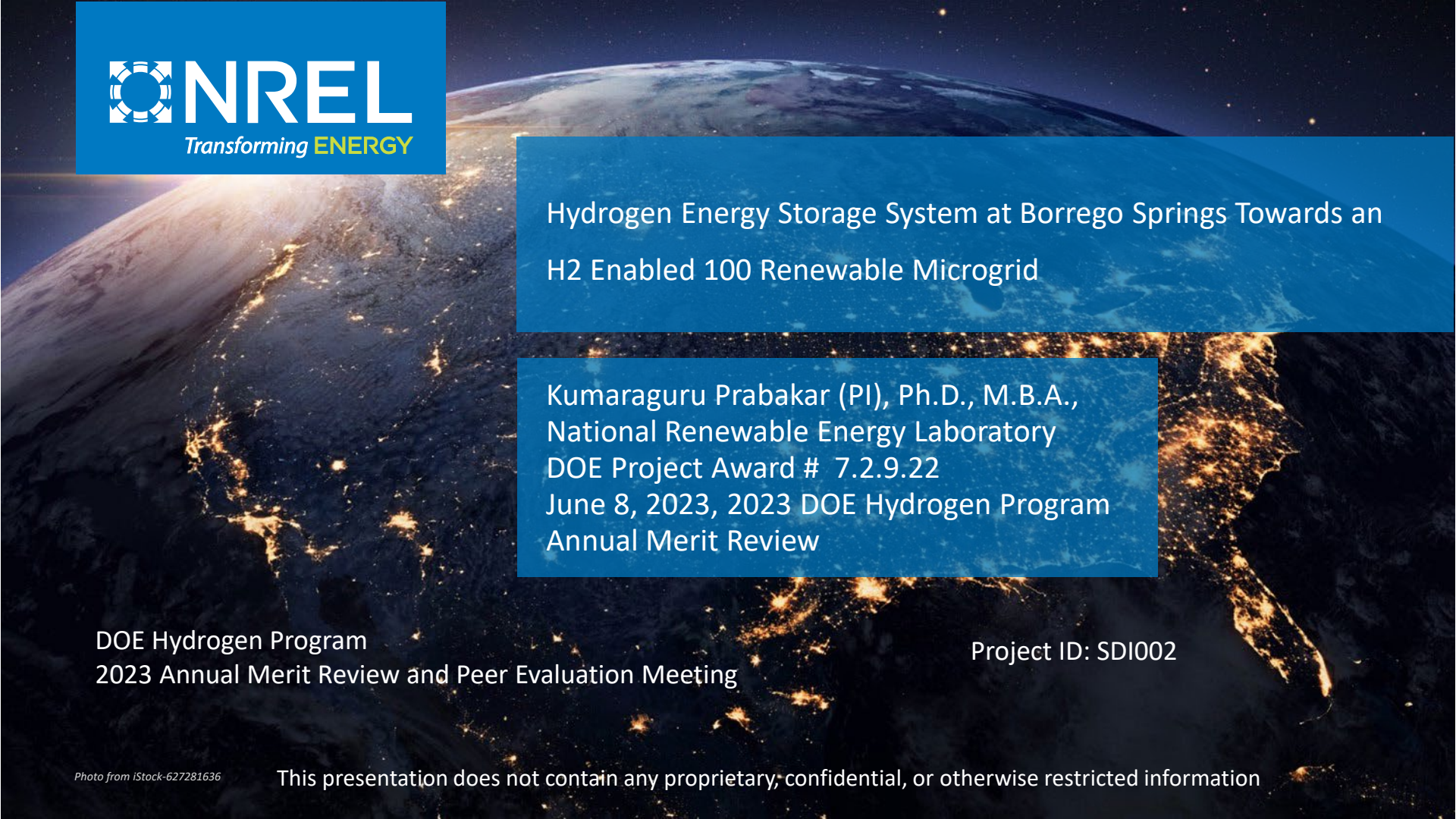


Hydrogen Energy Storage System at Borrego Springs Towards an H2 Enabled 100 Renewable Microgrid

Kumaraguru Prabakar (PI), Ph.D., M.B.A.,
National Renewable Energy Laboratory
DOE Project Award # 7.2.9.22
June 8, 2023, 2023 DOE Hydrogen Program Annual Merit Review

DOE Hydrogen Program
2023 Annual Merit Review and Peer Evaluation Meeting

Project ID: SDI002

Photo from iStock-627281636

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Project Goal

MAJOR GOALS & OBJECTIVES

Implement, characterize, and analyze advanced H_2 distributed energy resources and controls towards a 100% renewable Borrego Springs Microgrid:

- ✓ **Establish** intelligent control of H_2 distributed energy resources to stabilize the microgrid and reduce PV curtailment
- ✓ **Develop** hardware and conduct power hardware in the loop (PHIL) performance analysis to de-risk field deployment
- ✓ **Analyze** baseline and future operational characteristics of the Borrego Springs Microgrid under different H_2 configurations and characterize resiliency improvements
- ✓ **Share lessons learned** with the community and other stakeholders, via whitepapers, presentations, educational site visits, and other materials

Overview

Timeline and Budget

- Project Start Date: 09/01/22
- Project End Date: 08/30/24
- Total Project Budget: $4,674,000
  - Total DOE Share: $4,160,000
  - Total Cost Share: $514,000
  - Total DOE Funds Spent*: $34,359
  - Total Cost Share Funds Spent*: $0

* As of 04/07/2023

Barriers

- Barriers and Targets
  - Field deployment of electrolyzer and grid-forming fuel cell inverter to support advanced microgrid operation.
  - Disseminate field deployment results and characterize through data collected from the field and technical report.
  - Document and disseminate safety requirements for substation collocated hydrogen assets (electrolyzer and fuel cell assets).

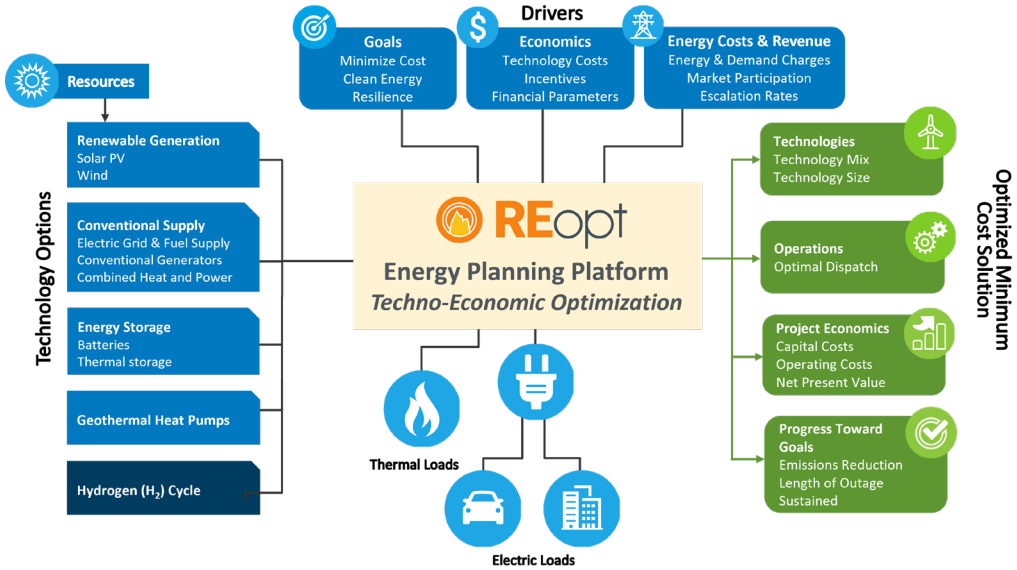
Partners

- NREL
- San Diego Gas & Electric Company, field deployment lead.
- PXiSE Energy Solutions, microgrid controller vendor.

Relevance/Potential Impact (analysis)

In this project, NREL will add hydrogen energy storage system (which includes fuel cell, storage tanks, and electrolyzer) as one of the technology options available in REopt®—a publicly available techno-economic decision-support platform developed by NREL researchers for energy system planning.

- Integrating hydrogen energy storage system into REopt will advance the DOE Hydrogen Program goals through the following project objectives:
  - Identifying the optimal sizing of hydrogen fuel cell, electrolyzer, and storage tanks required to achieve a 100% renewable microgrid for Borrego Springs
  - Quantifying reduction in greenhouse gas emissions and criteria pollutants resulting from: (i) replacing on-site diesel generators with H2 storage system, and (ii) using H2 assets to supply site loads during grid-connected microgrid operations.
  - Improve accessibility of planning for H2 assets for a wide range of REopt users including developers, researchers, government organizations, and utility and industry partners.

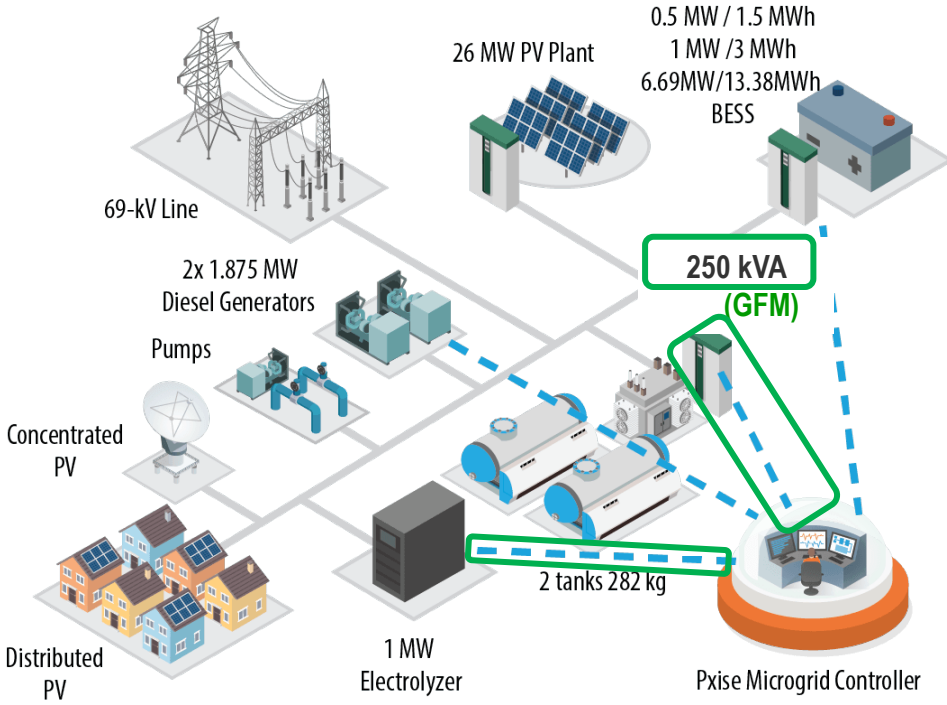


Relevance/Potential Impact (lab/field demonstration)

- Proposed project leverages existing and planned SDG&E funded H_2FC, electrolyzer, and storage.

Electrolyzer	Power consumption	1 MW
	H_2 Production Rate	18 kg/hr.
H_2 Storage	Working Capacity (total)	282 kg
	# tanks	2
	Operating Pressure Range	145-580 psig
Fuel Cell	Power Output	250 kVA **(grid-forming)**
	H_2 Consumption	17 kg/hr.
Microgrid Controller	**H2 assets integrated into Borrego microgrid controller**	

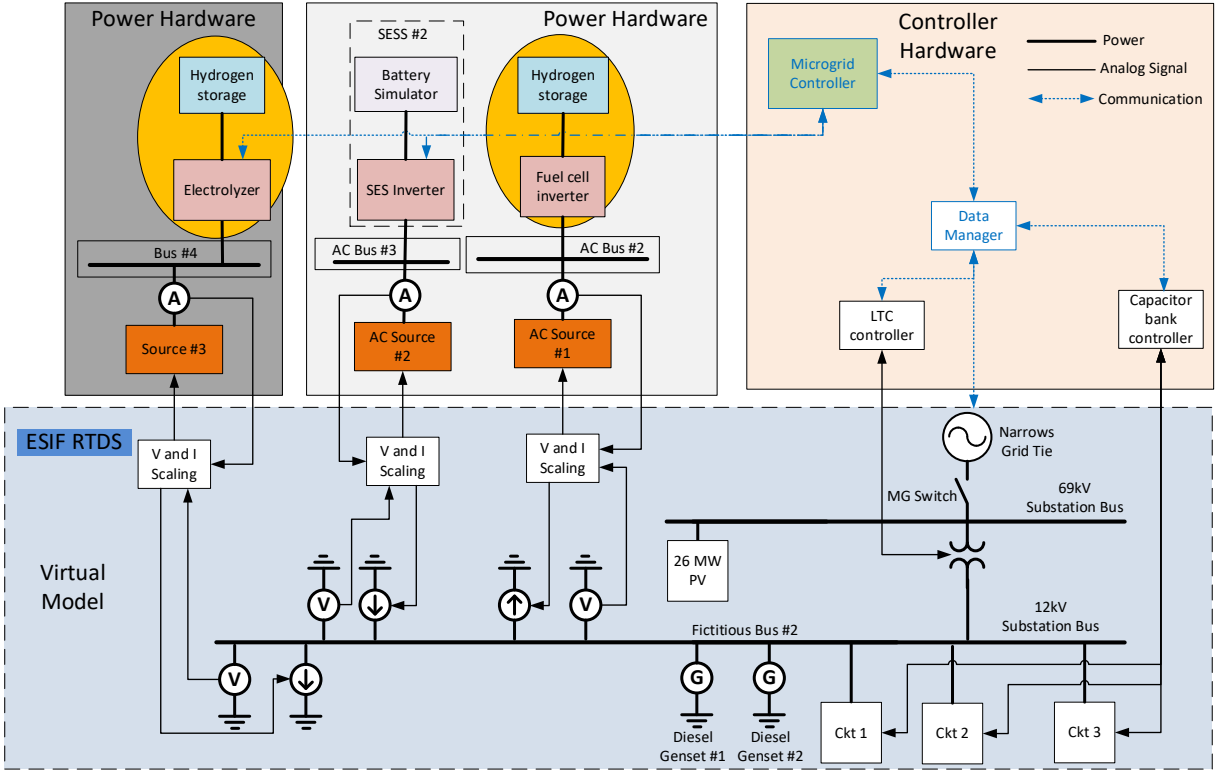
- Upgrade inverter with grid-forming capability
- Integrate hydrogen assets into Borrego Springs microgrid controller to demonstrate optimized control strategy
- **Green denotes planned upgrades through proposed project.*



Hydrogen Energy Storage System (HESS) upgrade elements

Relevance/Potential Impact (lab/field demonstration)

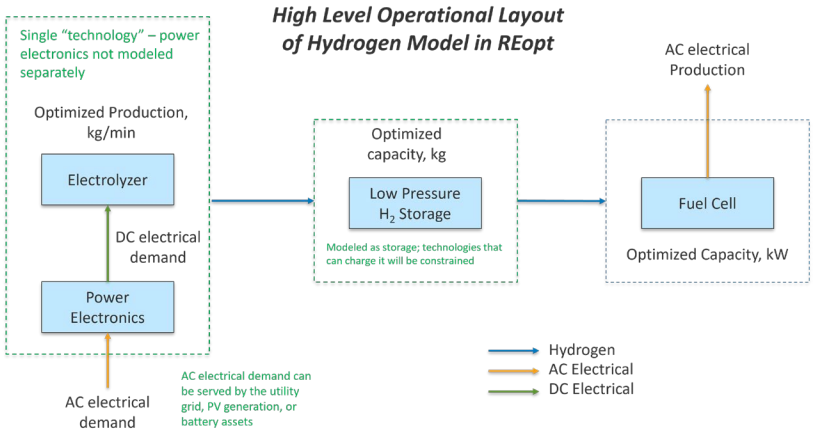
- Use of ARIES assets to run power and controller hardware-in-the-loop experiments to de-risk field deployment.



Approach (analysis)

Phase I - Model development

- Integrate hydrogen storage system components into REopt
  - Components that will be modeled near-term include hydrogen fuel cell, storage tanks, and electrolyzer
  - Future work could include the addition of high-pressure storage and compressor models to support hydrogen transportation analysis
- Integrate hydrogen fuel cell, storage tanks, and electrolyzer into REopt's resilience performance model to quantify outage survivability of the optimal hydrogen microgrid based on component reliability and availability.



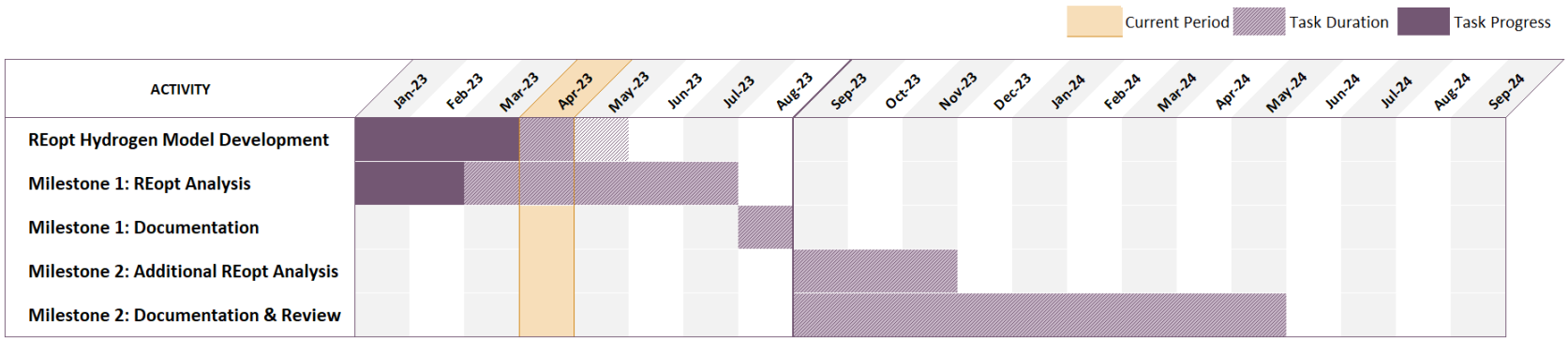
Phase II - Analysis

- **Scenarios Analyzed:**
  - Benchmark current microgrid operation without hydrogen assets
  - Quantify the benefits of integrating hydrogen storage system components into the microgrid with financial and resilience analyses in REopt:
    - Report metrics for the planned hydrogen system
    - Report metrics for a 100% renewable microgrid scenario
- **Outputs and Metrics:**
  - Optimal system sizes required to achieve the analysis goal
  - Optimal dispatch strategies (including minimizing PV curtailment)
  - Economic metrics (including capital costs, O&M costs, fuel costs, utility costs, and net present value)
  - Resilience metrics (outage survivability, reported as probability of survival)
  - Emissions metrics (including climate and health emissions)

Accomplishments and Progress

- The REopt task is currently in the model development phase. Since the receipt of the award, the project team has developed a fuel cell model within REopt (pending a few feature additions to improve the model).
- A detailed data request seeking site-specific inputs (such as typical annual interval loads, existing distributed resources at Borrego Springs, and technology specifications of the hydrogen assets procured) has been sent to SDG&E
- An extensive literature review is underway to identify the appropriate defaults, assumptions, and constraints for each of the hydrogen storage system components.

Borrego Springs - REopt Development and Analysis Timeline



Response to Previous Year Reviewers’

- This is a new project.
- This project was not presented in the previous year annual merit review.
- No reviewer comments.

Collaboration and Coordination

Partner	Comment
San Diego Gas and Electric Company, Sub contractor	Utility partner, field deployment lead.
PXiSE Energy Solutions, Sub contractor to SDG&E	Microgrid controller vendor.
Electrolyzer vendor	Not finalized
Fuel cell vendor	Not finalized

Remaining Challenges and Barriers

- Execute subcontract with SDG&E and initiate information exchange.
- Initiate shakedown experiments using ARIES equipment.
- Identify and complete subcontractors for SDG&E field assets upgrade (grid-forming inverter and microgrid controller interoperability).
- Conduct comprehensive literature review and engage subject matter experts in identifying appropriate defaults and assumptions to use in the analysis for hydrogen storage system components in REopt.

Proposed Future Work (analysis)

- FY23
  - Key milestone: Complete REopt analysis (8/31/2023)
    - Continue optimization model development:
      - Adding inputs and constraints for fuel cell, electrolyzer, and hydrogen fuel storage
      - Updating REopt's existing objective function to include the hydrogen assets
    - Integrate fuel cell, electrolyzer, and into REopt's resilience performance tool
    - Send additional data requests to SDG&E to obtain all the required site-specific inputs
    - Once the model development is concluded, request project stakeholders to perform validation and testing of the new REopt and resilience model
    - Perform REopt analysis for the three key scenarios identified
- FY24
  - Key milestone: Report analysis results (2/29/2024)
    - Seek stakeholder inputs on any additional REopt scenarios that might be beneficial to perform
    - Compile the relevant results and metrics for all the scenarios evaluated into a detailed report

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

Proposed Future Work (lab experiments/field deployment)

- Complete lab shakedown experiments with the hydrogen assets.
- Complete test plan documentation.
- Complete installation of hydrogen assets
- Complete installation of sensing equipment to collect and store data.

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

Summary

- **Optimal performance strategy and resulting annual hourly and annual energy use, emissions, operating costs, battery charge-levels, and hydrogen storage levels defined** (via analysis)
- **Demonstration that conventional diesel generators are not required when utilizing H_2 assets using optimized microgrid control scheme** (via field and analysis)
- **Resiliency benefits of additional H_2 assets** established (via analysis)
- Cost and resiliency benefits of **reduced PV curtailment** quantified (via HIL and analysis)
- Balance of system requirements established for **large scale deployment** (via HIL and analysis)
- Development of H_2 assets **hardware-in-the-loop testbed** using ARIES equipment (via HIL)
- **Transient stability utilizing H_2FC inverter as grid-forming asset** during islanding operations characterized (via HIL)
- **Operation of H_2 assets under different modes of microgrid operation** and power system events described (via HIL)
- **H_2FC fuel cell inverter control strategy and microgrid controller strategy established** (via HIL and field)
- Documentation outlining **safety precautions** identified during field operations (via field)
- **Whitepapers**, **publications**, stakeholder and community **site visits**

Feasibility of H_2 enabled 24/7 100% renewable microgrid demonstrated

Thank You

www.nrel.gov

PR-5D00-85597

This work was authored in part 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 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.

Technical Backup and Additional Information

Technology Transfer Activities

- No tech transfer activities.

Special Recognitions and Awards

- No special recognitions or awards this work received.

Publications and Presentations

- No publications.