2016 DoE Hydrogen and Fuel Cells Program Review

Validation of an Advanced High Pressure PEM Electrolyzer and Composite Hydrogen Storage, with Data Reporting, for SunHydro Stations

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Overview

Timeline	Targets/Barriers
Project start date: Dec 2012 Project end date: June 2017 Percent complete: 95%	 \$2.00-\$4.00/gge (2007\$) Hydrogen Storage
Budget / Funding	 Codes and Standards
Total spent (3/31/16): \$ 2,679,258 Total project value: \$ 2,810,544 Cost Share Percentage: 50%	 Lack of current H₂ Refueling Infrastructure Performance and Availability Data

Proton's Partners / Collaborators / Interactors

Air Products & Chemicals - Composite Storage / control - <u>Supplier</u> SunHydro LLC - Fueling Stations - <u>Collaborator</u> Toyota Motor Sales - FCHV Vehicles - <u>Interactor</u>



Relevance / Impact		
Target / Barriers	Proton team Project Goals	
\$2.00-\$4.00/gge	 Advanced PEM MEAs: (SH#1) Save Up to 8 kWh/kg H₂ - Ph. 2 Go/No-go > 57 bar H₂, ambient O₂ > In full-scale 65 cell stack, electrolyzer Compared to commercial 30 bar PEM 	
	 Adv. 57 bar PEM water electrolyzer (SH#1) Save up to 3.6 kWh/kg H₂ - Ph. 2 Go/No-go ➢ Reduce H₂ gas drying purge loss ➢ Station mechanical compression to 70MPa Compared to 30 bar H₂ supply 	
Hydrogen Storage	Adv. composite H ₂ storage (SH#1 and #2) Double useable storage per unit volume ≻ Cycle from 28 to 87MPa Compared to first generation storage tubes	



Relevance / Impact			
Target / Barriers	Proton team Project Goals		
Codes and Standards	 Compact Component Arrangements: <i>Fit SH#2 station within 12m ISO container</i> Safety and NFPA 2 code analysis Novel component arrangements Classified, non-classified zones Cooling, power, CSD, H₂ generation <i>Speed AHJ approval, reduce install cost</i> 		
Lack of H ₂ Refueling Infrastructure Performance and Availability Data	 Collect and report SH station performance Validate advanced technologies reliability SunHydro #1 station, SunHydro #2 station Energy use, # fills, kg dispensed, capacity Maintenance type and frequency, issues "%Uptime", any safety or customer issues Up to 24 months of station data 		



Safety Analysis for Novel Component Arrangement



Hazardous Operations Analysis

- Identify process hazards that could lead to safety related consequences
- Recommend ways for reducing risk of events associated with identified hazards
- Covers H2 generation, compression, storage, and dispensing, HVAC, and siting

Code Compliance Matrix

- Diagrams EX zone reduction using codeinformed compact component arrangements
- Implements NFPA 2:2016 revisions
- Utilized for siting containerized fueling station in Washington, D.C.
- Enables means to streamline permitting and reduce installation costs



Novel Component Arrangement

Goal: 12m station package, reliable, maintainable, permitted

- 6m ISO Container (x2)
 - Non-EX container houses electrolyzer, power, and controls
 - EX-rated container houses compression, storage, chilling, and dispensing equipment
- Lightweight 2 hr. firewall allows adjacent placement of EX and non-EX containers





- Individual site summary for Sun Hydro #1 & #2
- Station instrumentation install (retrofit & new)
- Monitor loads and status of each H₂ subsystem
- **Report collected Station data** using H₂ Refueling Station Templates to Hydrogen Secure Data Center at NREL.

Quarterly reports: (>24 months)

H2: kg produced, stored, dispensed, SAE J2719 quality, and costs Energy: kWh/kg for production, compression, dispensing Station reliability, maintenance, service data, and costs Station Safety incidents, near misses and hydrogen leaks

Data Acquisition/Reporting





Accomplishments and Progress

task	Description	Apr 2016 Progress	Expected Completion Date	Percent Complete
1	57 bar High Eff PEM Stack	Lessons learned from scale-up of process have been collected Stack has operated continuously as needed throughout year	2014Q1	100%
2	57 bar 65 kg/d H ₂ Generator	 57 bar upgrade components proof tested and installed 57 bar system operated throughout year to support data collection 57 bar dryer system tuned and optimized for energy savings 	2014Q3	100%
3	Composite Storage	Storage tube qualification completed Tubes delivered, installed, and commissioned Upgraded performance demonstrated	2014Q2	100%
4	57 bar input Compressor	Modifications for selectable input pressure completed Efficiency improvement with higher input pressure demonstrated	2014Q3	100%
5	Safety, Code/ Zone Analysis	State of MA permit issued, DC permit pending	2016Q2	98%
6	Novel Comp. Arrangements	SunHydro#2 design complete – 2X 20ft containers (generation & compression/storage) Container construction complete – installation in DC	2016Q2	98%
7	Data Acquisition System	Data acquisition hardware installed and operating for SH1 Data acquisition hardware installed for SH2 Data collection software changes for SH2 complete	2015Q4	100%
8	Formal Data Reporting	Data for Sun Hydro #1 reported to NREL for each quarter since 2013 Q4. Data for Sun Hydro #2 coincident with installation.	2017Q2	65%



Accomplishments and Progress Response to 2015 Reviewer's Comments

It is not entirely clear how broad the benefit of this project will be, beyond helping one company build two stations.

The project benefits include relative contribution of higher H2 generation pressure in reducing mechanical compression cost, field validation of Type II ground storage cylinders and a compact fueling station design optimized with the latest code compliances, and station data that highlights infrastructure development needs.

It would be good to see a discussion of how the project is supported by, and will support, automakers that are introducing fuel cell vehicles on the East Coast.

There are discussions happening regarding the future commercial use of the SH station in CT. Use of the SH station in DC is scheduled to begin in June 2016.

The project provides little or no detail about station costs.

The station costs include the energy to run the mechanical compressor, the electrolyzer, HVAC equipment, dispensing equipment, and lights and safety equipment, measured in \$/kWh. Costs vary by month based upon station use and uptime with an average of \$7.50/kg



Accomplishments and Progress

CSD Container Complete

Generation Container Complete

- Compression, Storage & Dispensing (CSD) Container complete, including all internal plumbing and wiring
- Received at Proton
- Prepped to ship to DC

- Hydrogen Generation Container complete, including plumbing, ventilation, and power, safety, and control panels
- Built at Proton
- Prepped to ship to DC









Accomplishments and Progress

SH1 Data Acquisition

Adapted reports to incorporate integrated data collecting with APCI

SH1 Data Reporting

- Submitted reports since 2013Q4
- Improving procedures to ensure data reflects true fueling operation with the instrumented H₂ generator
- Showing 4-8 kWh/kg reduction (5-10%)

SH2 Data Acquisition

- Equipment tested and installed
- Data collection scheduled to begin in June 2016

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Data Acquisition/Reporting

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Collaborations

Department of Energy, NREL and NPS - Installation and Operations

• NPS Siting, A&E, Construction, O&M of SunHydro #2 through the NREL Station case study project

SunHydro LLC Fueling Stations

- Owner of SunHydro#1 station in Wallingford CT and SunHydro#2 station in Brentwood Washington DC
- Cost share provider

Toyota Motor Sales - FCHV Vehicles

- Provided FCHV-adv cars used at SH#1
- No cost lease with SunHydro LLC

Air Products & Chemicals – Storage/control

- Supplier of advanced storage, commissioning
- <u>Supplier</u> of programming and dispensing data services

Future Work

Balance Phase 1 Major Activity

2Q'16 SunHydro#2 commissioning

-ACCOMPLISHED-

Phase 2 Major Activity

Ongoing Station data acquisition and reporting

Support NREL Hydrogen Station Case Study Project, provide lesson's learned and potential design improvements for site selection, A&E, construction, and M&O from Proton's perspective.

Project Summary

- <u>*Relevance*</u>: Addresses DoE goal of <\$4/gge, MYPP barriers of H₂ storage, codes, and lack of station performance data
- <u>Approach</u>: Adv. 57bar PEM water electrolyzer, next-generation 87MPa composite storage tanks, and skid-mounted compact refueling component arrangements with SunHydro#1 and SunHydro#2 stations. Data reporting 36+ months for both SunHydro stations with adv. components.
- <u>Tech Accomplishments</u>: 57bar stack and system built and tested; SunHydro#1 and #2 advance storage installed; SH#1 data monitoring and energy measurements ongoing; 8 kWh/kg energy reduction; SunHydro#2 installation
- <u>Collaborations</u>: SunHydro LLC (stations), Toyota Motors (vehicles), APCI (supplier storage upgrade and programming)
- **Future Work : SH#2 install, data reporting for SH#1 and SH#2**

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Technical Back-Up Slides

Fueling Tech Validation Tasks

Proton® C Series PEM Electrolysis Stack

10 Nm³/hr stack for Navy Life Support Application in 2008

- 57 bar H₂ differential pressure
- Over 1 million cell-hrs of validation
- Currently in serial production
- Over 18 months on-board submarines

• Derivative 30 bar version in 2009

- Basis of C-Series 30 Nm³/hr commercial product design
- Over 1.5 Million cell-hrs of customer field experience to date

PEM Electrolysis Life Testing – 'Mature'

*Note: Non-operating time and restarts removed from graph

SunHydro #1 Operations Jan 2011 – Dec 2015

>14,000 kg of hydrogen dispensed>3,600 high pressure H2 fillsServing fleet of 12 FCHV and paratransit

