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

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11 June 2015 4:15 PM

Project ID # TV020

Overview

Timeline

Project start date: Dec 2012
Project end date: June 2017
Percent complete: 87%

Budget / Funding

Total spent (2/28/15): $ 2,471,183
Total project value: $ 2,823,122
Cost Share Percentage: 50%

Targets/Barriers

- $2.00-$4.00/gge (2007$)
- Hydrogen Storage
- Codes and Standards
- Lack of current H_2 Refueling Infrastructure Performance and Availability Data

Proton's Partners / Collaborators / Interactors

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

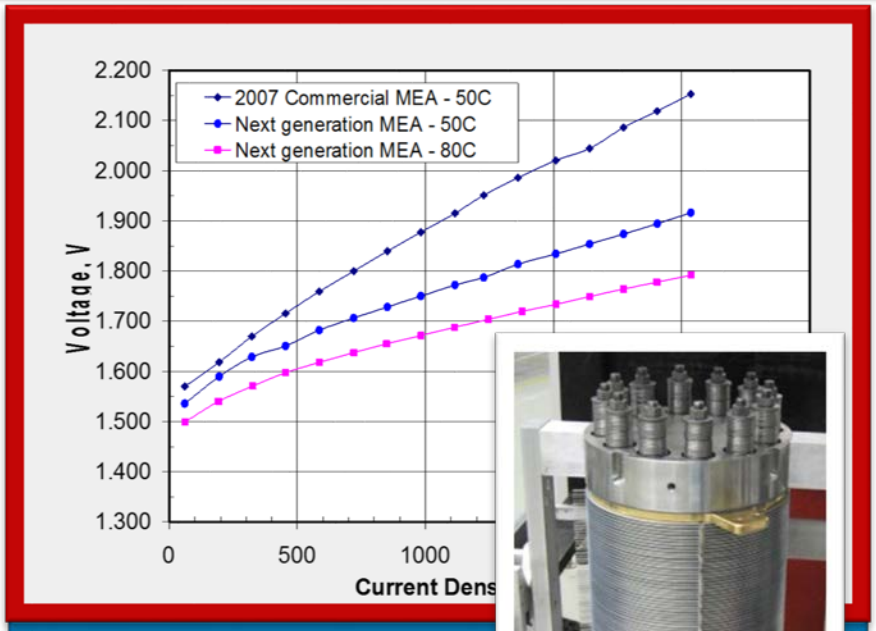
Relevance / Impact

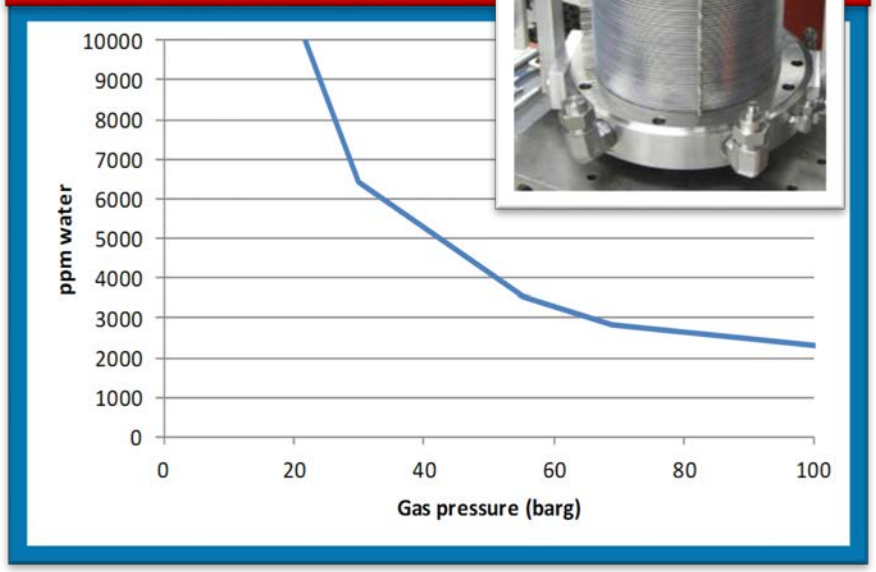
Target / Barriers	Proton team Project Goals
$2.00-$4.00/gge	**Advanced PEM MEAs: (SH#1)** ***Save Up to 8 kWh/kg H_2 - Ph. 2 Go/No-go*** ➢ 57 bar H_2, ambient O_2 ➢ In full-scale 65 cell stack, electrolyzer ***Compared to commercial 30 bar PEM*** **Adv. 57 bar PEM water electrolyzer (SH#1)** ***Save up to 3.6 kWh/kg H_2 - Ph. 2 Go/No-go*** ➢ Reduce H_2 gas drying purge loss ➢ Station mechanical compression to 70MPa ***Compared to 30 bar H_2 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	**<u>Compact Component Arrangements</u>:** ***Fit SH#2 station within 12m ISO container*** ➢ Safety and NFPA 2 code analysis ➢ Novel component arrangements ➢ Classified, non-classified zones ➢ Cooling, power, CSD, H_2 generation ***Speed AHJ approval, reduce install cost***
Lack of H_2 Refueling Infrastructure Performance and Availability Data	**<u>Collect and report SH station performance</u>** ***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***

Approach





57 bar, 65 kg/d H_2 Generator

Build 30 bar baseline generator

Upgrade H_2 gas components

- 30 bar to 57 bar, 1.5x proof

Build adv. full-scale 65-cell stack

- advanced thinner membrane
- advanced electrodes

Validate mechanical integrity

Validate voltage reduction

Make 65 kg H_2/day at 57 bar

***Goal*: 50% less dryer purge loss**

***Goal*: up to 8 kWh/kg H_2 savings**

Approach

Upgrade Compression & Composite Storage

Perform differential compressor comparison

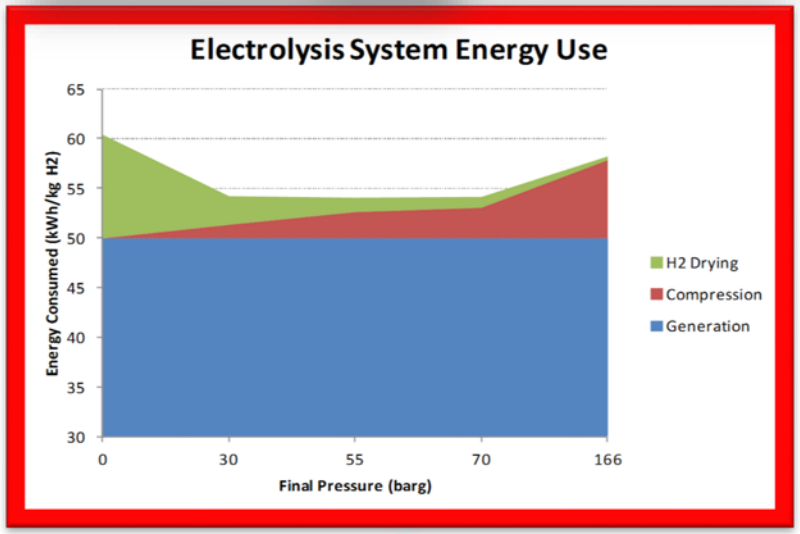
- 57-bar input at SunHydro #1
- 30-bar input at SunHydro #2

Upgrade/new storage systems,

- SunHydro#1 : add 3 new 280 / 870 bar H2 composite storage tubes to 6 existing 630 to 870 bar tanks
- new installation for SunHydro#2

Goal: SH#1 capacity increase

Goal: 2X kg/h increase



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Approach

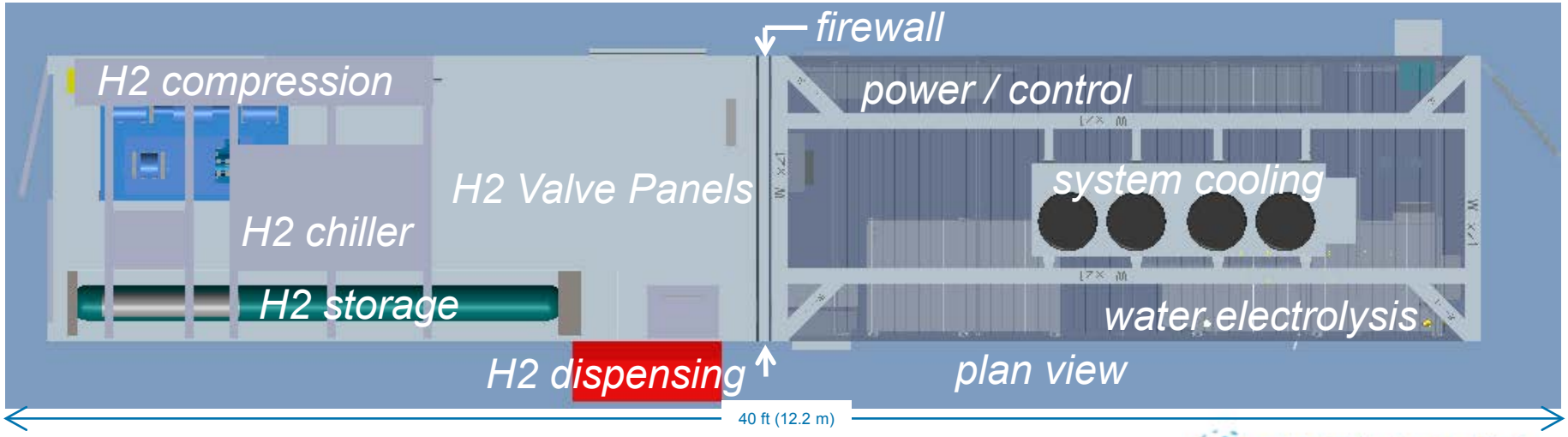
Safety, Code/ Zone Analysis

- Review/update hazard evaluations for station upgrades
- Author safety operations plan
- Diagram EX zone reduction using code-informed compact component arrangements
- Participate in NFPA 2 revisions

Novel Comp. Arrangements

- Non-EX electrolyzer adjacent to EX-rated CSD, in 12m ISO container
- Lightweight 2 h firewalls to demise
- Power, control, thermal in non-EX

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



Approach

Individual site summary for Sun Hydro #1 & #2

Station instrumentation install (retrofit & new)

Monitor loads and status of each H_2 subsystem

Report collected Station data using H_2 Refueling Station Templates to Hydrogen Secure Data Center at NREL.

Data Acquisition/Reporting

Quarterly reports: (24 months)

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

Accomplishments and Progress

task	Description	Apr 2015 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	*Continued involvement in NFPA 2 and ISO 19880-1* *Local AHJ and State of MA engaged and working permitting*	*2015Q2*	*90%*
6	Novel Comp. Arrangements	*SunHydro#2 design complete – 2X 20ft containers (generation & compression/storage)* *Construction underway – container received, generator manufactured, CSD completed and received*	*2015Q2*	*80%*
7	Data Acquisition System	*Data acquisition hardware installed and operating for SH1* *Data acquisition hardware prep'd for SH2* *Data collection software changes for SH2 complete*	*2015Q2*	*75%*
8	Formal Data Reporting	*Data for Sun Hydro #1 reported to NREL for each quarter since 2013 Q4.*	*2016Q2*	*35%*

Accomplishments and Progress

Response to 2014 Reviewer's Comments

Concern about unplanned releases of hydrogen with a containerized high pressure hydrogen storage system.

The container for the hydrogen storage is open at the top.

Known for sometime that voltage reduction target was a challenge, yet I did not hear any information on any new approaches to address this issue.

As a tech val project, this scope included the first ever scale-up of one new advanced MEA fabrication process. A number of parallel paths are being pursued that simultaneously achieve MEA cost reduction and performance improvement.

The late arrival of the cylinders, the slow spend rate and the less than transparent progress on permitting serve as flags that some critical potential show stoppers need to be addressed.

The storage tubes were highly advanced and required materials and fabrication qualification concurrent with the project, including an iterative procurement and qualification schedule. Spending has caught up due to major equipment arrivals. Permitting process proceeding through local and state of MA authorities.

It would be helpful to have adequate data for the total energy consumption kWh/kg H_2 of SunHydro1.

The watt-meters and data acquisition part of this project are focused on determining just that. More information on slide 14.

Accomplishments and Progress

57 bar, 65 kg/d H_2 Generator

Operating 30-bar generator

Upgraded 57-bar H_2 components

- Passed hydro proof test
- Installed and operational
- Dryer purge reduced 45% (3.2 kWh/kg)

Built adv. full-scale 65 cell stack

- 1st scale-up achieved cost reduction, stable voltage (0.5 kWh/kg)
- Later work resolved fabrication issue on larger platform cell (3.5 kWh/kg reduction)

Accomplishments and Progress

Upgrade Compression & Composite Storage

Upgrade/new storage systems

- 6 new 280/870 bar storage tubes received (3 for SH1, 3 for SH2)
- SH1 tubes commissioned June 2014
- Demonstrated 5 consecutive vehicle fills

Compressor Design

- Compressor controller software modified to allow 30-bar / 55-bar selectable
- Measured efficiency improvement due to stack EC compression limited by non-optimal buffer tank
- Buffer tank optimization increases stack improvement to 5 kWh/kg

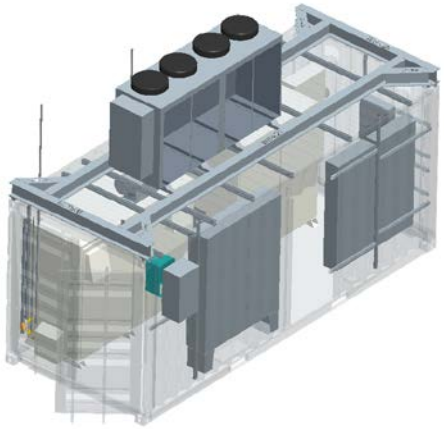
Accomplishments and Progress

CSD Container Complete

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

Generation Container Progress

- Container fabrication and modifications complete
- Insulation, fire barriers, bulkheads, and mounting unistrut installed
- All major and minor components allocated, purchased and ready for integration



Accomplishments and Progress

SH1 Data Acquisition

- Local data monitoring transitioned to integrated data collecting with APCI compressor upgrade
- Adapting reports to incorporate integrated data approach

SH1 Data Reporting

- Submitted reports since 2013Q4
- Improving procedures to ensure data reflects true fueling operation with the instrumented H_2 generator
- Showing 4-8 kWh/kg reduction (5-10%)

SH2 Data Acquisition

- Equipment tested, awaiting integration during SH2 construction

Data Acquisition/Reporting

Individual Site Summary

Item	Data	Units
Data last updated	12/31/2013	m/d/yyyy
Person and/or company responsible for Data	Proton OnSite	name
General Station Information		
Energy Provider	Proton OnSite (PV); Wallingford Electric (grid)	
Site Owner	SunHydro LLC Tom Sullivan	
Unique Station Identifier	SunHydro#1	
Location	Wallingford, CT	City, State
GPS Lat	41.49217	degrees
GPS Lon	-72.76083	degrees
Ground Breaking Date	7/1/2010	m/d/yyyy
First Public Fueling Date	10/15/2010	m/d/yyyy
Still in Operation (Yes, No)	Yes	
Final date of Site Operation		m/d/yyyy
Process Flow Diagram	See SunHydro#1 Process Diagram	
(Production, Refueling, Both Production & Refueling, Co-Production (H2 & Electricity - No Refueling), Co-Production (H2 & Electricity - With Refueling)	Production and Refueling	
Production Method (Reformation, Electrolysis)	Electrolysis	
Production (if applicable)		
Reformer Manufacturer		
Reformation Method		
Feedstock (for Reformation)		
Electrolyzer Type (PEM, Alkaline, etc.)	PEM	
Electrolyzer Manufacturer	Proton OnSite	
Electrolyzer Size	200	kW
Electricity Source (if Electrolysis; e.g., Grid, PV, Wind, Hydro, etc.)	Grid and PV	
Design Production Capacity	2.7	kg H2/hour
Intended Production Daily Operation	24	hours/day
Design Electrical Production Capacity		kW
Output Pressure	30	bar
Compressing and Dispensing		
Compressor type(s), manufacturer(s) and rated pressure(s)	2 stage oil-free piston, Hydro-Pac, 870	type, mfg, bar
Dispensing Capacity per day	65	kg H2/day
Peak Performance Dispensing Capacity per hour	15	kg H2/hour
Method of Precooling	Chiller	Description
Precooling type and temperature	T-20 (-20)	type (deg C)
Number of Dispensers and Type	SAE TIR 2601, H70-T-20, H35 Tank	#-type
Storage		
onsite storage capacity (gaseous)	90	kg
onsite storage capacity (liquid)		kg
1. number of tanks, pressure and capacity	3, 870bar, 45kg (pending upgrade to 135kg)	#, bar, kg
1. tank description	Steel/CF composite	
2. number of tanks, pressure and capacity	2, 870bar, 30kg	#, bar, kg
2. tank description	Steel/CF composite	
3. number of tanks, pressure and capacity	2, 870bar, 30kg	#, bar, kg
3. tank description	Steel/CF composite	
4. number of tanks, pressure and capacity	2, 870bar, 30kg	#, bar, kg
4. tank description	Steel/CF composite	
Other Information		
Survivability (Max Temp, Min Temp)	50, -20	degrees C
Hydrogen Infrastructure Footprint (excluding dispenser)	640	sq feet
Permanent H2 Storage Footprint	64	sq feet
Removable H2 Storage Footprint (example: Trailer)		sq feet
Design Period	120	days
Permit Period	90	days
Construction Period	150	days
Commissioning Period	30	days
Additional information		

igure 1. SunHydro #1 Compression, Storage, Dispensing Containerized Sy

Figure 2. Hydrogen from Proton System Test Facility

Figure 3. Compression and Storage, SunHydro #1

Figure 4. Cold Block and Chiller enable H70 Fast Fill

Collaborations

SunHydro LLC - *Fueling Stations*

- *Owner of SunHydro#1 station in Wallingford CT and SunHydro#2 station in Braintree MA*
- *Cost share provider*

Toyota Motor Sales - *FCHV Vehicles*

- *Provides 12 FCHV-adv cars used at SH#1 and #2*
- *No cost lease with SunHydro LLC*

Air Products & Chemicals – *Storage/control*

- *Supplier of advanced storage, commissioning*
- *Supplier of programming and dispensing data services*

Future Work

Balance Phase 1 Major Activity

2-3Q SunHydro#2 build-out, installation, commissioning

Phase 2 Major Activity

Ongoing Station data acquisition and reporting

Project Summary

Relevance: **Addresses DoE goal of <$4/gge, MYPP barriers of H_2 storage, codes, and lack of station performance data**

Approach: **Validate H_2 fueling infrastructure performance gains of an adv. 57bar PEM water electrolyzer, next-generation 87MPa composite storage tanks, and skid-mounted compact refueling component arrangements with an updated SunHydro#1 station and a fully containerized SunHydro#2 station. Data reporting to 24 months for both SunHydro stations with adv. components.**

Tech Accomplishments: **57bar stack and system built and tested; SunHydro#1 and #2 advance storage received; SH#2 designed and fabrication well underway; SH#1 data monitoring and energy measurements ongoing; 8 kWh/kg energy reduction**

Collaborations: **SunHydro LLC** (stations), **Toyota Motors** (vehicles), **APCI** (supplier storage upgrade and programming)

Future Work : **Calculations on buffer tank sizing, SH#2 install, continue data monitoring for SH#1 and SH#2**

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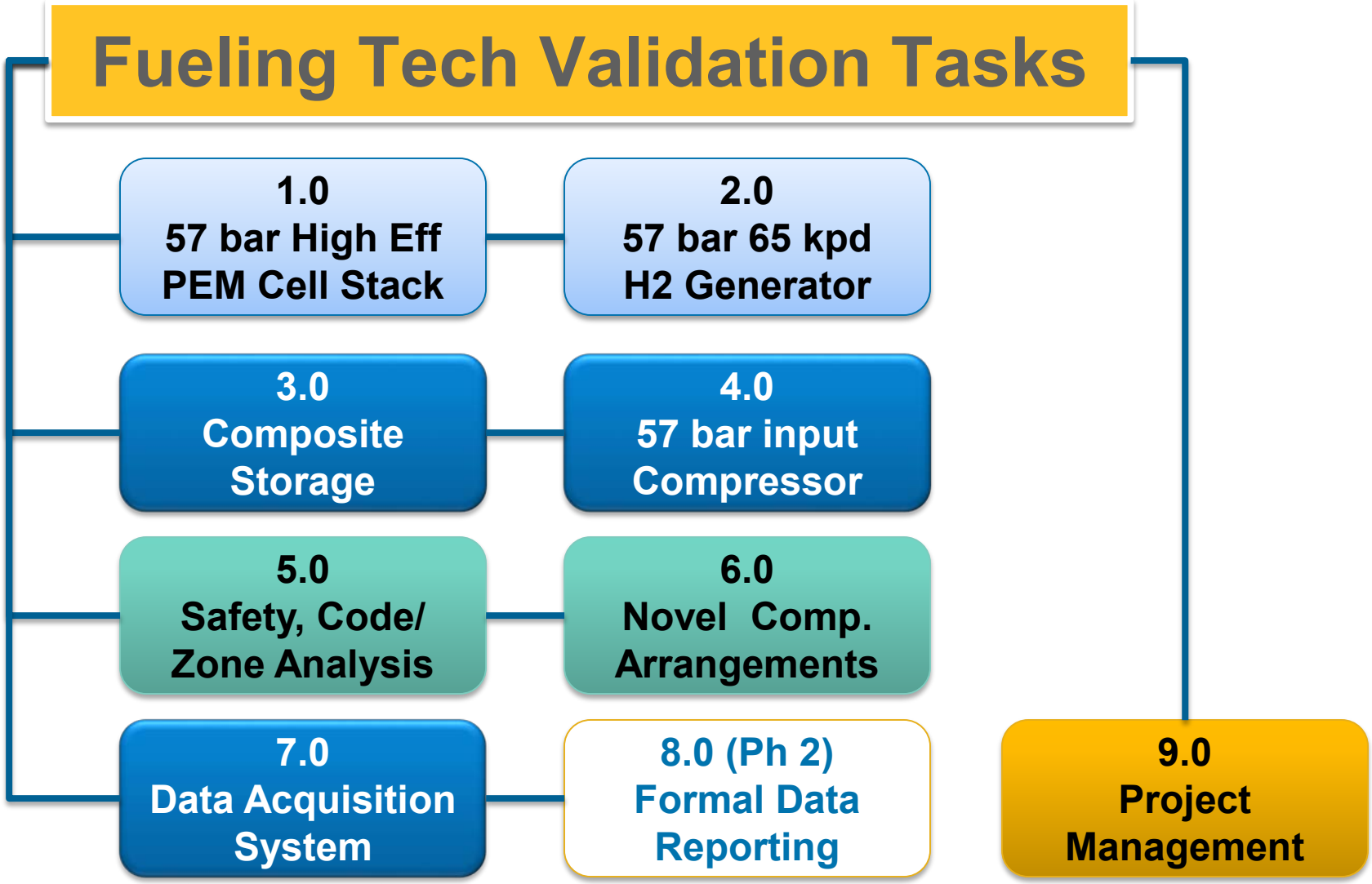
Technical Back-Up Slides

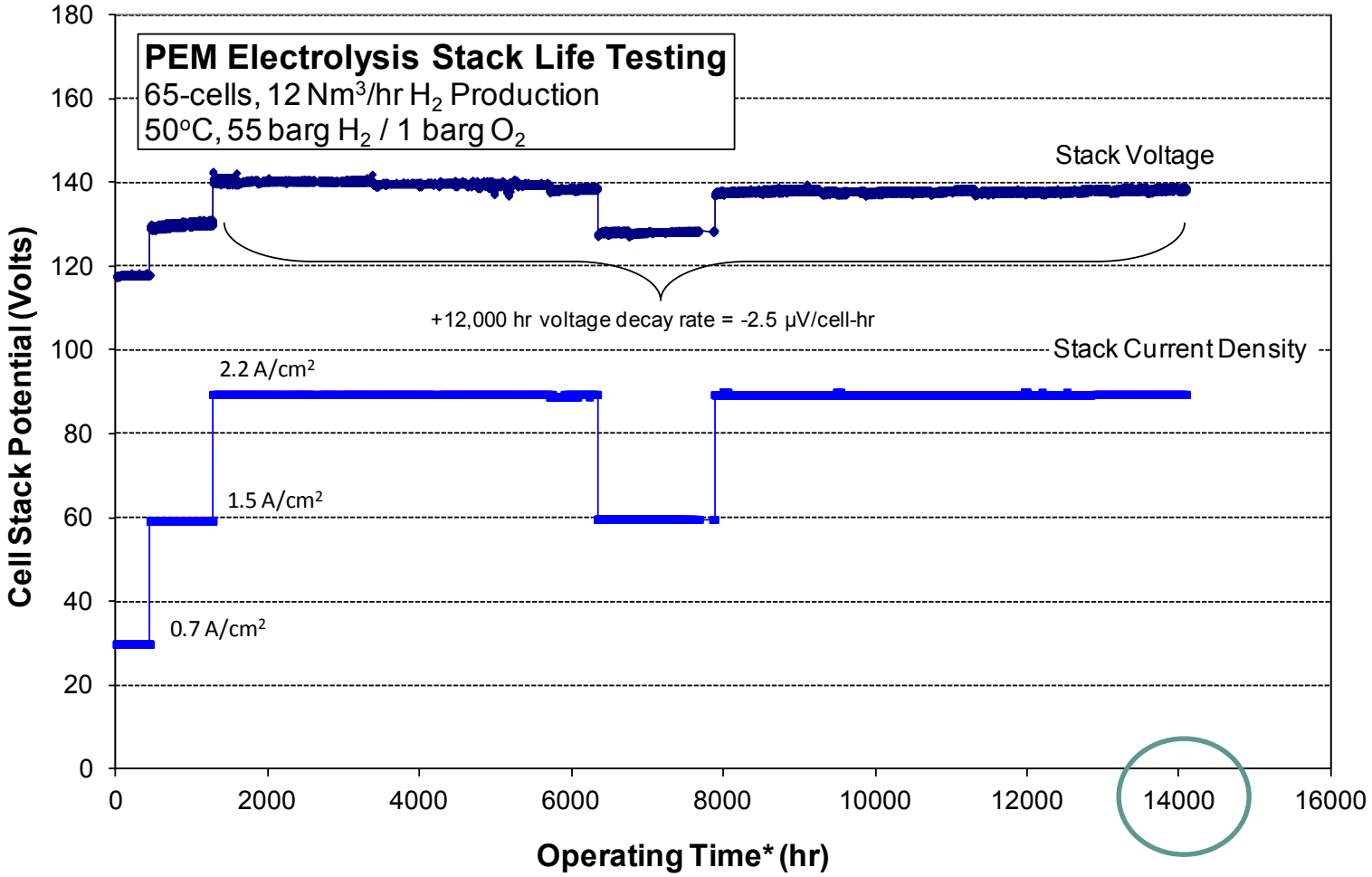
Approach


Fueling Tech Validation Tasks
1.0
57 bar High Eff
PEM Cell Stack
2.0
57 bar 65 kpd
H2 Generator
3.0
Composite
Storage
4.0
57 bar input
Compressor
5.0
Safety, Code/
Zone Analysis
6.0
Novel Comp.
Arrangements
7.0
Data Acquisition
System
8.0 (Ph 2)
Formal Data
Reporting
9.0
Project
Management

Proton® C Series PEM Electrolysis Stack

- **10 Nm^3/hr stack for Navy Life Support Application in 2008**
  - 57 bar H_2 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 Nm^3/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

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SunHydro #1 Operations

Jan 2011 – Dec 2014

>10,000 kg of hydrogen dispensed

>3,500 high pressure H2 fills

Serving fleet of 12 FCHV and paratransit

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SunHydro #1 Diagram

A. 75 kW photovoltaic array
B. Net metering / grid connection
C. 65 kg/d H_2 Generation from H_2O
D. 30 hp / 87MPa H_2 Compression
E. 135 kg H_2 Storage @ 83 MPa
F. H35-Tamb / H70-T-20 Dispensers