2014 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

### Larry Moulthrop

Principle Investigator



19 June 2014 1:45:00 PM



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

## **Overview**

Targets/Barriers
<ul> <li>\$2.00-\$4.00/gge (2007\$)</li> <li>Hydrogen Storage</li> </ul>
<ul> <li>Codes and Standards</li> </ul>
<ul> <li>Lack of current H<sub>2</sub> Refueling Infrastructure Performance and Availability Data</li> </ul>

#### **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>

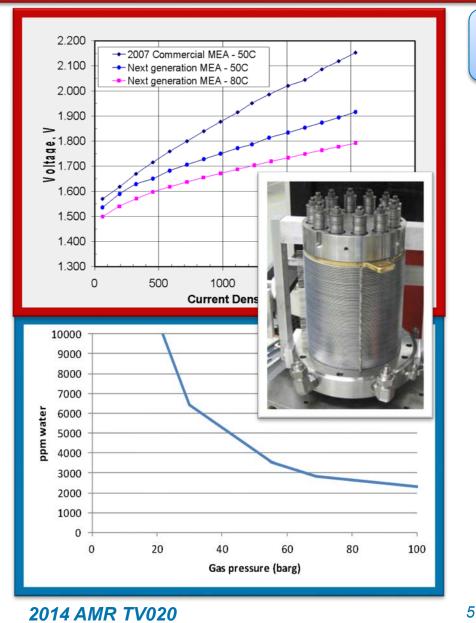


Relevance / Impact				
<b>Target / Barriers</b>	Proton team Project Goals			
\$2.00-\$4.00/gge	<ul> <li>Advanced PEM MEAs: (SH#1)</li> <li>Save Up to 8 kWh/kg H₂ - Ph. 2 Go/No-go</li> <li>&gt; 57 bar H₂, ambient O₂</li> <li>&gt; In full-scale 65 cell stack, electrolyzer</li> <li>Compared to commercial 30 bar PEM</li> </ul>			
	<ul> <li>Adv. 57 bar PEM water electrolyzer (SH#1)</li> <li>Save up to 3.6 kWh/kg H₂ - Ph. 2 Go/No-go</li> <li>➢ Reduce H₂ gas drying purge loss</li> <li>➢ Station mechanical compression to 70MPa</li> <li>Compared to 30 bar H₂ supply</li> </ul>			
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 / Impact				
<b>Target / Barriers</b>	Proton team Project Goals			
Codes and Standards	<ul> <li>Compact Component Arrangements: <i>Fit SH#2 station within 12m ISO container</i></li> <li>Safety and NFPA 2 code analysis</li> <li>Novel component arrangements</li> <li>Classified, non-classified zones</li> <li>Cooling, power, CSD, H<sub>2</sub> generation <i>Speed AHJ approval, reduce install cost</i></li> </ul>			
Lack of H <sub>2</sub> Refueling Infrastructure Performance and Availability Data	<ul> <li>Collect and report SH station performance</li> <li>Validate advanced technologies reliability</li> <li>SunHydro #1 station, SunHydro #2 station</li> <li>Energy use, # fills, kg dispensed, capacity</li> <li>Maintenance type and frequency, issues</li> <li>"%Uptime", any safety or customer issues</li> <li>Up to 24 months of station data</li> </ul>			





#### 57 bar, 65 kg/d H2 Generator

#### Build 30bar baseline generator Upgrade H2 gas components

30 bar to 57 bar, 1.5x proof

#### Build adv. full-scale 65 cell stack

- advanced thinner PEM membrane
- advanced screened electrodes
   Validate mechanical integrity
   Validate voltage reduction
   Make 65 kg H2/day at 57 bar
   Goal: 50% less dryer purge loss
   Goal: up to 8 kWh/kg H<sub>2</sub> savings



#### Upgrade Compression & Composite Storage

# Perform differential compressor comparison

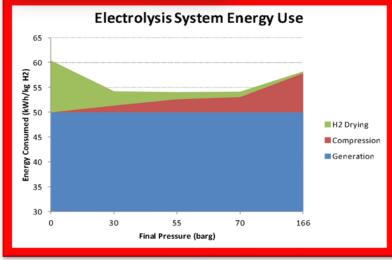
- 57 bar input at SunHydro #1
- 30 bar input at SunHydro #2

#### 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: kWh/kg reduction Goal: kg/h increase







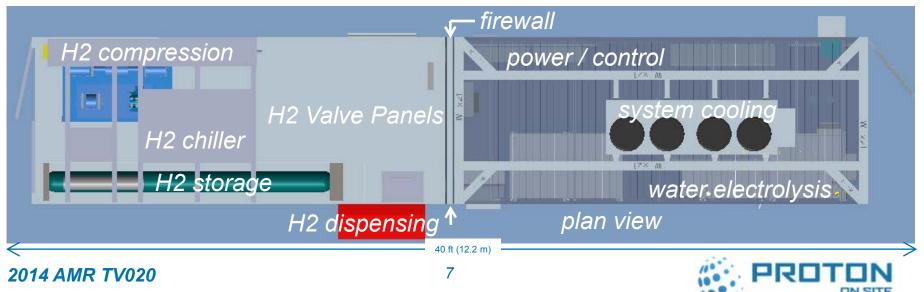
#### Safety, Code/ Zone Analysis

- 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 EXrated CSD, in 12m ISO container
- Lightweight 2 h firewalls to demise
- Power, control, thermal in non-EX

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



- Individual site summary for Sun Hydro #1 & #2
- Station instrumentation install (retrofit & new)
- Monitor loads and status of each H<sub>2</sub> subsystem
- **Report collected Station data** using H<sub>2</sub> Refueling Station Templates to Hydrogen Secure Data Center at NREL.
- **Quarterly reports: (24 months)**

#### **Data Acquisition/Reporting**



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



task	Description	Apr 2014 Progress	Expected Completion Date	Percent Complete
1	57 bar High Eff PEM Stack	High efficiency membrane processing equipment in use Stack built and passed manufacturing ATP	2014Q1	90%
2	57 bar 65 kg/d H <sub>2</sub> Generator	Baseline Generator built 57 bar upgrade components built, tested, and awaiting installation	2014Q2	85%
3	Composite Storage	Storage tubes on order Delivery significantly delayed Site installation plan and materials ready	2014Q2	50%
4	57 bar input Compressor	Compressor design confirmed for 57 bar Modifications underway for selectable input pressure	2014Q2	75%
5	Safety, Code/ Zone Analysis	NFPA 2 station and onsite generation chapter revisions Local AHJ engaged and working permitting	2014Q3	75%
6	Novel Comp. Arrangements	SunHydro#2 design complete – 2X 20ft containers (generation & compression/storage) Construction underway – container received, generator manufactured, CSD close to complete	2014Q3	70%
7	Data Acquisition System	Data acquisition hardware installed and operating for SH1 Data acquisition hardware prepped for SH2 Data collection software changes for SH2 underway	2014Q3	60%
8	Formal Data Reporting	Data for Sun Hydro #1 reported to NREL for 2013Q4 and 2014Q1	2016Q2	20%



# **Accomplishments and Progress** Response to 2013 Reviewer's Comments

The investigator should focus more on cost and where it needs to be. / Cost is probably the main obstacle in deploying electrolyzer based fueling stations. More emphasis needs to be placed on cost reduction efforts.

The project seeks to show H2 cost reduction through efficiency improvements, up to 12 kWh/kg potential. The project seeks to reduce infrastructure hardware cost through novel arrangement that minimizes classified electrical equipment. The project seeks to reduce infrastructure installation cost through reduction in required area, site preparation, and separation distances.

SunHydro LLC and Proton OnSite both share the same ownership. This could restrict the transfer of technology to other electrolyzer and H2 station OEMs.

Learnings from component arrangements are based on open-source building code. Learnings on station reliability will enhance overall data record.

Relevance and impact are limited since this project evaluates one design and one set of components (e.g, just one type of hydraulic compressor and one electrolyzer)

Proton expects the DoE will compare and contrast our evaluation with data from other projects and technologies









#### 57 bar, 65 kg/d H2 Generator

#### Operating 30bar generator Upgraded 57bar H2 components

- H2 dryer / Phase Separators
- Passed hydro proof test
- Install awaiting station upgrade

#### Built adv. full-scale 65 cell stack

- Scaled up advanced MEA manufacturing process
- Passed ATP
- Initial voltage higher than predicted based on sub-scale testing



Upgrade Compression & Composite Storage

# Upgrade/new storage systems

- 6 new 280/870 bar storage tubes on order (3 for SH1, 3 for SH2)
- Delivery delayed 7 months
- Expected install/commission May 2014
- Site prepped for installation

#### **Compressor Design**

- Compressor design confirmed for 57bar input
- Software modifications complete and awaiting tube install/commission





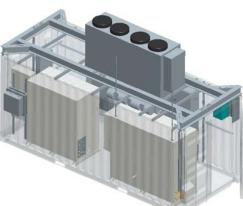
#### **CSD Container Progress**

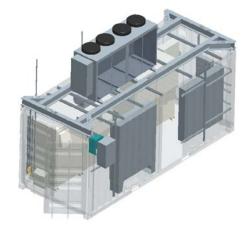
- Compression, Storage & Dispensing (CSD) Container at 95% Complete
- Final plumbing between skidded components taking place.



#### Generation Container Final Model Design

- Design complete
- Fabrication at 35% Complete
- All major and minor components allocated, purchased and ready for integration
- Container received and being modified







#### **SH1 Data Acquisition**

- Panel retrofit installed PLC, power meters
- Integrates with APCI fueling data delivery (awaiting software update during tube install/commission)
- Local data monitoring

#### SH1 Data Reporting

 Submitted 2013Q4 and 2014Q1 fueling data to NREL

#### **SH2** Data Acquisition

- Panel items received
- Integrate during SH2 construction
- Software upgraded for discrete cooling energy monitoring

Individual Site Summary				
, , , , , , , , , , , , , , , , , , , ,				
Item	Data	Units		
Datalartupdated	1213112013	mfdfyyyy		
Perzon andfor company responsible for Data		name		
General Station Information				
Energy Provider Site Ouner	roton On Site (FV); Wollingtord Electric (grid SunHydro LLC Tom Sullivon	0		
Unique Station Identifier	SunHy dra #1			
Location	Wallingford, CT	City, State		
GPSLat	41.48217	dogroor		
GPSLan	-72:76083	dogroor		
Ground Broaking Date	7492010	mfdfyyyy		
First Public Fueling Date	10/15/2010	mfdfyyyy		
Still in Operation (Yer, No)	Par			
Final date of Site Operation		młdłyyyy		
Process Flow Diagram	See SunHydra#1Fracies Diegrem			
(Production, Refueling, Both Production &				
Rofueling,				
Co-Production (H2 & Electricity - No Refueling),				
Co-Production (H2 & Electricity - With Refueling)	Fraduction and Reducting			
Production Method (Reformation, Electrolyziz)				
Productio Refermer Manufacturer	n (if applicable)			
Reformation Method				
Foodstack (for Reformation)				
Electrolyzer Type (PEM, Alkaline, etc.)	FEM			
Electrolyzer Manufacturer	Fratas OsSite			
Electrolyzer Size	200	kW		
Electricity Source (if Electrolyziz; e.q., Grid, PV,				
Wind, Hydro, etc.)	Grid on dFY 2.7	ka H2/hour		
Derign Production Capacity Intended Production Daily Operation	27 N	ka H2fhaur haursfdar		
Darign Electrical Production Capacity		LW		
Output Prozzuro	.30	bar		
	q and Dispensing			
Compressor type(s) , manufacturer(s) and rated				
prozzuro(z)		type,mfq,bar		
Dirponring Capacity por day	15	kqH2/day		
Peak Performance Dispensing Capacity per hour	15	kq H2/hour		
Mothed of Proceeding Proceeding type and temporature	Chiller 7-20(-20)			
		Description		
	7.466.479	Dorcription type (deq C)		
		type (deq C)		
Number of Dirponrors and Type	542718-2401, H70-7-20, H38 Tamb			
S	54E7862441, H70-7-20, H357amk Storage	typo (doq C) \$-typo		
ansitostarago capacity (gasoaw)	54ETH:2401, H70-7-20, H35 Tomb Storage 80	typo(doqC) \$-typo kq		
S anzitostarago capacity (garoaur) anzitostarago capacity (liquid)	SMETAR2444, HTM-7-24, HTM Tamé Storage M	typo(doqC) <b>8-</b> typo kq kq		
S anzitestarage capacity (gareaw) anzitestarage capacity (liquid) 1. number af tankr, pressure and capacity	SALTIRZIAL, HTA-T-ZA, HSR Tomb itoraqe 80 3, ATAbar, 4564 (scading upgrode to 15564)	typo(doqC) <b>8-</b> typo kq kq		
S unsitestaraqo capacity (qaromu) unsitestaraqo capacity (liqui) 1. number of tanks, procesuro and capacity 1. tank description 1. tank description	SAETIFE2661, HTA-T-20, HSE Tamb itorage 80 3. ATMan, 45ke (sonodine up arada ta 155ke) 5. Kodd CE comparie	typo(doqC) <b>\$</b> -typo kq kq <b>\$</b> ,bar,kq		
source of the second se	SALTIFICAL HIV-T-20, HIS Jank <b>Corage</b> 50 3, 6700 m, 450 g(sea dine up or ode to 125 kg) Stead GT comparis 2, 6700 m, 500 g	typo(doqC) <b>8-</b> typo kq kq		
8 anriteztarago capacity (igurauy) anriteztarago capacity (igura) 1. number af tanke, prezrus an d capacity 1. tank decription 2. number af tanke, prezrus an d capacity 2. tank decription	SAETIFE2601, HTM-7-20, HSE Temb Itorage 50 3, 6708 or, 456 of (son ding up or ode to 155 kg) SteedVCF comparite 2, 6708 or, 30kg SteedVCF comparite	typo(doqC) <b>\$</b> -typo kq kq <b>\$</b> ,bar,kq		
snritestarage capacity (arown) anritestarage capacity (lavid) 1. number aftanka prozura and capacity 1. takid serritima 2. number aftanka, prozura and capacity 2. number aftanka, prozura and capacity 3. number aftanka, prozura and capacity 3. number aftanka, prozura and capacity	SALTIN 21404, H716-7-214, H28 Fond <b>Lorage</b> 80 SciUto	typo (doq C) <b>*-</b> typo ką ką <b>*</b> ,bar,ką <b>*</b> ,bar,ką <b>*</b> ,bar,ką		
moritor tare so especity (second) moritor tare so especity (second) f. comber of andar, preserve and especity f. tank de arc ristma 2. comber of tanks, preserve and especity 2. tank de arc ristma 3. comber of tanks, preserve and especity 3. tank de arc ristma 4. comber of tanks, preserve and especity	SATTR2461, HTV-7-20, HSS Tamb Rorage 99 2, 0704 av, 454 (foreding sported to 1554 of R 1704 av, 9504 (foreding sported to 1554 of R 1704 av, 9504 Stock977 comparise R 2004 (for comparise R 2004 (for comparise) R 2004 (for comparise) R 2004 (for comparise)	typo (doqC) *-typo ką ką *,bar,ką *,bar,ką		
anzites the equip equip (queue) monites there as especify (queue) function of the function equip (queue) function of the function of equip (queue) function of equip (queue) (queue) function of equip (queue) (queue) (queue) function of equip (queue) (queue) (queue) (queue) function of equip (queue)	SAFTREVAL HTV-T-24, H28 Tamb by SAFTREVE of the up predic to 1585 of Stability and the up predic to 1585 of Stability and the up predictor Stability and the up predictor	typo (doq C) <b>*-</b> typo ką ką <b>*</b> ,bar,ką <b>*</b> ,bar,ką <b>*</b> ,bar,ką		
noritas tareqa especity (quaaw) moritas tareqa especity (quaaw) 1. comba er fanda, prazerar on especity 2. tank da carejan 2. comba er fanda, prazerar on especity 3. comba er fanda, prazerar on especity 3. comba er fanda, prazerar on especity 3. comba er fanda, prazerar on especity 4. comba er fanda, prazerar on especity 4. comba er fanda, prazerar on especity 0. Cother	SATTR2464, HYP-1-20, H28 Tamb Rerage 99 2, 0704 or, 454 (conditions over advice 1284 of R. 1974 or, 454 (conditions over advice 1284 of R. 1974 or, 304 3, 0704 or, 304 5, 02047 comparise Scob07 comparise Scob07 comparise Scob07 comparise Scob07 comparise Scob07 comparise Scob07 comparise	typo(doqC) <b>8</b> -typo ką <b>8</b> ,bar,ką <b>8</b> ,bar,ką <b>8</b> ,bar,ką <b>8</b> ,bar,ką		
ancites there as a capacity (auranu) monites there as a capacity (flug capacity flug capacity capacity) flug capacity flug capacity flug capacity flug capacity capacity flug capacity capacity capacity flug capacity capacity capacity flug capacity (flug capacity flug capacity flug survivality) (flug capacity flug capacity flug survivality) (flug capacity flug capacity flug capacity survivality) (flug capacity flug capacity flug capacity survivality) (flug capacity flug capacity flug capacity flug capacity survivality) (flug capacity flug capac	SAFTIR2464, HTV-7-20, H28 Famb Rorage 99 2, 1704 an, 554 Aproxidia superado to 1254 aj 2, 1704 an, 504 Aproxidia superado to 2, 1704 an, 504 3, 1704 an, 504 5, 1704 and 50 1107 matica 1107 matica	typo (doq C) <b>*-</b> typo ką ką <b>*</b> ,bar,ką <b>*</b> ,bar,ką <b>*</b> ,bar,ką		
noritas tarega especity (quaaw) moritas tarega especity (quaaw) 1. comber of today, prazvers on expectivy 1. tank of today prazvers on expectivy 2. comber of today, prazvers on expectivy 3. comber of today, prazvers on expectivy 3. comber of today, prazvers on expectivy 4. comber of today, prazvers on expectivy 4. tank description 5. Guiden and today (Mar Lang, Min Lang) Mydresa hof starvers for Entrative (cochduling	SATTR2161, KYV-7-20, K28 TamA Rorsq PF 2, 0706 or, 454 cfrondingsported to 1254 cf 2, 0706 or, 454 cfrondingsport 2, 0706 or, 454 cfrondingsport 2, 0706 or, 504 2, 0706 or, 504 2, 0706 or, 504 2, 0706 or, 504 3, 0706 or, 504 5, 0706 or, 506 5, 0706	typo(doqC) kq kq kq kjbar,kq #;bar,kq #;bar,kq doqroorC		
ancites that e.g. e.g. e.g. e.g. e.g. e.g. (y ( i guarany) monites that e.g. e.g. e.g. (y ( i guarany) 1. comber of that e.g. percent on e.g. e.g. (y 2. comber of that e.g. percent on e.g. e.g. (y 3. comber of that e.g. percent on e.g. e.g. (y 4. comber of that e.g. e.g. (comber of that e.g. e.g. (comber 4. comber of that e.g. e.g. (comber of that e.g. e.g. (comber 5. g. (comber of that e.g. e.g. (comber of that e.g. e.g. (comber 5. g. (comber of that e.g. (comber of that e.g. (comber 5. g. (comber of that e.g. (comber of that e.g. (comber 5. g. (comber of that e.g. (comber of that e.g. (comber 6. g. (comber of that e.g. (comber of	SATTRESON, HYPE-T-RR, HYPE Tamb torage 80 Software, USA (grandine suparado ta 1954.0) Software, USA (grandine suparado ta 1954.0) Software (Standorf annyalita Software) (Standorf annyalita Software) (Standorf annyalita Software) (Standorf annyalita Software) Information Standorf annyalita Standorf annyalita Standorf annyalita Standorf annyalita Standorf annyalita	typo(doqC) &-typo kq kq *,bar,kq *,bar,kq *,bar,kq doqroorC rafoot		
norites tareque especity (queueu) morites tareque especity (queue) 1. combe erraque especity (queue) 2. combe err d'ander, prezerver en est especity 2. combe err d'ander, prezerver en est especity 3. combe erraf tanke, prezerver en est especity 4. combe erraf tanke, prezerver en est especity 4. combe erraf tanke, prezerver en est especity By dragen hir ærtverture Fatter jarte (in cochding Hy dragen hir ærtverture Fatter jarte) (cochding giapparen Hittig areque Fatter) Paramanet Hittig areque Fattering	SATTRESON, HYPE-T-RR, HYPE Tamb torage 80 Software, USA (grandine suparado ta 1954.0) Software, USA (grandine suparado ta 1954.0) Software (Standorf annyalita Software) (Standorf annyalita Software) (Standorf annyalita Software) (Standorf annyalita Software) Information Standorf annyalita Standorf annyalita Standorf annyalita Standorf annyalita Standorf annyalita	typo (dogC) *typo ką ką *,bar,ką *,bar,ką *,bar,ką dogroorC rafoot rafoot		
an rite stare of eacity (queraw) monite stare of eacity (queraw) 1. comber of today, process on a cose sity 2. comber of today, process on a cose sity 2. comber of today, process on a cose sity 3. comber of today, process on a cose sity of today 4. cose of today of today, process of today, proc	SATTRESON, HYPE-T-RR, HYPE Tamb torage 80 Software, USA (grandine suparado ta 1954.0) Software, USA (grandine suparado ta 1954.0) Software (Standorf annyalita Software) (Standorf annyalita Software) (Standorf annyalita Software) (Standorf annyalita Software) Information Standorf annyalita Standorf annyalita Standorf annyalita Standorf annyalita Standorf annyalita	typo(doqC) &-typo kq kq *,bar,kq *,bar,kq *,bar,kq doqroorC rafoot		
minite strarspin capacity (quanu) minite strarspin capacity (quanu) f. number of stade, preserve and capacity 1. tank de acription 2. number of stade, preserve and capacity 2. tank de acription 3. number of tank, preserve and capacity 3. tank de acription 4. number of tank, preserve and capacity 4. tank de acription 5. Surviveshilty (Haz Tany, Hin Tany) Hy dragen hir artirecture famping (acadum giapanes) Permanent His Tareges Famping	SATTRESING ATTO-T-Sig ASS Famb torage 80 3,0708 as, 583 of Grandine up arode to 155 big 3,0708 as, 583 of Grandine up arode to 155 big 3,0708 as, 588 of Grandine up arode to 155 big 5,0708 of Granding and the 3,0708 or 588 of Granding and the 5,0208 of Granding and the 5,0208 of Granding and the 5,020 of Gra	typo (dogC) *-typo ką ką *,bar,ką *,bar,ką *,bar,ką *,bar,ką dogroor C rafoot rafoot		
minite starsque copacity (quanau) minite starsque copacity (quanau) fu comba et today, prozerva en di copacity 1. tanà dia corpitan 2. unuhar at tanàn, prozerva en di copacity 2. tanà dia cristian 3. unuhar at tanàn, prozerva en di copacity 3. tanà dia cristian 4. unuhar at tanàn, prozerva en di copacity 4. tanà dia cristian 5. unuhar at tanàn, prozerva en di copacity 1. di cha di caristian 5. Unuhar at tanàn, prozerva en di copacity 1. di cha di caristian 5. Unuhar at tanàn, prozerva en di copacity 1. di cha di caristian 5. Unuhar at tanàn, prozerva en di copacity 1. di cha di caristian 6. di caristian 1. di caris	5471972161 H716-7-20( H285 TamA 109749 - 98 547509 - 98 (conclusion on provide to 1258 c) 547609 - 98 (conclusion on provide to 1258 c) 547609 - 980 - 28 2 (1970 - 28) 2 (1970 - 28) 3 (1970 - 28) 5 (1970 - 28	typo (dogC) <b>*</b> -typo kq kg *,bar,kg *,bar,kg *,bar,kg dogroor C rafoot rafoot rafoot rafoot		
maritestarage especity (quanu) maritestarage especity (quanu) f. number at tealer, preserve an el capacity 1. tank duarestaria 2. unmber at tealer, preserve an el capacity 2. tank duarestaria 3. unmber at tealer, preserve an el capacity 4. tank duarestaria 4. unmber at tealer, preserve an el capacity by dress of have a capacity 4. tank duarestaria 5. unmber at tealer, preserve an el capacity by dress of have tracket and the original for a service at tealers (conclution disparse) Permonent HS teres a fast print Rennesits HS Starses fast print (conclution permit el capacity of permit a service fast print Rennesits HS Starses fast print (conclution permit el capacity of permit	5471972461, XYV-7-20, XXX TamA <b>Rorage</b> <i>PR</i> 2, 8786 or, 484 (consider argue role to 1854 c) <i>Scientific argumenta</i> <i>Scientific argumenta</i> <i>B. Standoff argumenta</i> <i>B. Scientific argumenta</i> <i>B. Scientifi</i>	typo (doq C) <b>8-typo</b> kq kq <b>8.bar,kq</b> <b>8.bar,kq</b> <b>8.bar,kq</b> <b>8.bar,kq</b> <b>9.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.bar,kq</b> <b>10.</b>		
marite starage operativ (quanu) marite starage operativ (quanu) f. tomber at tealer, preserve and cogesity f. tomber at tealer, preserve and tealer, preserve f. tomber at tealer, preserve and tealer, preserve f. tomber at tealer, preserve and tealer, preserve f. tomber at tealer, preserve and tealer, tealer, preserve f. tomber at tealer, preserve and tealer, tealer, preserve f. tomber at tealer, preserve and tealer, tealer, preserve f. tomber at tealer, preserve at the tealer of tealer, preserve f. tomber at tealer, preserve at the tealer of tealer, preserve at the tealer of tealer of tealers, preserve at the tealer of tealers, preserve at te	5471972461, XYV-7-20, XXX TamA <b>Rorage</b> <i>PR</i> 2, 8786 or, 484 closed large provide to XXX of <i>SocietSC answarts</i> <i>SocietSC answarts</i> <i>Bythere</i> , 2004 <i>SocietSC answarts</i> <i>Bythere</i> , 2004 <i>SocietSC answarts</i> <i>Bythere</i> , 2004 <i>SocietSC answarts</i> <i>Bythere</i> <i>SocietSC answarts</i> <i>Bythere</i> <i>SocietSC answarts</i> <i>Bythere</i> <i>SocietSC answarts</i> <i>Bythere</i> <i>SocietSC answarts</i> <i>Bythere</i> <i>SocietSC answarts</i> <i>Bythere</i> <i>SocietSC answarts</i> <i>SocietSC answarts</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere</i> <i>Bythere <i>Bythere <i>Bythere</i> <i>Bythere <i>Bythere <i>Bythere <i>Bythere</i> <i>B</i></i></i></i></i></i>	type (deq G) <b>a</b> -type kq ka bar,kq <b>a</b> ,bar,kq <b>b</b> ,bar,kq <b>d</b> ,bar,kq <b>d</b> ,bar,kq <b>d</b> ,bar,kq <b>d</b> ,cqreer C rafoot rafoot rafoot dayz		





# 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**

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



# **Future Work**

#### Balance Phase 1 Major Activity

- 2-3Q 57 bar PEM water electrolyzer test\*
- 2-3Q 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

#### **3Q-onward** Station Data Acquisition





# **Project Summary**

- <u>*Relevance*</u>: Addresses DoE goal of <\$4/gge, MYPP barriers of H<sub>2</sub> storage, codes, and lack of station performance data
- <u>Approach</u>: Validate H<sub>2</sub> 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.
- <u>Tech Accomplishments</u>: 57bar stack and system built; SunHydro#1 and #2 advance storage ordered; SH#2 designed and fabrication begun; SH#1 data monitoring underway
- <u>Collaborations</u>: SunHydro LLC (stations), Toyota Motors (vehicles), APCI (supplier storage upgrade and programming)
- <u>Future Work</u>: Perform adv. PEM test; 57bar electrolyzer install, SH#1 storage upgrade, compressor test, SH#2 install & data monitoring

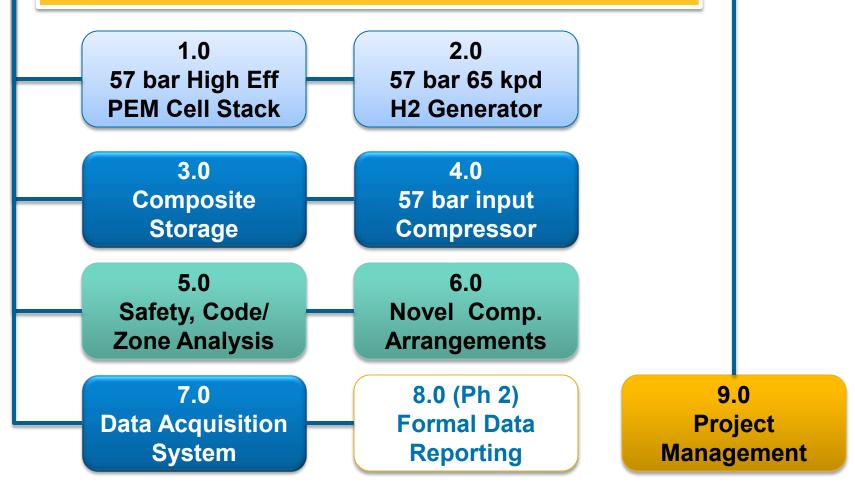
Larry Moulthrop 203-678-2188 LMoulthrop@ Proton OnSite.com



# **Technical Back-Up Slides**









# **Proton® C Series PEM Electrolysis Stack**

#### 10 Nm<sup>3</sup>/hr stack for Navy Life Support Application in 2008

- 57 bar H<sub>2</sub> differential pressure
- Over 1 million cell-hrs of validation
- Currently in serial production
- Over 18 months on-board submarines

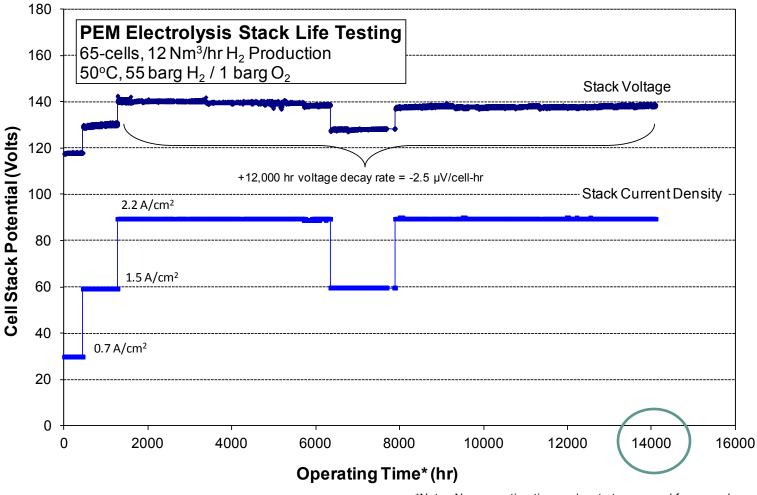
#### • Derivative 30 bar version in 2009

- Basis of C-Series 30 Nm<sup>3</sup>/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 – Apr 2014



# >7000 kg of hydrogen dispensed>2500 high pressure H2 fillsServing fleet of 12 FCHV and paratransit





