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

Larry Moulthrop

Principle Investigator

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Crystal City Marriott

Project ID # TV020

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Overview

Timeline

***Project start date*: Dec 2012**
***Project end date*: Sep 2015**
***Percent complete*: 12%**

Budget / Funding

$ 1,400,000 total DoE share

$ 1,420,397 total cost share

***FY12 Funding* : $ 0**

***FY13 Funding* : $1,196,763**

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*

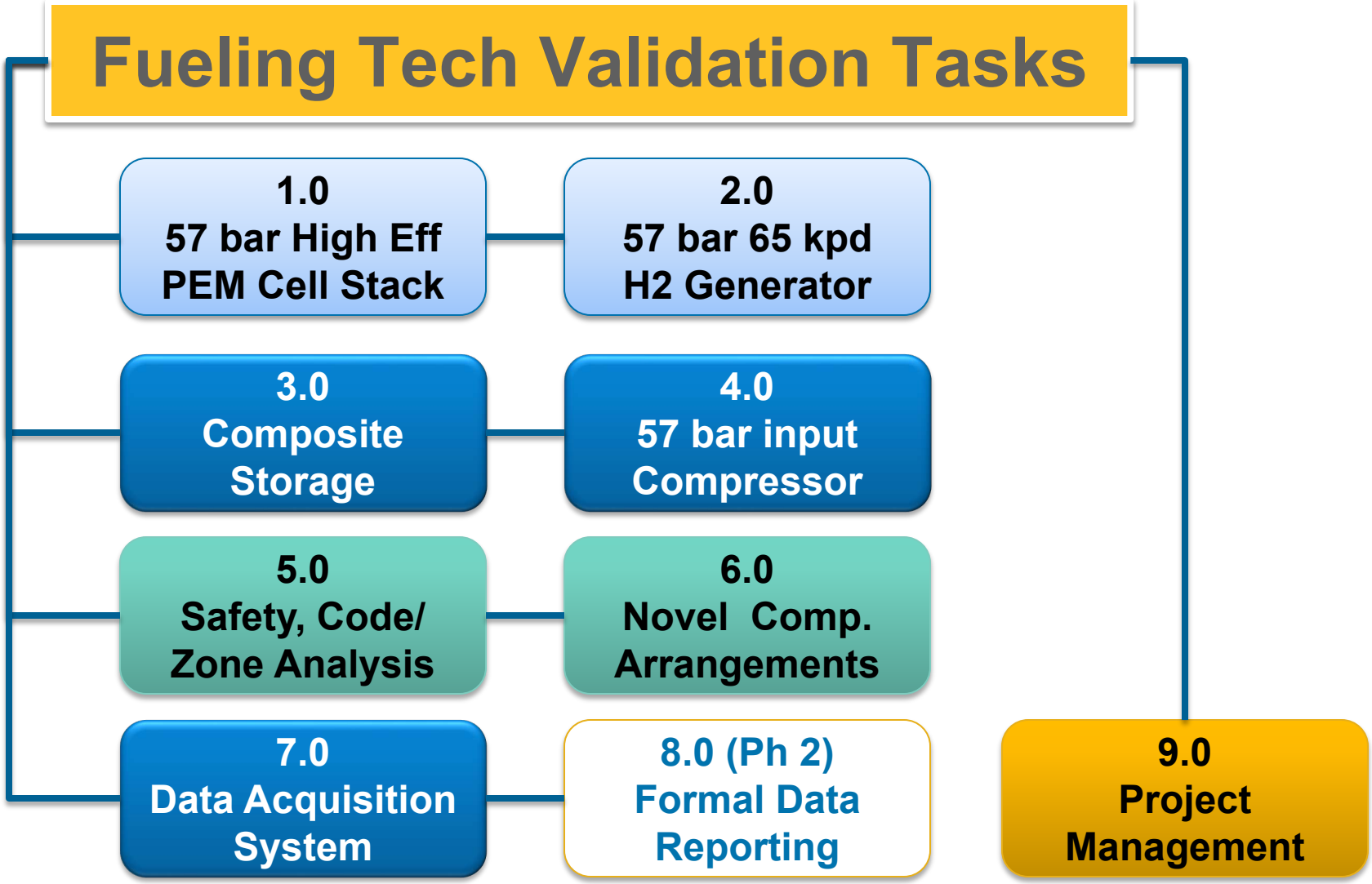
Relevance

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*** ➢ H_2 gas drying purge loss ➢ Station mechanical compression to 70MPa ***Compared to 30 bar H_2 supply***
Hydrogen Storage	**Adv. composite H2 storage (SH#1 and #2)** ***Double useable storage per unit volume*** ➢ Cycle from 28 to 87MPa ***Compared to first generation storage tubes***

Relevance

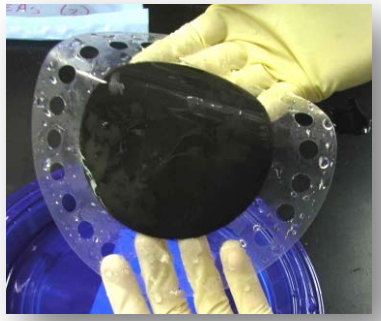
Target / Barriers	Proton team Project Goals
Codes and Standards	**<u>Compact Component Arrangements</u>:** ***Fit SH#2 station within 12m ISO container*** ➢ Safety and NFPA 2 code analysis ➢ Novel component arrangements ➢ Classified, non-classified zones ➢ Cooling, power, CSD, H_2 generation ***Speed 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***

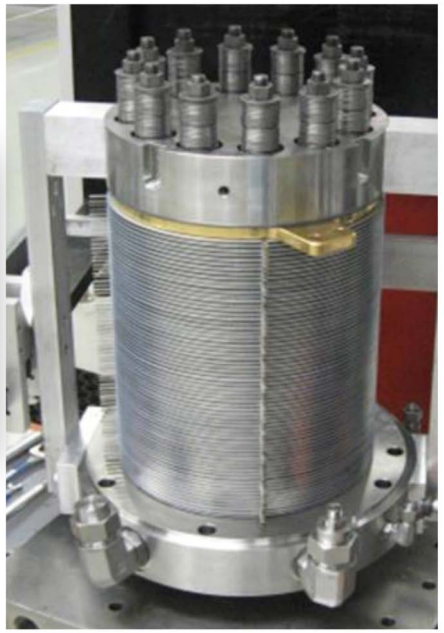
Approach


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

Approach

1.0
57 bar High Eff PEM Cell Stack





Build adv. full-scale 65 cell stack

- advanced thinner PEM membrane
- advanced screened electrodes
- 57 bar mechanical design - latest production methods (from subscale)

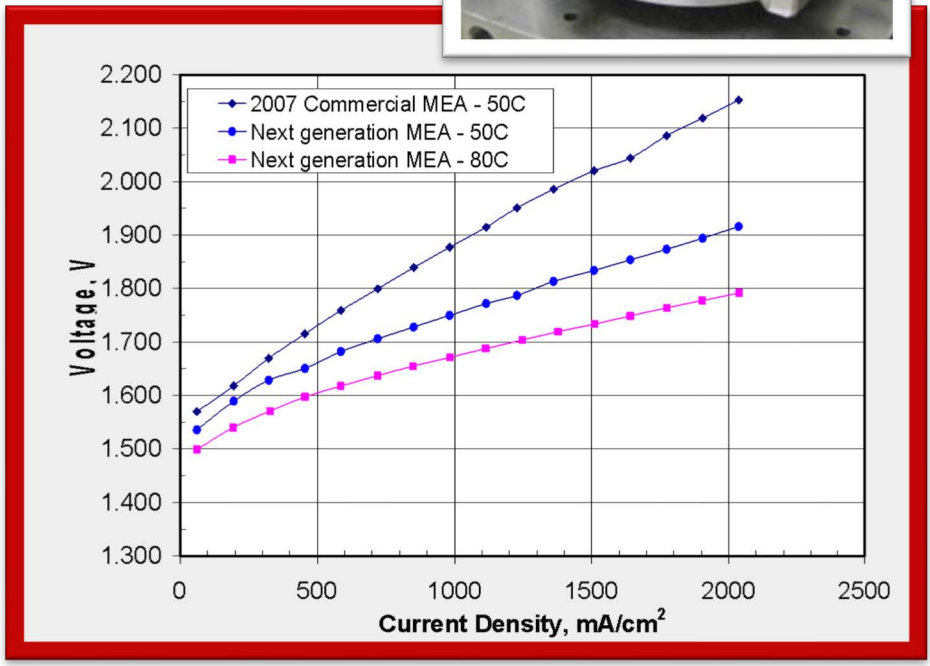
Validate mechanical integrity

- 57 bar H_2 operating; 1.5x proof

Validate voltage reduction

- < 2.1, goal of 1.85 v/cell

***Goal*: up to 8 kWh/kg H_2 savings vs. 30 bar commercial model**



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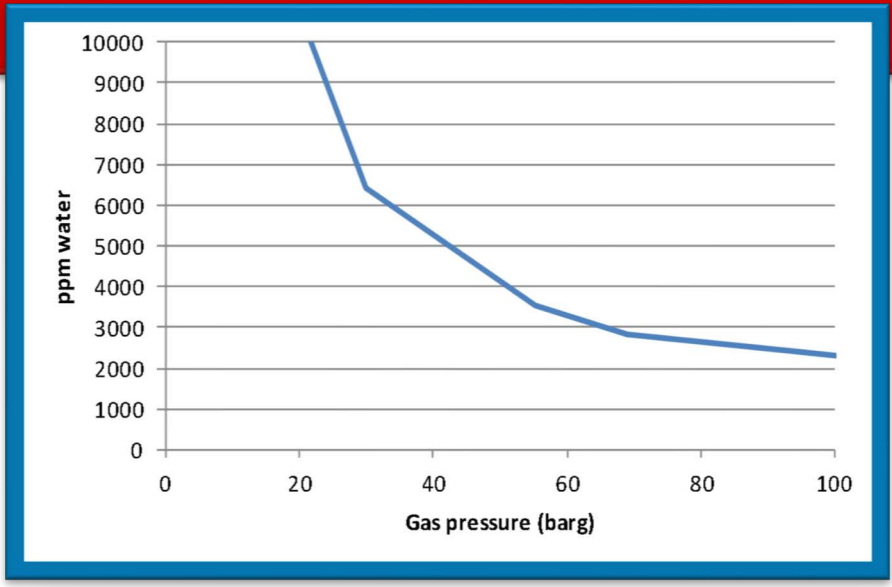
Approach



2.0
57 bar, 65 kg/d H2 Generator

Build 30 bar baseline generator

- At SunHydro #1

Upgrade H2 gas components

- 30 bar to 57 bar, 1.5x proof

Make 65 kg H2/day at 57 bar

- Three (3) 57 bar cell stacks
  - Advanced cell stack
  - Two older 57 bar stacks

***Goal*: Approach 50% less purge loss* with 57 bar generation vs. 30 bar operation**

* *Swing bed regeneration*

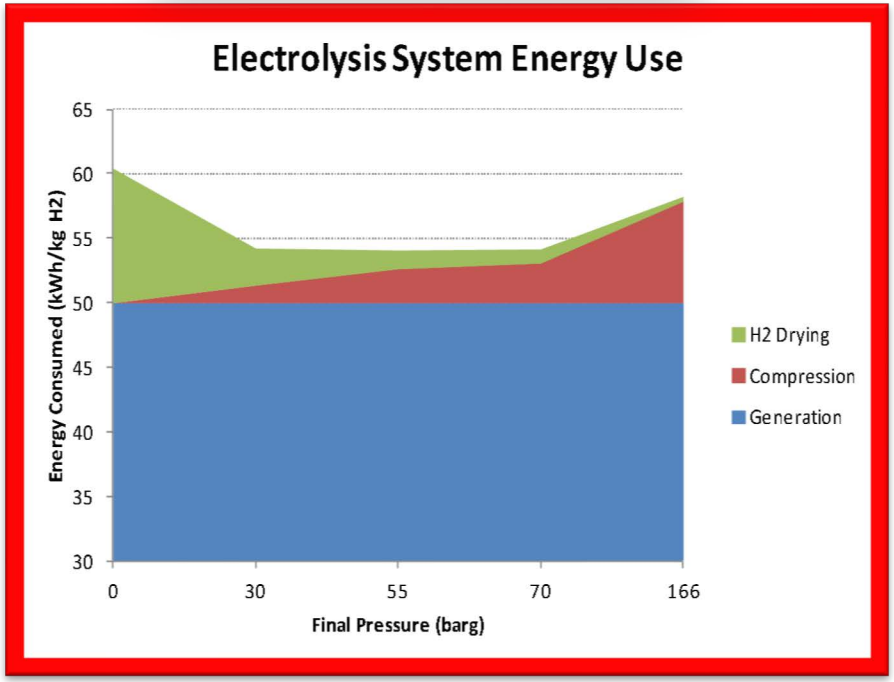
Approach

3.0 Composite Storage

- **Upgrade/new storage systems, SunHydro#1 and #2**
  - 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
- **Validate 280 - 870 bar operation,SunHydro#1 and #2**

Goal*: *SunHydro#1 dispensing capacity increase ~16 kg/hr to about 30 kg/hr, with only 50% increase in tubes

Approach



4.0
57 bar input Compressor

Perform differential compressor comparison

- Adjust SunHydro#1 compressor to accept 57 bar input
- 57 bar input to 30 bar on SunHydro#1 and #2

***Goal*: kWh/kg reduction**

***Goal*: kg/h increase**

SunHydro#1 mechanical compressor can accept input from 21 to 57 bar, while SunHydro#2 is a 30 bar input model

Approach

5.0 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

6.0 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

- Survey station information
- Dimensional layout, simple process flow diagram

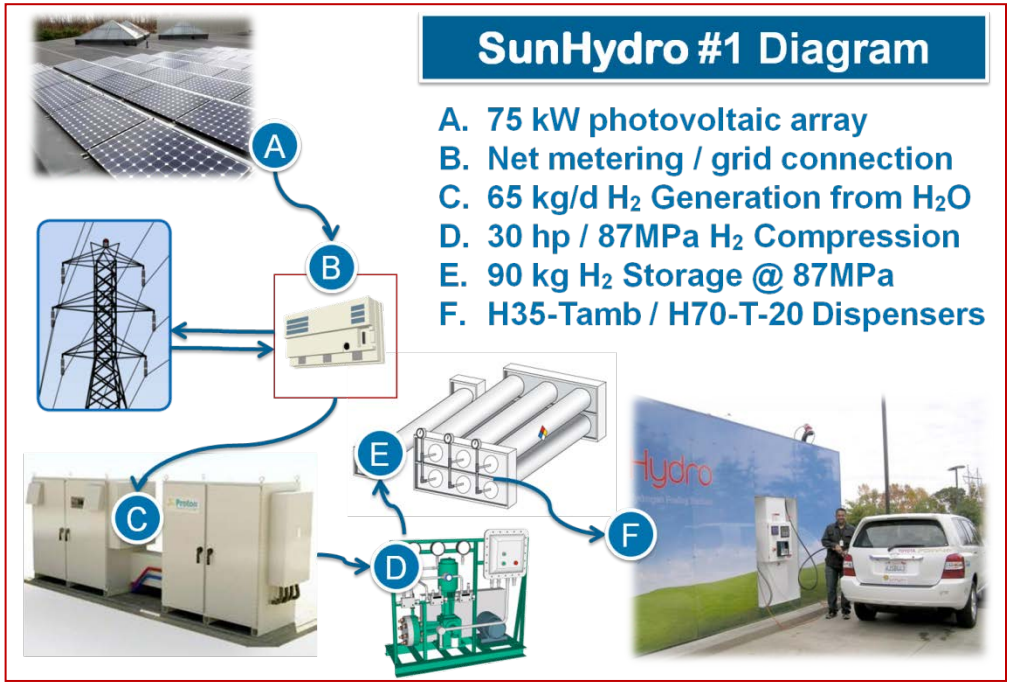
Data collection plan

- Existing data acquisition – identify gaps
- Modifications and additions

Station instrumentation install, SH#1, SH#2

- Monitor specific loads and operational status of each H_2 production, compression, storage, dispensing subsystem

7.0
Data Acquisition System



Approach

8.0 (Phase 2)
Formal Data Reporting

Report collected SH#1 and #2 Station data using H_2 Refueling Station Templates to Hydrogen Secure Data Center at NREL.

Quarterly reports: (up to 24 months)

- H_2 : 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

SunHydro #1
- 2010 -
SunHydro
SunHydro
FUEL CELL
F-CELL
SunHydro
SunHydro
Solar Powered Hydrogen Fueling Stations
SunHydro #2
-2013-

Accomplishments and Progress

task	Description	Mar 2013 Progress
1	57 bar High Eff PEM Stack	*Materials ordered for Aug 2013 assembly* *New MEA Tooling ordered*
2	57 bar 65 kg/d H_2 Generator	*Baseline Generator built* *57 bar upgrade in process*
3	Composite Storage	*Storage ordered for Sep 2013 commissioning* *Construction planning underway*
4	57 bar input Compressor	*Compressor design confirmed for 57 bar*

- Long lead materials and services ordered
- Build, test during 2Q,3Q 2013

Accomplishments and Progress

task	Description	Mar 2013 Progress
5	Safety, Code/ Zone Analysis	*NFPA 2 revisions underway*
6	Novel Comp. Arrangements	*Design in process for SunHydro#2 arrangements*
7	Data Acquisition System	*Data survey , simple diagram* *Ordered software changes to stations*
8	Formal Data Reporting	*Contingent on Phase 2 Go/No Go* *Expect data activity to start in 3Q*

- Station analysis and novel design underway
- Data Acquisition planning underway
- Anticipate Go/No-go Phase 2 in 3Q

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 10 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

2Q	**Adv. Cell stack MEA tooling testing**
2Q	**Modifications for 57 bar to baseline Generator**
3Q	**Advanced PEM stack build, test ***
3Q	**57 bar PEM water electrolyzer build, test ***
2-3Q	**Station analysis and novel design**
2-3Q	**Data Acquisition design and installation**
3-4Q	**SunHydro#1 storage commission, compressor test**
3-4Q	**SunHydro#2 arrangements, permitted, commissioned**

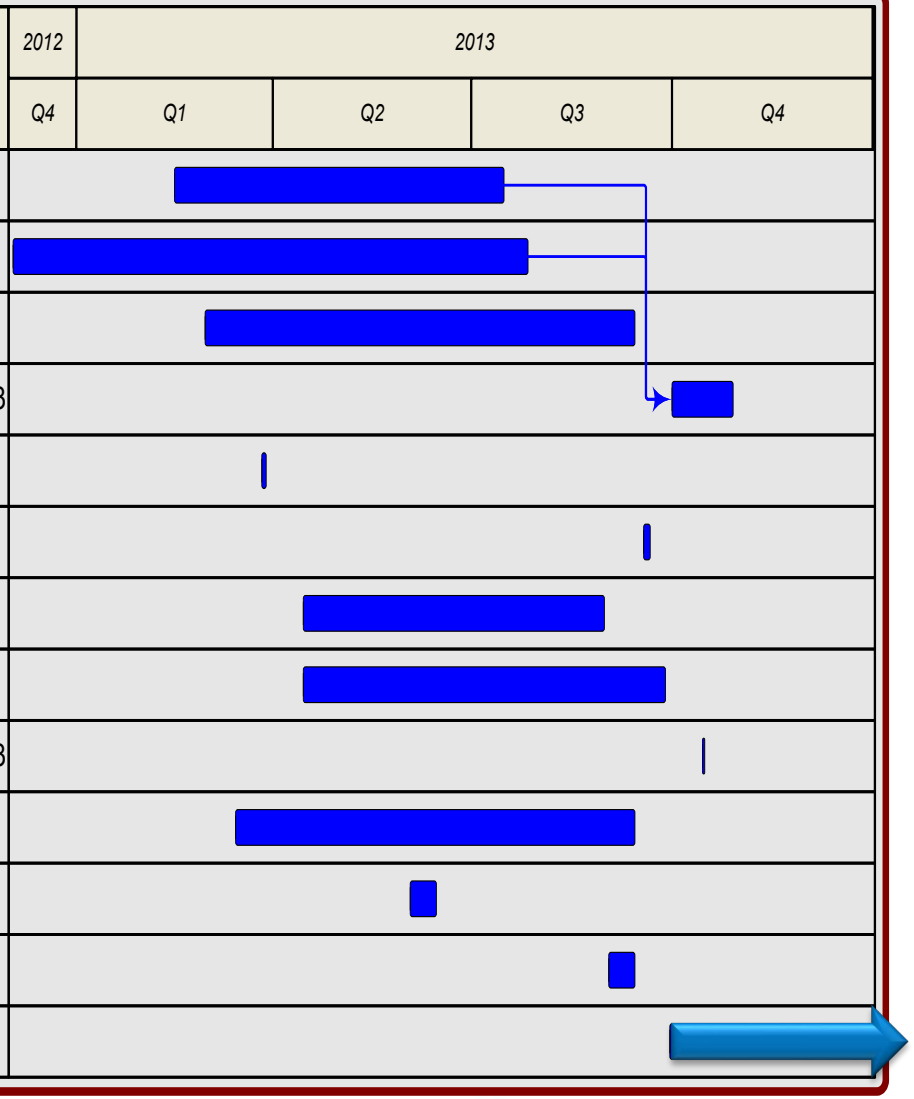
**Adv stack, 57 bar system eff. Go/No-go Phase 2*

Phase 2 Major Activity

4Q-1Q, onward **Station Data Acquisition**

Technical Task Schedule

ID	Task Name	Start	Finish
1	1.0 Adv. 57bar Stack V&V	2/15/2013	7/15/2013
2	2.0 Electrolyzer 57bar 65kpd V&V	12/3/2012	7/26/2013
3	3.0 Composite storage V&V	3/1/2013	9/13/2013
4	4.0 Compressor Eff./Throughput 57bar	10/1/2013	10/28/2013
5	*Order Composite storage*	3/27/2013	3/28/2013
6	*Commission Upgraded SH#1*	9/18/2013	9/20/2013
7	5.0 Safety Code/Zone Analysis	4/15/2013	8/30/2013
8	6.0 Novel Component Arrangements	4/15/2013	9/27/2013
9	*Commission SH#2*	10/15/2013	10/15/2013
10	7.0 Data Acquisition Design/Install	3/15/2013	9/13/2013
11	*SH#1 DAQ install and test*	6/3/2013	6/14/2013
12	*SH#2 DAQ install and test*	9/2/2013	9/13/2013
13	8.0 Formal Station Data Reporting	9/30/2013	9/30/2015



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 both SunHydro stations with adv. components.**

Tech Accomplishments: **Baseline PEM electrolyzer built; cell stack long lead items ordered; SunHydro#1 and #2 advance storage ordered; SH#2 arrangements underway; SH#1 diagrammed**

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

Future Work : **Perform adv. PEM stack build and test; 57bar electrolyzer upgrade, SH#1 storage upgrade, compressor test, SH#2 arrangement, data plan/instrumentation, data reports**

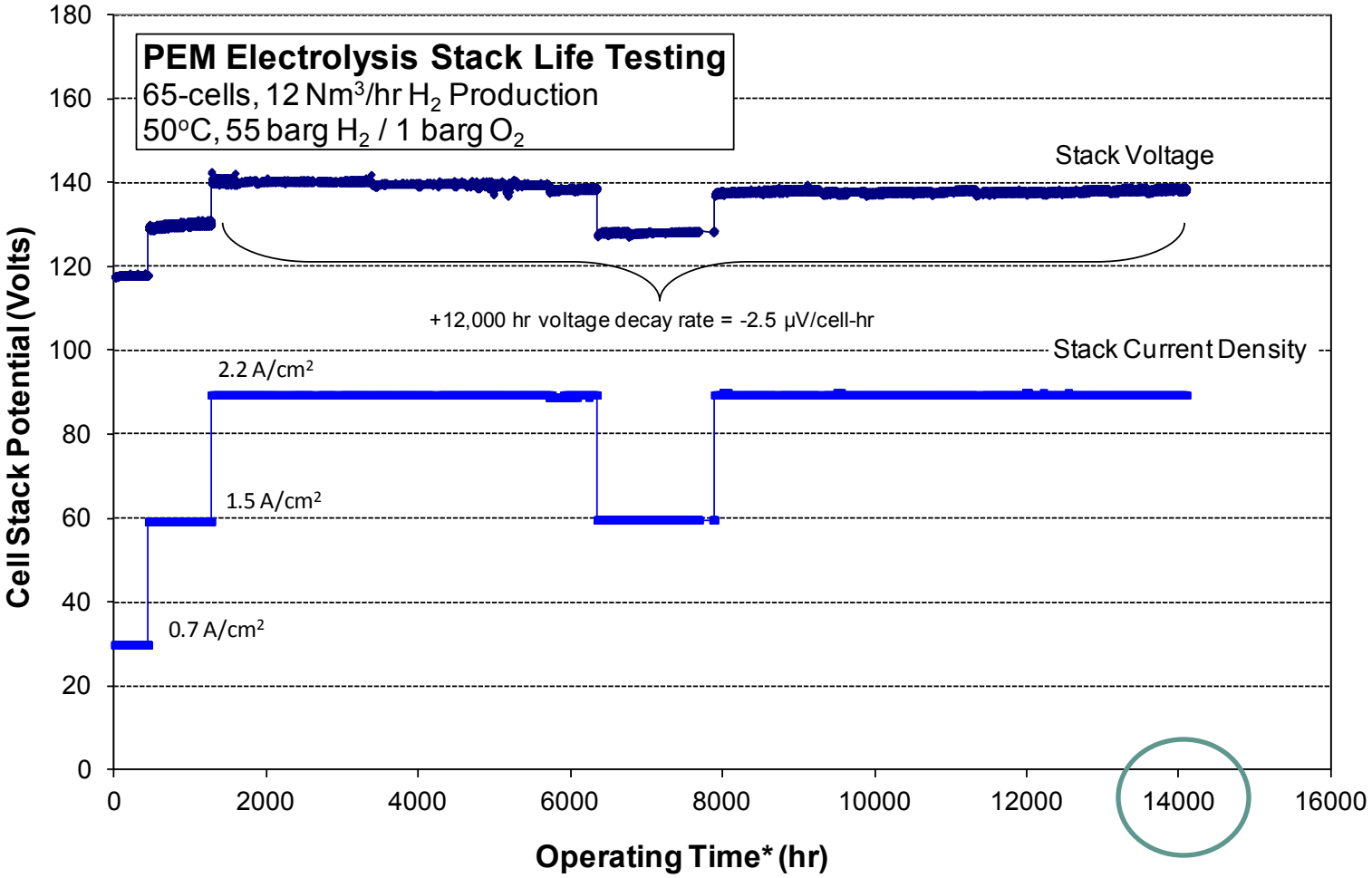
Larry Moulthrop 203-678-2188 LMoulthrop@ Proton OnSite.com

Technical Back-Up Slides

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

SunHydro #1 Operations

Jan 2011 – Mar 2013

~5800 kg of hydrogen dispensed

~1500 high pressure H2 fills

Serving fleet of 10 FCHV and paratransit

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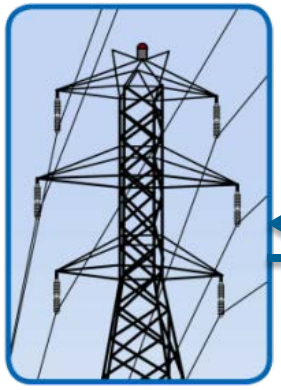
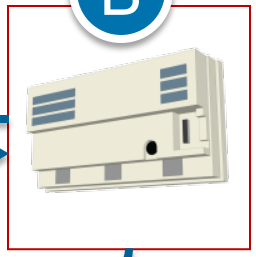
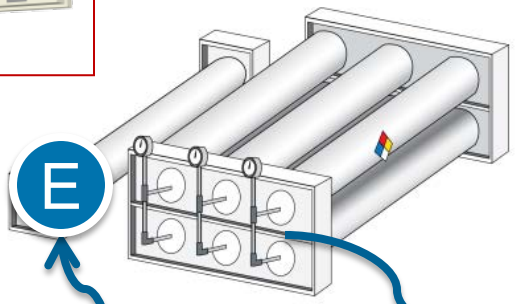
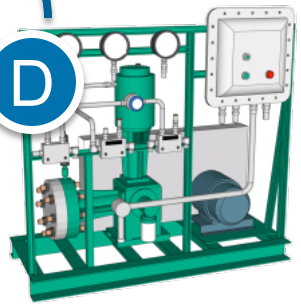
SunHydro #1 Diagram

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. 90 kg H_2 Storage @ 87MPa
F. H35-Tamb / H70-T-20 Dispensers









SunHydro #2 Package Concept

- Total system in site-ready shipping container
- Aids serial manufacture, ease of deployment

***Challenge**: meet Code electrical clearances and performance with compact, practical arrangement*

***Plan**: SunHydro commissions station Fall 2013*