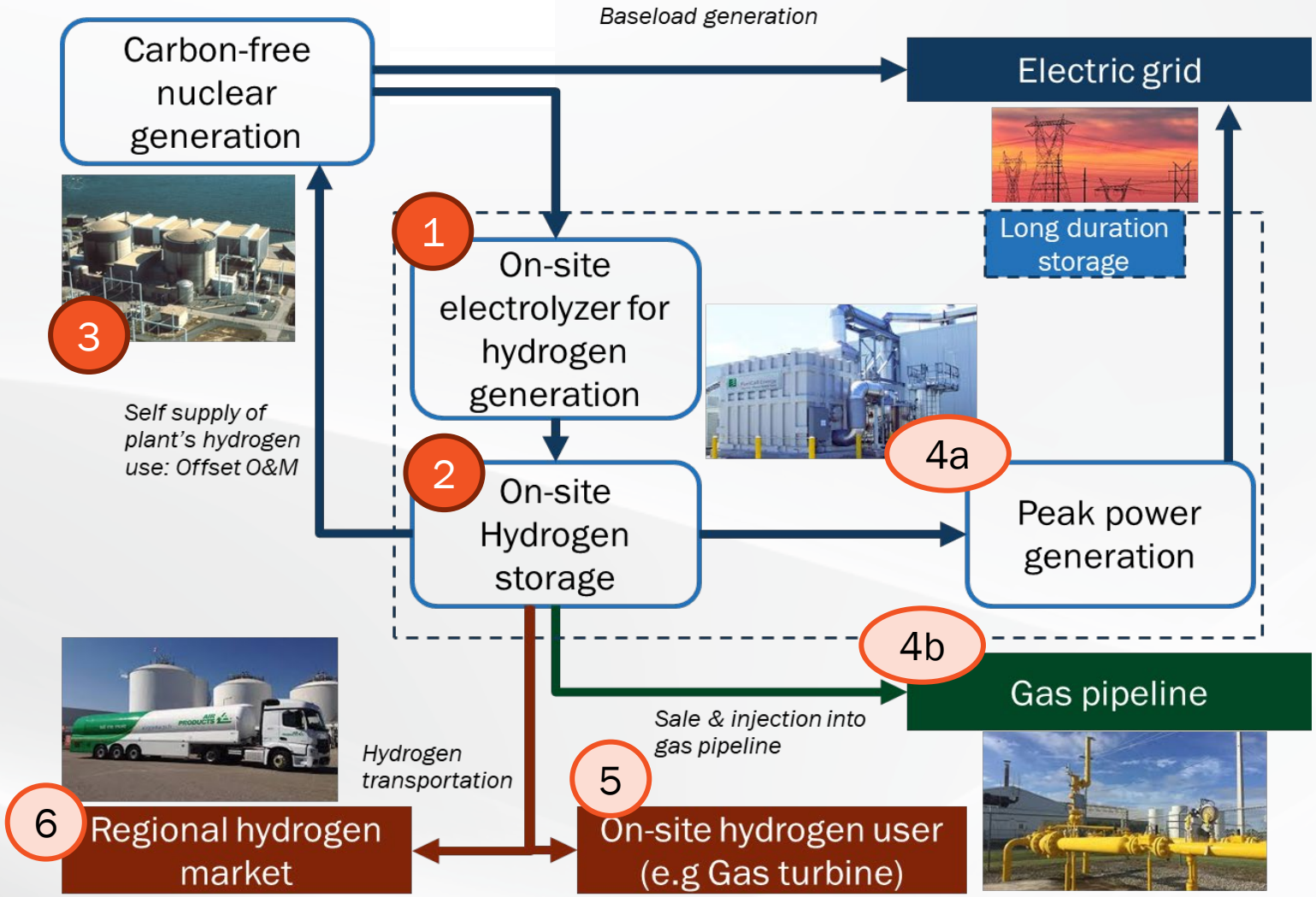
Approach: Exploring hydrogen production as a way to enhance the value of NPPs



The project will demonstrate pathways 1-3. In budget period 2, the team will implement installation, operation and scale-up analysis. #4 is being pursued with a state grant

Tasks and Milestones

Task #	Task	Description	Verification	Month from start
1.0	**Successful selection of an optimal site.**	Site selection is announced to project partners		1
2.0-A	**30% conceptual engineering design complete**	30% Engineering report is completed		11
4.0	**Demonstrate dynamic operation of a ~1 MW electrolyzer**	Perform factory acceptance testing and demonstrate dynamic operation of a ~1 MW electrolyzer.		11
4.0	**Simulation model of electrolyzer operation**	Verified by inspecting the results of a simulation model of the local electrical grid including interactions between the grid and the nuclear station and a 1 MW PEM system		9
5.0	**Identification of optimal sites for scale-up.**	Verified by a technical report comparing candidate sites and down selecting the optimal location for future scaleup.		11
2.0-B	**Site specific Final Engineering design**	100% design engineering is completed with input from Nel		18
6.0	**Economic feasibility assessment of scale-up**	Verified by a technical report assessing the economic feasibility of future scaleup.		35
8.0	**Start of steady state operation of electrolyzer**	Verified by the steady state hydrogen production		29
9.0	**Demonstration of dynamic operation at site**	Verified by the demonstration of remote connection and dynamic operation of the installed 1 MW electrolyzer.		35
10.0	**Perform a project specific assessment of cyber security issues**	A report documenting a project specific assessment of cyber security aspects in accordance with recommendations		35

Completed

In progress

Not started

NMP: Hydrogen Pilot Demonstration Project

Project Manager – Robert Beaumont

Current Status

- Electrolyzer and compressor installed
- System integration testing is complete
- Working through punch list of non-critical items to complete installation
- System has supplied Nine Mile Point since March 7, 2023

Next Steps

• Complete installation punch list activities	6/30/23
• Complete financial analysis	6/30/23

Remaining risks

- Financial – total costs were within original budget, but some budget categories need to be realigned based on actual costs compared to estimates.
- Schedule – none

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NMP: Hydrogen Pilot Demonstration Project

Project Manager – Robert Beaumont

Pouring concrete for electrolyzer on left, rigging power supply into place on right

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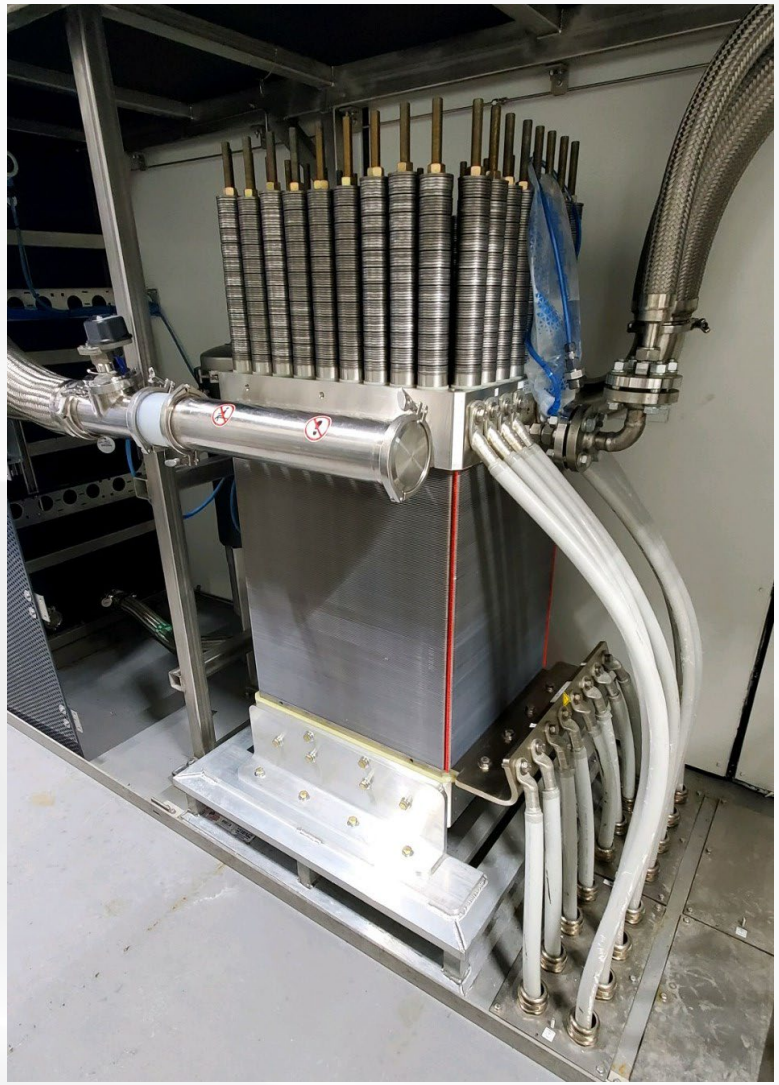
NMP: Hydrogen Pilot Demonstration Project

Project Manager – Robert Beaumont



Electrolyzer Area to left: backup generator, power supply, and electrolyzer

Cell stack installed to right.

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NMP: Hydrogen Pilot Demonstration Project

Project Manager – Robert Beaumont

Electrolyzer and cooling unit to left
Compressor below

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NMP: Hydrogen Pilot Demonstration Project

Project Manager – Robert Beaumont

Electrolyzer and cooling unit to left
Compressor and tanks to right

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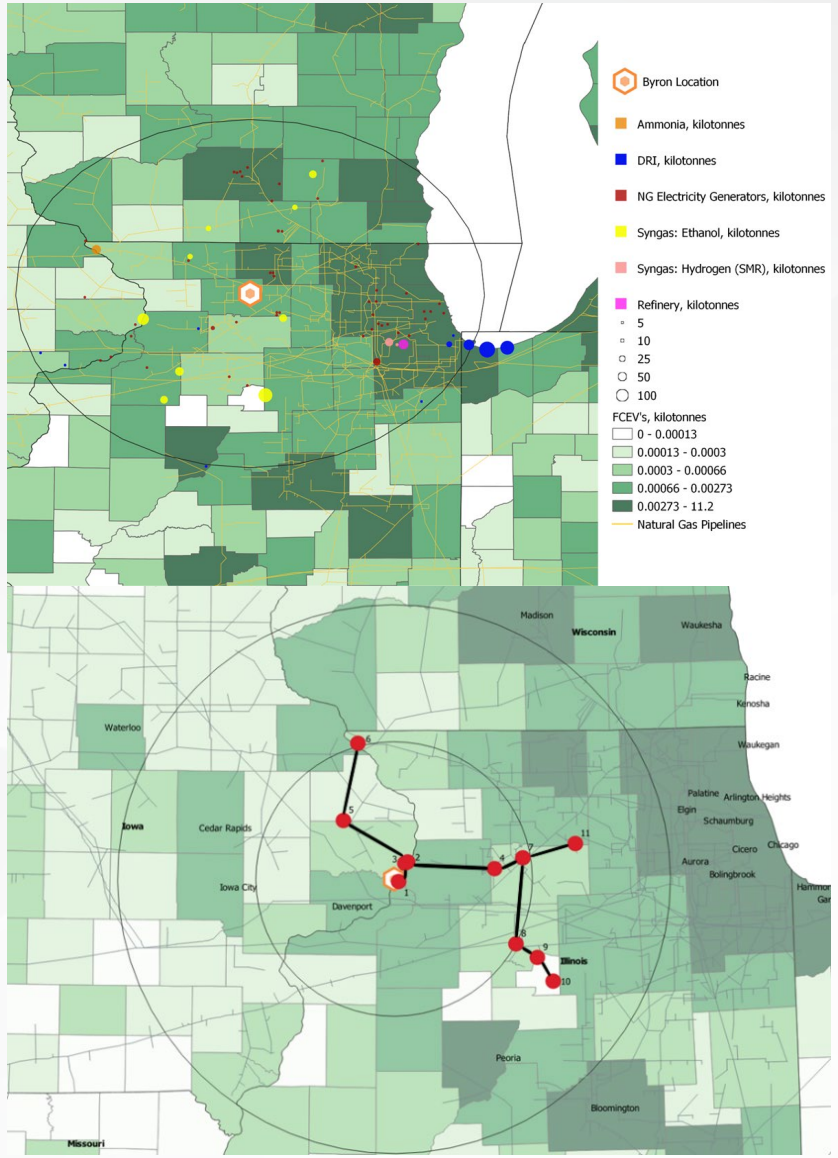
ANL: Market demand, GHG emissions and delivery cost evaluation for Nuclear H_2

H_2 markets and potential demand estimates for following generating station were evaluated:

1) Dresden GS
2) Quad Cities
3) Clinton GS
4) Limerick GS
5) Ginna GS
6) La Salle GS
7) Braidwood GS
8) Byron GS
9) Calvert Cliffs GS

- The potential H_2 market demand was calculated for near-term and long-term opportunities of refinery operations, ammonia production, H_2/NG electricity generators, synthetic fuels (synfuels) near CO_2 sources, direct reduction of Iron and in proximity to these nuclear power plants.
- Life cycle emissions were calculated for nuclear produced H_2.
- Emissions associated with end use applications are evaluated and compared to conventional technologies.
- Delivery costs were evaluated by simulating a pipeline network and using Hydrogen Delivery Scenario Analysis Model (HDSAM).
- Transportation and storage are major cost drivers for utilizing H_2
- Cost of avoided CO_2 was estimated for different end use applications using nuclear-H_2.
- Nuclear hydrogen can qualify for the highest production tax credits under IRA provision 45V.



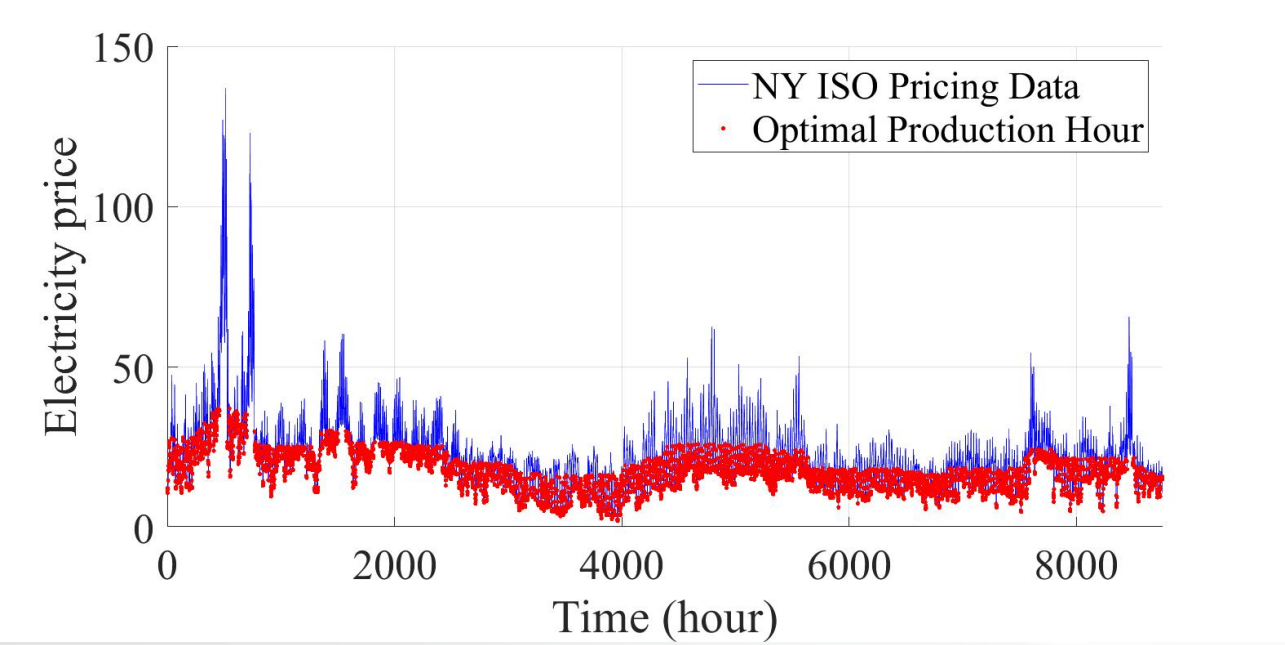
Simulations of Scaled Economic Dispatch Using Front-End Controller

Accomplishments

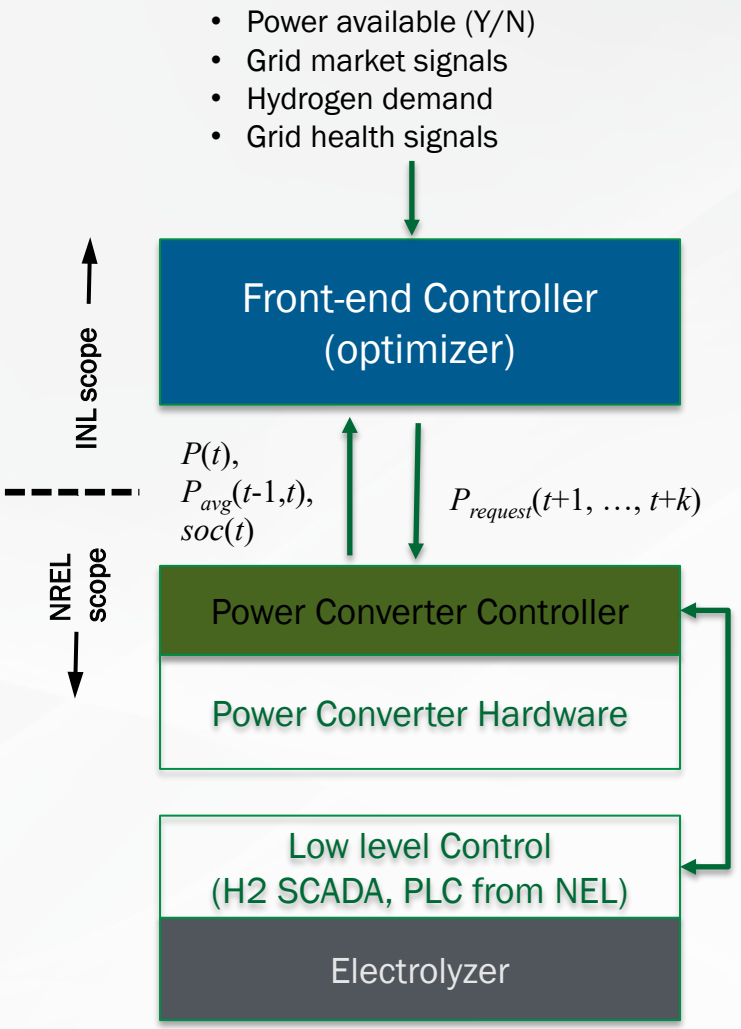
- Developed and tested front-end controller that uses data from power markets, grid, and the electrolyzer to optimize dispatch of hydrogen production

Results

- With fixed H_2 demand, electrolyzer daily capacity factor is ~constant and buffered by storage. Cost projections enable using lowest cost electricity for H_2 production to maximize system profits



Simulated hydrogen annual production assuming electrolyzer is operated 14 hrs/day with H_2 storage capacity of 5 tonnes.



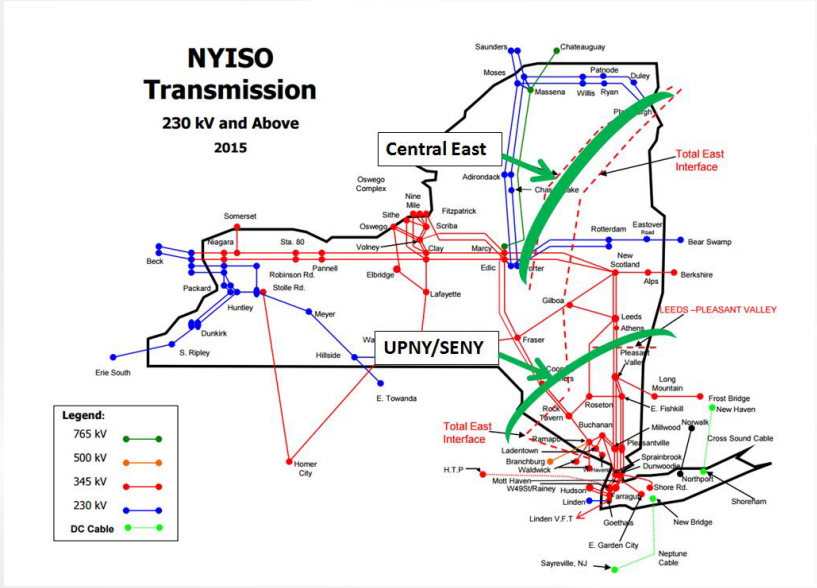
Simulations of Scaled Electrolyzer Demand-Response Dispatch

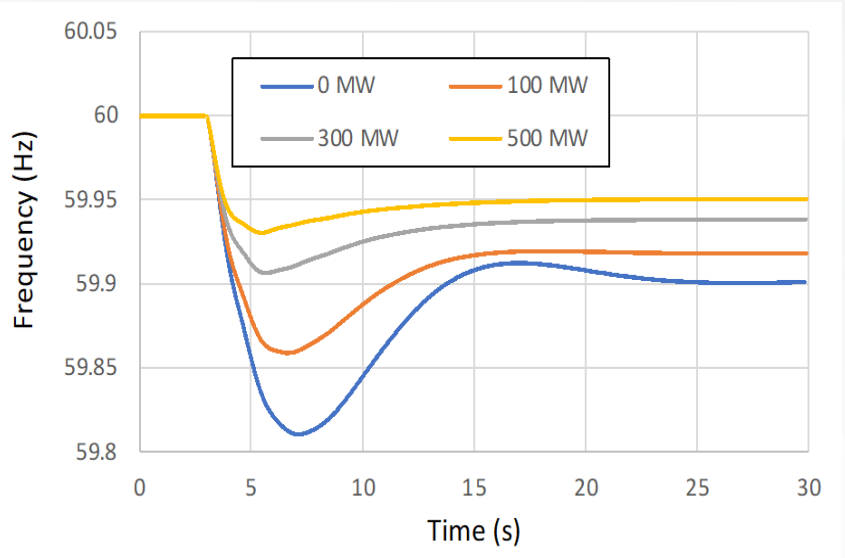
Accomplishments

- Performed transient grid analyses that indicate dynamic operation of scaled PEM system can decrease grid max. frequency delta due to generator fault.
  - Simulation used IEEE 39-bus standard (New-England Power System)
  - PEM system was located at bus 39, connected to a 1 GW nuclear power plant. A droop-based controller provided autonomous demand response
  - A generator fault (N-1 contingency) was simulated at generator 10 (250 MW) on bus 2 to create frequency transients.

Results

- Max. frequency delta decreased from 0.189 Hz without PEM system to 0.069 Hz for 500 MW PEM





Scenario	Max. Freq. Delta (Hz)
0 MW	0.189
100 MW	0.141
300 MW	0.093
500 MW	0.069

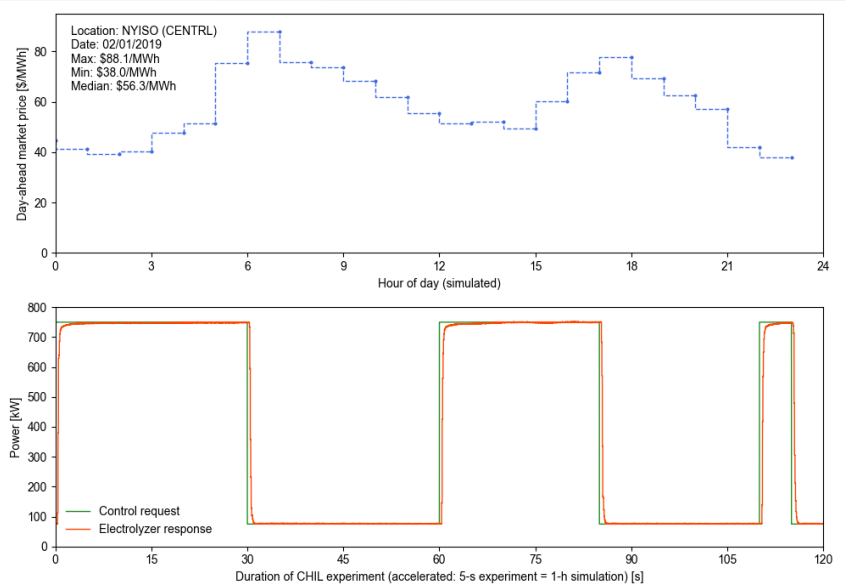
Accomplishments and Progress: NREL

Accomplishments

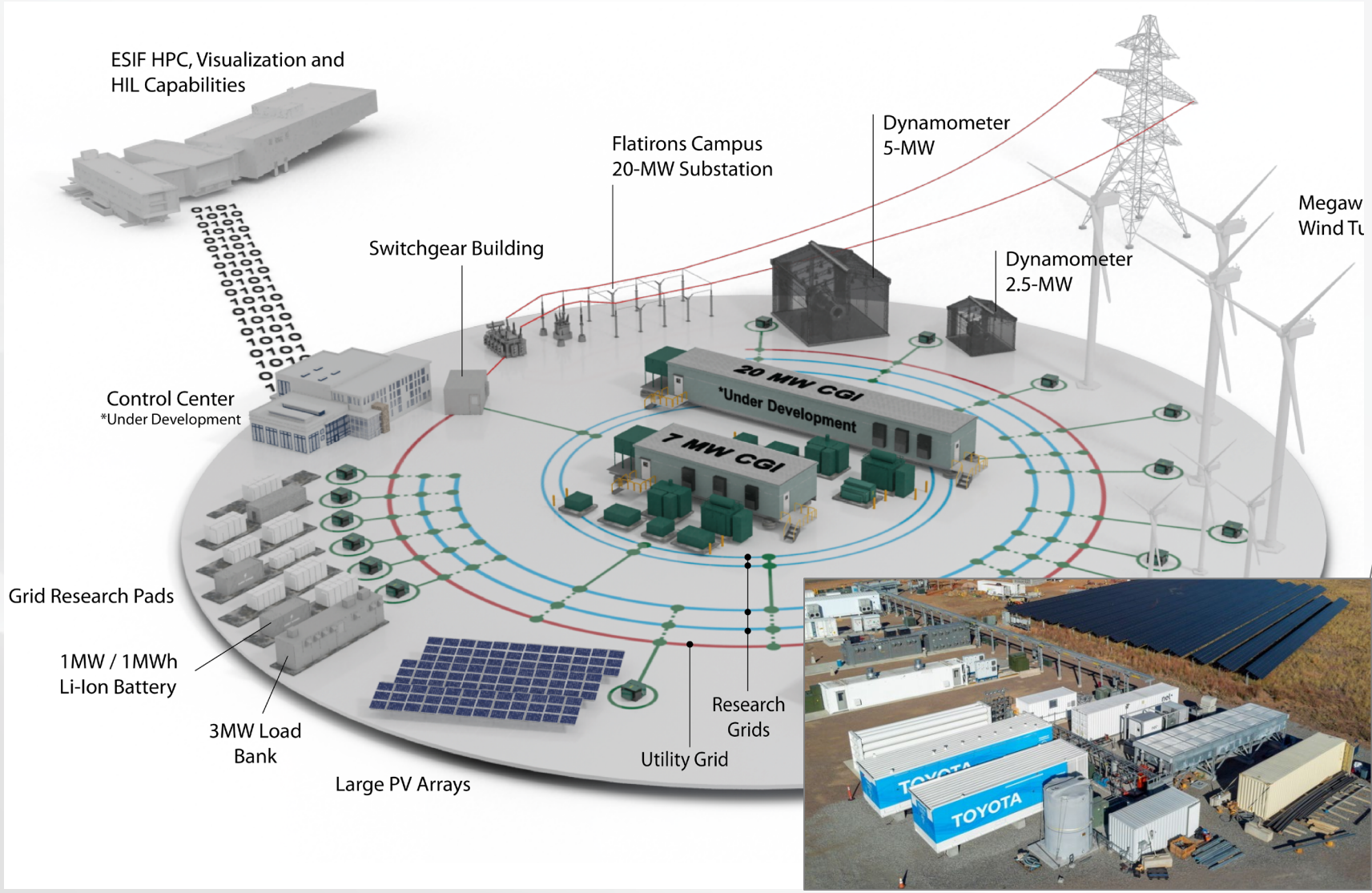
- Established a communication link between the front-end controller (FEC) and NREL's electrolyzer testbed with a 750-kW stack
- Refined the power-to-current conversion model with temperature effects
- Performed HIL tests of the electrolyzer system using dynamic control signals from FEC while maintaining operational constraints for hydrogen systems (**completed Milestone 4.2**)
- Shared lessons learned regarding water in systems that can freeze and cause damage before systems are ready for operation

Future Work/In Progress

- Provide hardware validation tests at Flatirons Campus if needed
- Host a site visit NREL Flatirons Campus for the Constellation team to compare operational experience and know-how between the two similar systems



MW Scale Hydrogen Systems Capabilities at NREL



Integrated Megawatt Scale Hydrogen System

- 1.25 MW PEM Electrolysis
- 600 KG Ground Storage — 20 MWh Chemical
- 3k PSI H_2 Compression
- 1.0 MW PEM Fuel Cell

Collaboration and Coordination

Partner	Role
Constellation	Lead applicant responsible for overall project, design, installation and operation of the 1MW electrolyzer. Licensing, regulatory market deliverables.
Nel	Vendor supplier for prototype test unit. Providing support for prototype electrolyzer testing
INL	Development of front end controller, dynamic operation of prototype electolyzer
NREL	Development of front end controller, dynamic operation of prototype electolyzer
ANL	Analysis for scaled-up hydrogen production, hydrogen market analysis

Personnel requirements

- **Electrolyzer**
  - Automatic operation – load following
  - Vendor quarterly maintenance – filter changes, sensor calibrations, and safety checks – 20 person hours/quarter
  - Weekly operations checks – air compressor blow downs, filter checks – 4 person hours/week
- **Compressor**
  - Automatic operation – sensing trailer pressures to start/stop charging
  - Vendor annual maintenance – oil change, sensor calibrations, filter changes, and safety checks – 20 person hours/year
  - Biweekly operations checks – head priming if needed – 1 person hour/week
- **Remote monitoring**
  - System added to business network (noncritical) to allow remote monitoring from control room.

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Summary of progress and future work

- **Project achievements**
  - 100% Final Engineering design completed
  - Installation and start of steady state operation of electrolyzer (started operation on 3/7/2023)
  - ANL has completed mapping hydrogen demand and infrastructure for potential scaleup sites
  - Successfully kicked-off $12.5M follow-on NYSERDA grant to install hydrogen fuel cell at NMP as a long duration storage
  - Submitted hydrogen hub application for Mach H2 based on learnings from the project
  - Received Nuclear Energy Institute's Top Innovative Practice (TIP) award in 2023
- **Lessons learned**
  - Compressor factory acceptance testing needed to be reperformed due to poor set up
  - Temperature bands for upstate NY required specialized valve seal materials which had long lead times
  - Many long lead time components were identified and were challenged due to supply chain issues.
- **External events/communication**
  - Organized in-person launch event at NMP in January 2023. Continue media engagements on local and national level: S&P Global, World Nuclear News, Nuclear Engineering International, RTO insider, Utility Dive, Power Engineering, Axios, Oswego County today, The eagle tribune, Power Magazine,
  - Continue to attend Conferences, industry events to knowledge share: IAEA, EPRI, ANS, Hydrogen Americas, MIT CANES
  - Prepare technical publications in research journals: IEEE
- **Future work**
  - Demonstration of dynamic operation on site

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Acknowledgments

- Financial support from DOE EERE Fuel Cell Technology Office under award #**DE-EE0008849**

- DOE program manager: Michael Hahn

- Constellation team and project manager: Robert Beaumont

- National lab teams

- Nel Hydrogen team

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