Integrated Hydrogen Production and Consumption for Improved Utility Operations

2020 DOE Hydrogen & Fuel Cells Technologies Office

Annual Merit Review Poster

PI: Monjid Hamdan

VP of Engineering

Giner ELX, Inc.

89 Rumford Ave.

Newton, Ma. 02466

Project ID: TA030

Overview

Timeline

- **Project Start:** May. 1st, 2020
- **Project End:** April 30th, 2023
- **Percent Complete:** 00%

Budget

- **Total Project Budget:** $9.1 M
  - **Total Federal Share:** $4.25 M
  - **Total Recipient Share:** $4.84 M
  - **Total DOE Funds Spent*:** $0.0 M

* As of 3/31/2020

Technical Barriers[1]

- System(s) Integration, Reliability, Cost, Performance, and Efficiency

Technical Targets: Small Compressors: Fueling Sites (~100 kg H_2/hr)[2]

Characteristics	Units	2015 Status	2020 Target
Hydrogen Levelized Cost (Production Only)[3]	$/kg	3.90	2.30
Electricity Price[3]	$/kWh	0.049	0.031
Electrolyzer Cap. Cost Contribution[2]	$/kg	0.50	0.40
Electrolyzer Stack Efficiency[3]	% (LHV)	76	78
	kWh/kg-H_2	44	43
Electrolyzer System Efficiency[3]	% (LHV)	73	75
	kWh/kg-H_2	46	44.7
Aggregate cost of transport, distribution, & fueling[4]	$/gge	2.00	<2.00
Fuel Cell System Costs[5]	kW_{net}$	53	40

[1] Office of Energy Efficiency and Renewable Energy (EERE) announcement DE-FOA-0002022
[2] HFTO MYRD&D Plan (2015)
[3] Hydrogen Production, Central Water Electrolysis, HFTO MYRD&D Plan (2015)
[4] Hydrogen Delivery, HFTO MYRD&D Plan (2015)
[5] Fuel Cells, Integrated Transportation Fuel Cell Power Systems Operating on Direct Hydrogen HFTO MYRD&D Plan (2016)

Partners

- Orlando Utilities Commission (OUC) - Utility Co./System Integration/Solar
- General Motors, LLC (GM) - Stationary Fuel Cell Systems
- OneH2 - Storage Dispensing and Compression
- Giner ELX, Inc. - Electrolyzers
- Univ. of Central Florida/ Florida Solar Energy Center (UCF-FSEC) - TEA
- National Renewable Energy Lab (NREL) Solar Energy Technology Center (SETO) - Modelling

Relevance

Overall Project Objectives

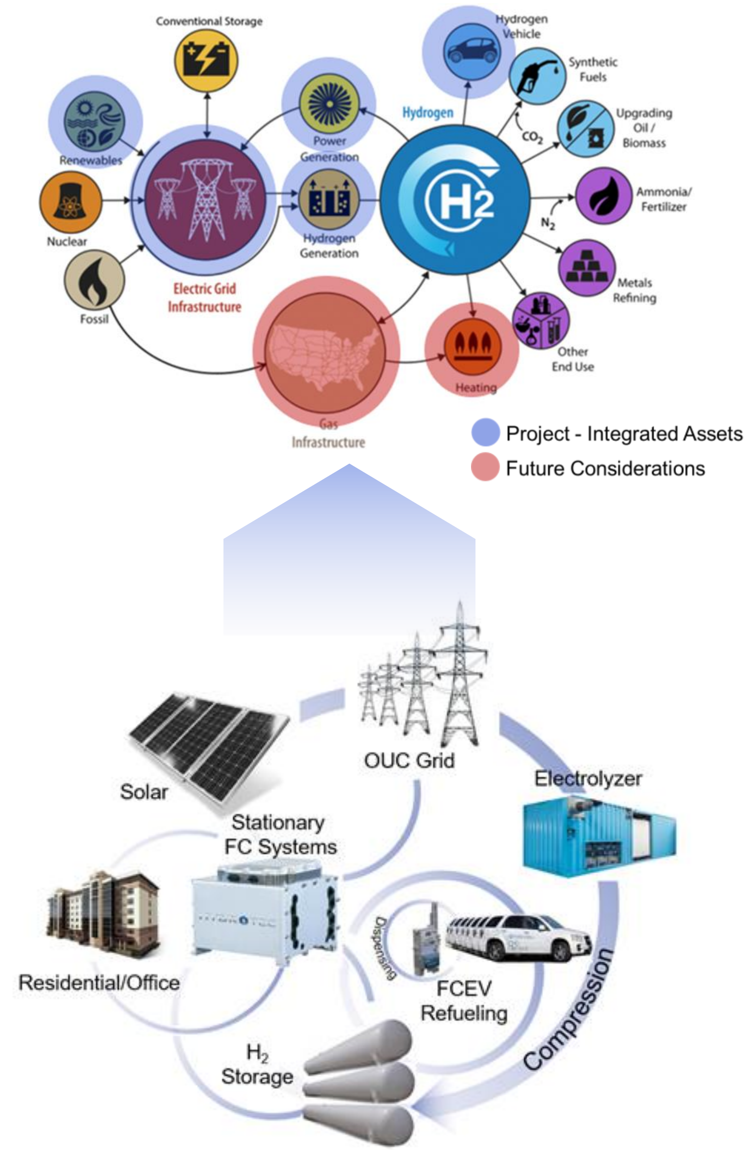
- Demonstrate grid-level hydrogen assets to incentivize and assist the hydrogen economy across multiple sectors
- Manufacture & assemble integrated system incorporating PEM-based electrolysis for H_2 production, compressed H_2 storage, H_2 dispensing for FCEV refueling, and stationary fuel cells for electricity generation
- Develop and optimize economic dispatch models based on grid-level controls to address high penetration renewable integration impacts

FY 20 Objectives

- Complete techno-economic analysis
- Complete and optimize designs of individual system units
- Develop model demonstrating path to < \$2/kg-H_2

Impact

- Grid-integrated hydrogen assets enable system operators to leverage intermittently available electricity to produce hydrogen for use in FCEVs, back-up power, and grid operational use cases
  - Ensures that the hydrogen is produced at the lowest electricity cost, and then consumed for the greatest possible value
  - Develops business models where utilities provide both electricity and hydrogen fuel, supporting both the grid and the transportation sector

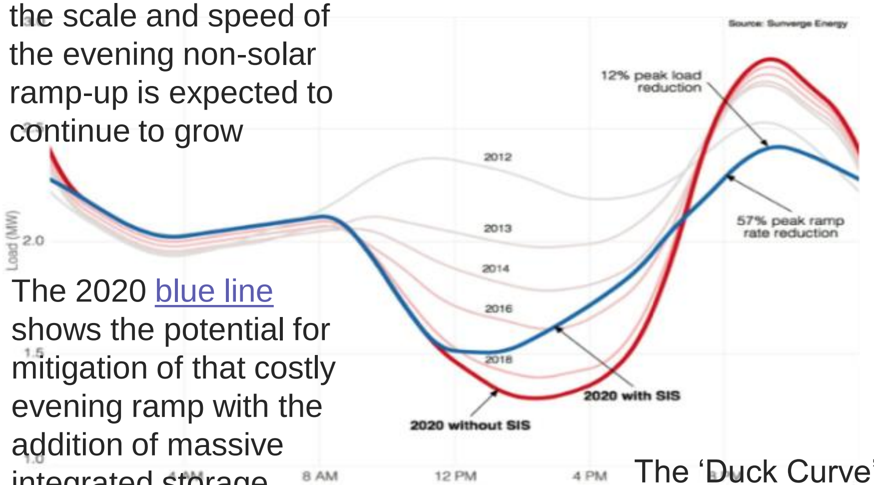


Background

- Duck Curve indicates steep ramping requirements and over-generation risk, accentuated w/ increasing solar PV
- Long-duration (8+ hours) required to address ramp-rates
- Solution: Hydrogen production at utility scale can provide long duration capacity as a controllable load
  - Dispatch electrolyzers to reduce overgeneration risks and smooth ramp rates

The 2020 red line shows the scale and speed of the evening non-solar ramp-up is expected to continue to grow

The 2020 blue line shows the potential for mitigation of that costly evening ramp with the addition of massive integrated storage (“SIS”)



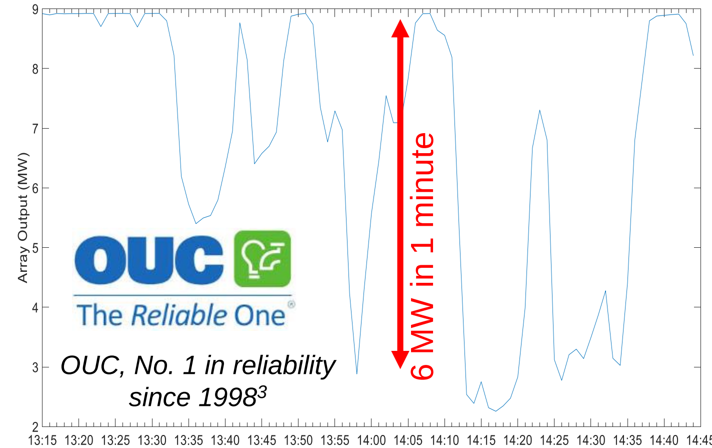
The ‘Duck Curve’ belly grows as solar output soars

The “California Duck” Chart[1]

Non-solar generation required over a 24-hour period (2012 to 2020)

Orlando Utility Commission

Output Variation from an 8.9 MW_{AC} PV Array[2]



- OUC’s solar penetration is < 1% retail sales, but increases to 10% by 2022, and could be 20% by 2024+
- Solution: PEM Electrolyzer with fast response time, and scalable to TWh
  - Electrolyzers can provide renewably generated hydrogen and provide grid services as a controllable load with fast response times
  - Development of hydrogen markets required

Sources: [1] CAISO. [2]OUC. [3] Florida Public Service Commission. [3]OUC.

Approach: Program Overview

H_2-Cost Reduction
Grid-Integrated Control
Cyber Security

TEA, System Optimization & Design — Year 1

- Technoeconomic Analysis
- Complete/Optimize design(s) of individual system units (FC, Electrolyzer, PV Array, Storage, Dispensing)
- Develop utility control architecture to dispatch Grid-integrated H2 Assets
- Demonstrating path to achieve < \$2/kg-H_2

Unit Assemblies Utility Integration — Year 2

- Complete individual system unit assemblies, delivery, and integration:
  - 90 Nm^3/hr electrolyzer BOP and three (3) 30 Nm^3/hr electrolyzer stacks installed
  - Two (2) 60 kW [100 kW peak] FC systems
  - 350 bar compressor, storage and dispensing units,
- Integration of individual system units with OUC Utility

Utility Integrated Operation — Year 3

- Integrated Operation
- Demonstrate integrated system dispatch with utility
- Complete economic and market feasibility studies, establishing multiple value streams for hydrogen

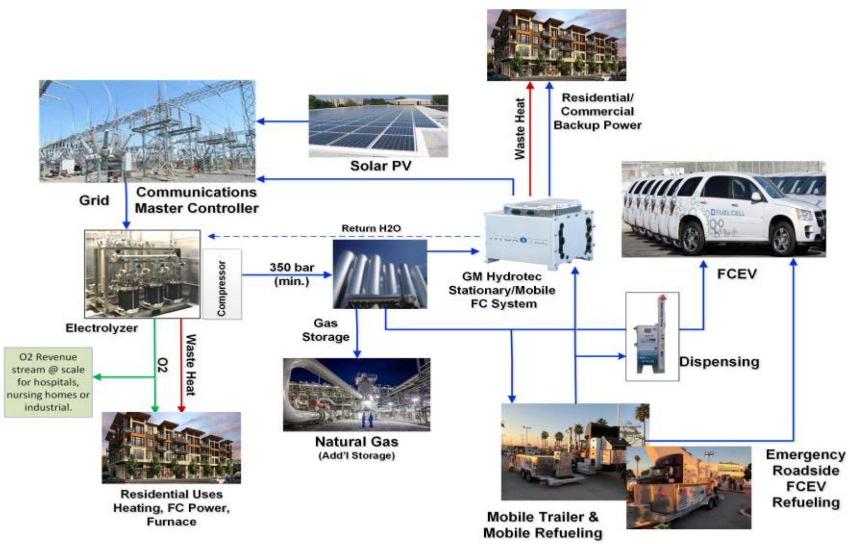
Approach: YR1 Tasks & Milestone Progress

Task No.	Task Title	Mile-stone	Milestone Description (Go/No-Go Decision Criteria)	Progress Notes	Percent Complete
1	Techno-Economic Feasibility Study	M1.1	Complete Techno-Economic Feasibility Study. Demonstration path to achieve \$2-4/kg. Summarizing the potential for PV-electrolyzer systems to increase the optimal PV penetration in the U.S. and/or reduce the cost to hit a high PV penetration target	TEA Initiated	0%
2	Electrolyzer Design	M1.2	Complete preliminary design of electrolyzer unit.	In process	0%
3	Stationary and Mobile Fuel Cell Power Generation System	M1.3	Complete optimization/design of fuel cell-based power generation system.	In process	0%
4	Hydrogen Storage, Dispensing Design	M1.4	Complete sizing of the storage system to meet hydrogen delivery demands, including vehicular and stationary fuel cell applications.	In process	0%
5	OUC Host Site Design and Preparation	M1.5	Complete site prep for systems integration	In process	0%
6	OUC Development of Economic Dispatch Models	M1.6	Complete Economic Dispatch Models. This information will be used to develop utility control architecture (and will be an ongoing process that will be optimized in Y2)	In process	0%
7	Cybersecurity Analysis	-	Initiate cybersecurity analysis related to grid integrated systems and hydrogen safety.	In process	0%
Go/No-Go Decision Y1			**Develop utility control architecture to dispatch integrated Utility, Electrolyzer, Storage, and Fuel Cell systems based on PV RES at OUC. Demonstrating path to achieve < \$2/kg-H_2**	-	

Techno-Economic Feasibility Studies

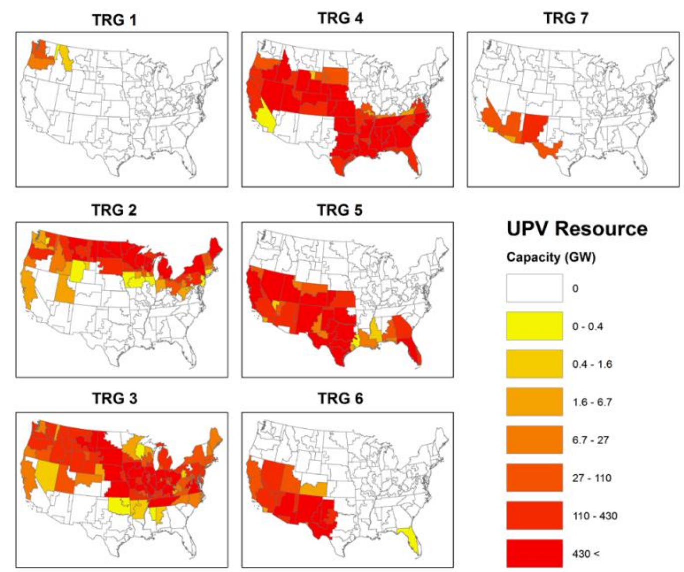
Integrated Asset-based Studies

- Determine lowest cost electric from PV and least-cost way of building and operating the electrical PV system with integrated hydrogen assets
- **M1.1a**: Demonstration path to achieve <$2/kg-$H_2$



Large-Scale Utility PV based

- **ReEDs Model**[1]: ReEDS solar photovoltaic technologies modeling: large-scale utility PV and distribution-side utility-scale PV
- Identifies the least-cost mix of technologies that meet regional electric power demand requirements
- **M1.1b**: Paper summarizing the potential for PV-electrolyzer systems to increase the optimal PV penetration in the U.S. and/or reduce the cost to achieve a high PV penetration target



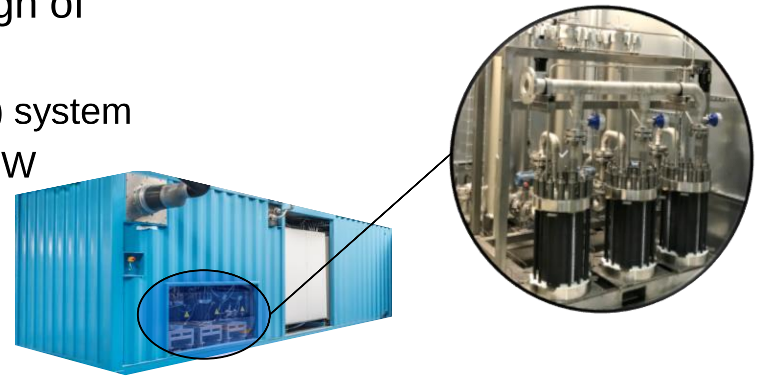
[1]Source: Cohen, Stuart, Jon Becker, Dave Bielen, Maxwell Brown, Wesley Cole, Kelly Eurek, Will Frazier, et al. 2019. Regional Energy Deployment System (ReEDS) Model Documentation: Version 2018. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-72023. https://www.nrel.gov/docs/fy19osti/72023.pdf.

Utility Hydrogen Asset Optimization

Electrolyzer Design

Complete preliminary design of electrolyzer unit

- 90 Nm^3/hr-H_2 (200 kg/d-H_2) system
- Power Consumption: 0.5 MW
- Three (3) 30 Nm^3/hr stacks



Stationary and Mobile Fuel Cell Power Generation System

Complete optimization/design of fuel cell-based power generation system

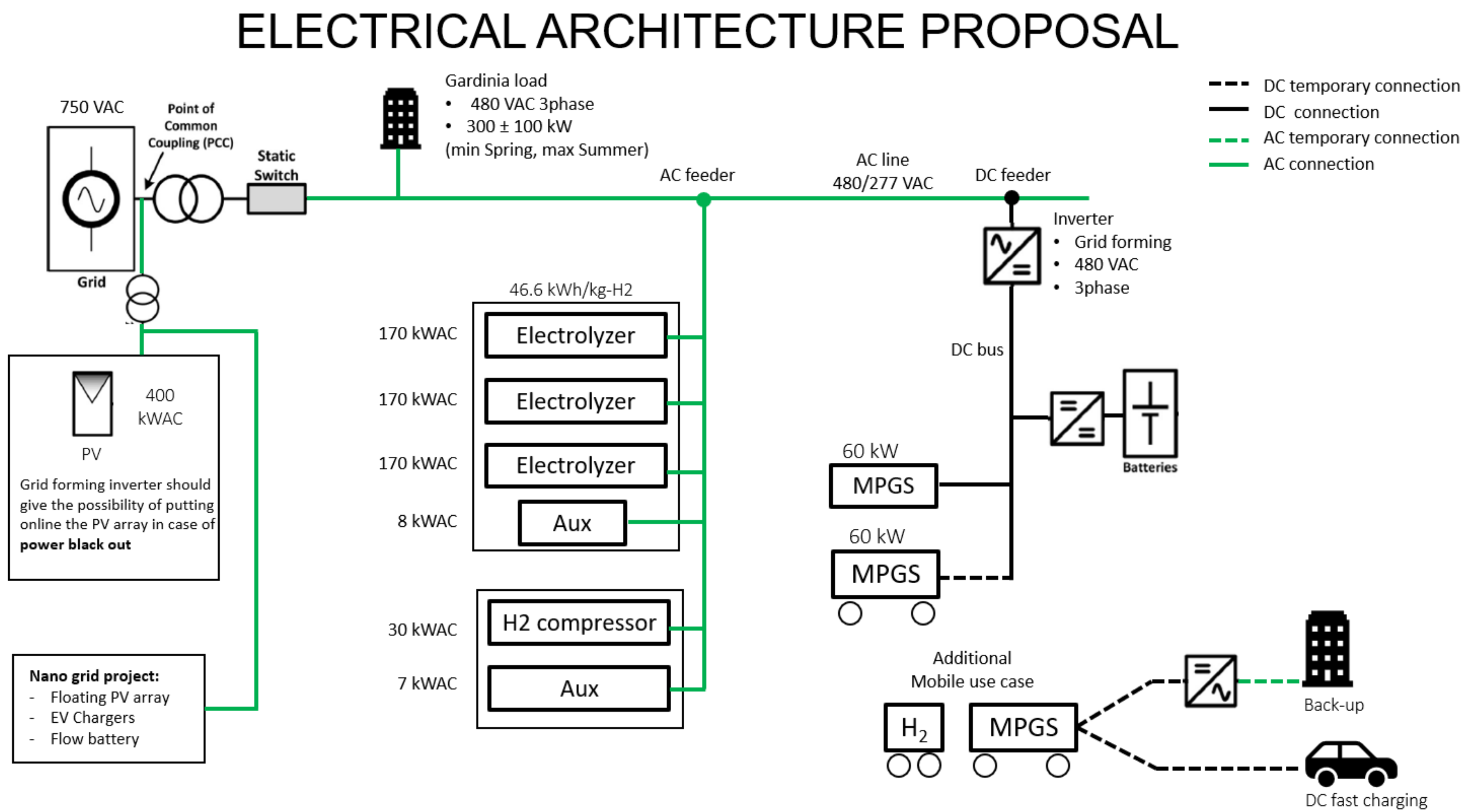
- Stationary and mobile fuel cell units
- Peak output: 200kW peak power (combined)

Hydrogen Storage Dispensing Design

Complete sizing of the storage system to meet hydrogen delivery demands, including vehicular and stationary fuel cell applications

- Equipment for 350 bar Hydrogen Compressor,
- Two (2) Dispensers,
- Two (2) 250 kg storage vessels

Utility Site Architecture Design



Preliminary architecture design at utility site demonstrating hydrogen asset tie-in to OUC grid

Collaborations/Acknowledgements

Giner ELX, Inc. -Monjid Hamdan -Prime	Industry	Electrolyzer system engineering, development, and deployment
Orlando Utilities Commission (OUC) -Justin Kramer -Chanda Durnford --Subcontractor	Utility	Utility Company/Solar Integration/FCEV Fleet
General Motors, LLC. (GM) -Adam King -Subcontractor	Industry	Stationary Fuel Cell Systems/Electrical Generation
OneH2 -Michael Dawson -Subcontractor	Industry	Storage, Dispensing, and Compression
Univ. of Central Florida-Florida/Solar Energy Center (UCF-FSEC) -James Fenton -Subcontractor	Academia	Techno-Economic Analysis: Solar to H_2, Integrated System. Optimization: technical, operational, energy efficiencies, and safety
National Renewable Energy Lab (NREL) -Paige Jadun -Mark Ruth -Bryan Pivovar --Subcontractor	National Lab	Modelling: Modify and update Regional Energy Deployment System (ReEDS). Determine potential for electrolyzer systems to increase the penetration of PV

Department of Energy
DOE Fuel Cell Technologies Office (HFTO)
Solar Energy Technologies Office (SETO)
-Mr. Brian Hunter (GO)
-Dr. Sunita Satyapal

Summary

- **Program Start on 5/01/2020**
  - Initiated Technoeconomic feasibility Studies
    - FSEC
    - NREL-ReEDS
  - Initiated optimization of system designs

Future Plans* (FY2020-21)

- **Complete Techno-economic Feasibility Studies**
  - Demonstration path to achieve <$2/kg.
  - Demonstrate potential for PV-electrolyzer systems to increase the optimal PV penetration in the U.S. and/or reduce the cost to hit a high PV penetration target
- **System**:
  - Complete preliminary design(s), sizing, and optimization of Electrolyzer , Stationary Fuel Cell, Compression, Storage, and Dispensing systems
  - Complete preparation at OUC utility site for integration of hydrogen assets
  - Complete Utility dispatch models and utility control architecture

Future Challenges

- Procurement/delay of FCEV(s)

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