

Highly Efficient, 5kW CHP Fuel Cells Demonstrating Durability and Economic Value in Residential and Light Commercial Applications



Project ID: H2RA003
Don Rohr
May 13, 2011

OVERVIEW

Timeline

- Project start – September 2009
- Project end – September 2012
- 70% complete

Budget

- Total project funding - \$6.7M
 - DOE - \$3.37M
 - Plug Power - \$3.37M
- Funding in FY10 - \$0
- Funding in FY11 - \$0

Barriers

- Barriers addressed:
 - A. Durability
 - B. Cost
 - C. Performance

Partners

- Interactions/collaborations
 - University of California Irvine
 - Sempra Energy
- Project Leads
 - Dr. Jack Brouwer
 - Randy Brown

OBJECTIVES - RELEVANCE

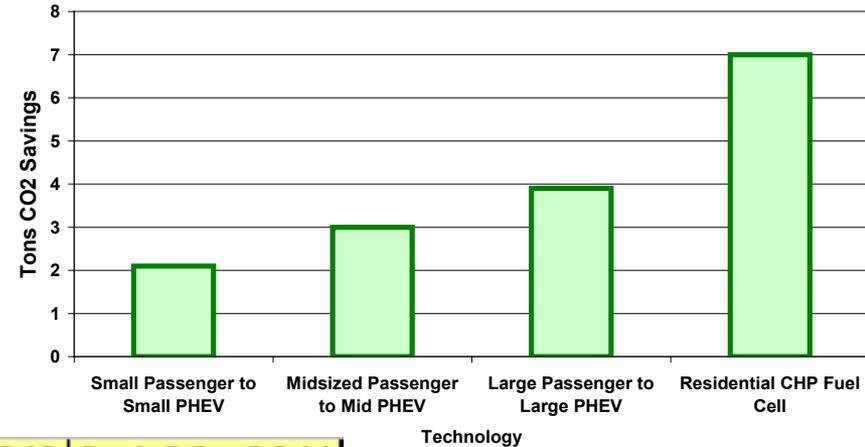
The objective of this demonstration program is to substantiate the durability and economic value of **GenSys Blue** and verify its technology and commercial readiness for the marketplace.

Characteristic	Units	Goal	1st GO - 2Q10	2nd GO - 2Q11
Electrical efficiency at rated power	%	40	>30	>30
CHP efficiency at rated power	%	90	>80	>80
Cost (qnty < 15)	\$/kWe	10,000	20,000	20,000
Durability at < 10% rated power degradation	hr	10,000	2,000	8,700
Noise	dB(A)	<55 at 10m	<55 at 10m	<55 at 10m
Emissions (combined NO _x , CO, SO _x , hydrocarbon, particulates)	g/MW/hr	< 1.5	< 1.5	< 1.5



OBJECTIVES - RELEVANCE

CO2 Emissions Comparison

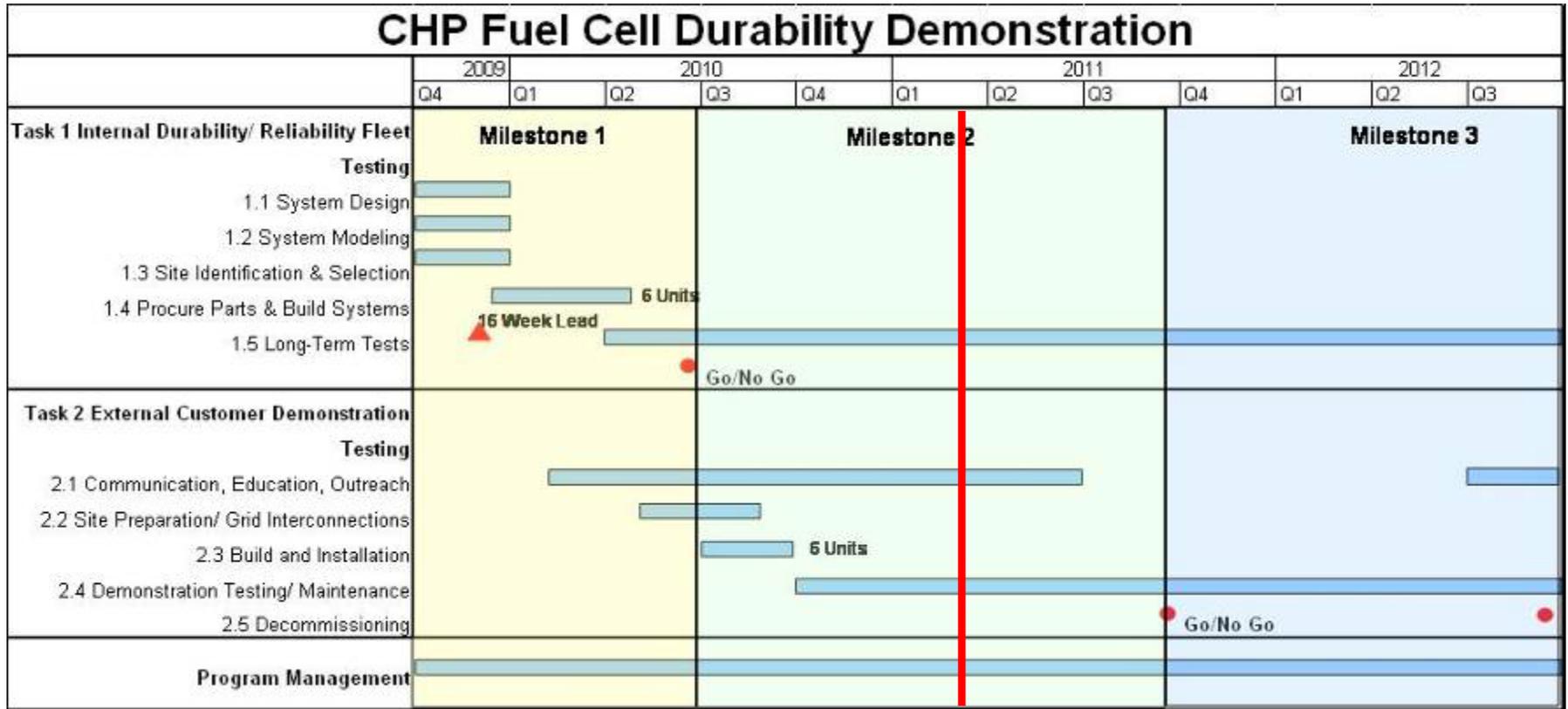


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In 2Q10 the team held its first GO/NO decision.

MILESTONES - APPROACH



CHP FUEL CELL DURABILITY DEMONSTRATION - TASKS

- Task 1: Internal Durability/ Reliability Fleet Testing
 - Task 1.1: System Design
 - Task 1.2: System Modeling
 - Task 1.3: Site Identification and Selection
 - Task 1.4: Procure Parts and Build Systems
 - Task 1.5: Long Term Tests
 - *1st GO/NO GO Decision*

- Task 2: External Customer Demonstration and Testing
 - Task 2.1: Communication, Education and Outreach
 - Task 2.2: Site Preparation, Natural Gas and Grid Interconnection
 - Task 2.3: Build and Installation
 - Task 2.4: Demonstration Testing and Maintenance
 - *2nd GO/NO GO Decision*
 - Task 2.5: Decommissioning

- Task 3: Project Management
 - Task 3.1: Cost Analysis

TASK 1.1: SYSTEM DESIGN - COMPLETE

Product Characteristics	
Minimum Continuous Output	0.5 kW
Maximum Continuous Output	2.5 kW to 5.0 kW
Operating Fuel	Natural Gas
Dimensions	101cm x 71cm x 122cm
Weight	250kG
Nominal Voltage	120Vac 60Hz or 230Vac 50Hz
Efficiency (Electric/CHP)	30% / 85% LHV
Integrated Burner	Variable Output (7kW / 25kW)
Operating Conditions	
Location	Indoors
Ambient Temperature Range	0°C - 40°C

Plug Power design initiatives:

- **Controls and efficiency improvements**
 - Start-up, thermal response and heat modulation improvements, improved thermal recovery
 - From 89% peak total efficiency to 94%
- **Manufacturability improvements**
 - Enclosure, piping, insulation and wiring
 - Reduced build time from > 120 hours to < 50
- **Design for certification**
 - Integrated with commercial automatic burner control system
 - Reduced exhaust temperature
- **Reduction in material cost**
 - From ~\$90k to \$53k in volumes < 20

The low cost, reliable, simple to install design with a compelling value proposition yields an energy efficient green product that delivers value to the customer.



TASK 1.2: SYSTEM MODELING

- **Objective:** Using Matlab-Simulink, develop a dynamic model and simulation of the **GenSys Blue** fuel cell system, correlate with data from the reliability fleet and use the model to further understand and improve the design.
- **Approach:** Develop independent models of the stack, fuel processor and burner then integrate these into a system model; demonstrating initially steady-state capability and then dynamic.
- **Status:** Sub-system models, system integration and steady-state capability complete. Dynamic development ongoing.

UCI is leading the system modeling effort. The team is correlating data generated by the model with data from the reliability fleet.



National Fuel Cell
Research Center



TASK 1.2: SYSTEM MODELING

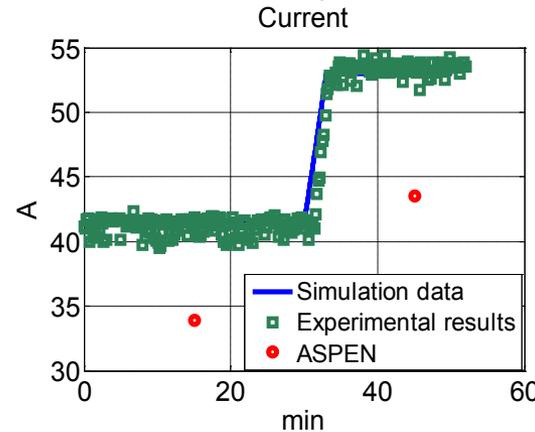
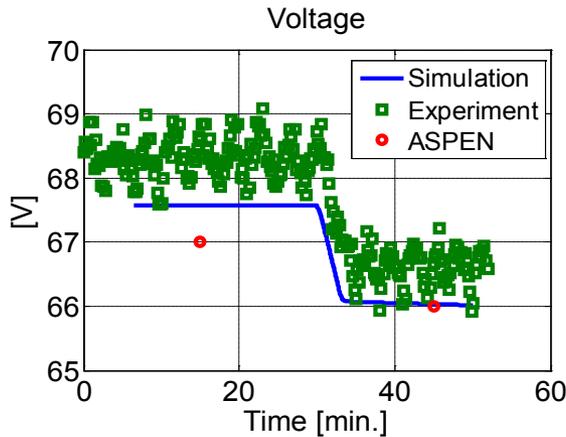
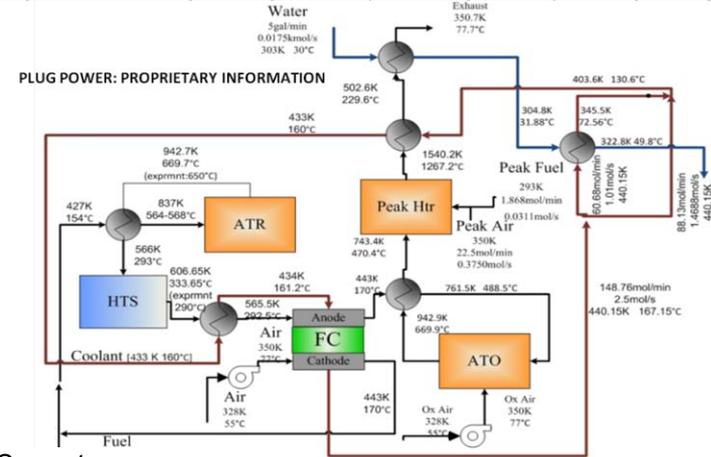
Completed Work

- Fuel Processor Model Modifications
- System Integration
 - Dynamic capability
 - Ability to adjust parameters to match various data

Ongoing work

- Continued fine tuning of parameters such that UCI models agree with Plug Power models
- Verify dynamic UCI model with experiments at UCI

	Molar flow rate	CH ₄	CO	CO ₂	H ₂	H ₂ O	T
	[kmol/s]						[K]
ASPEN model	2.14E-04	0.002	0.008	0.077	0.246	0.111	626.7
New HTS	2.01E-04	0.001	0.006	0.086	0.271	0.112	604.3
Previous HTS	2.01E-04	0.001	0.034	0.059	0.243	0.140	570.1



TASK 1.3: SITE IDENTIFICATION AND SELECTION



Sempra Energy in California is assisting the team with site selection in their territory for external reliability testing:

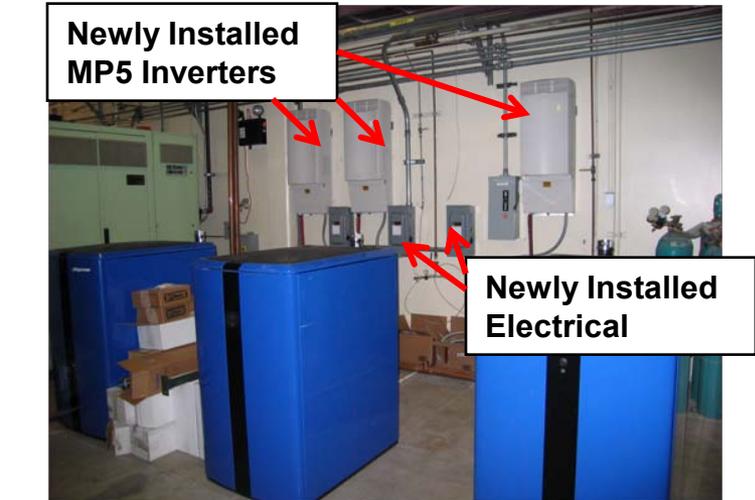
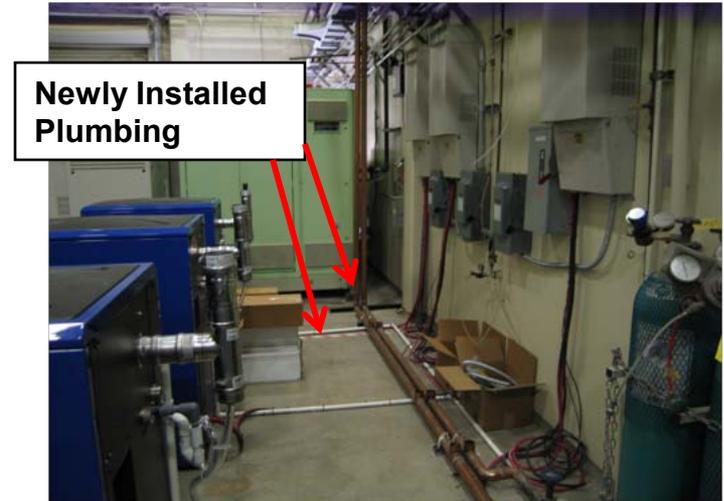
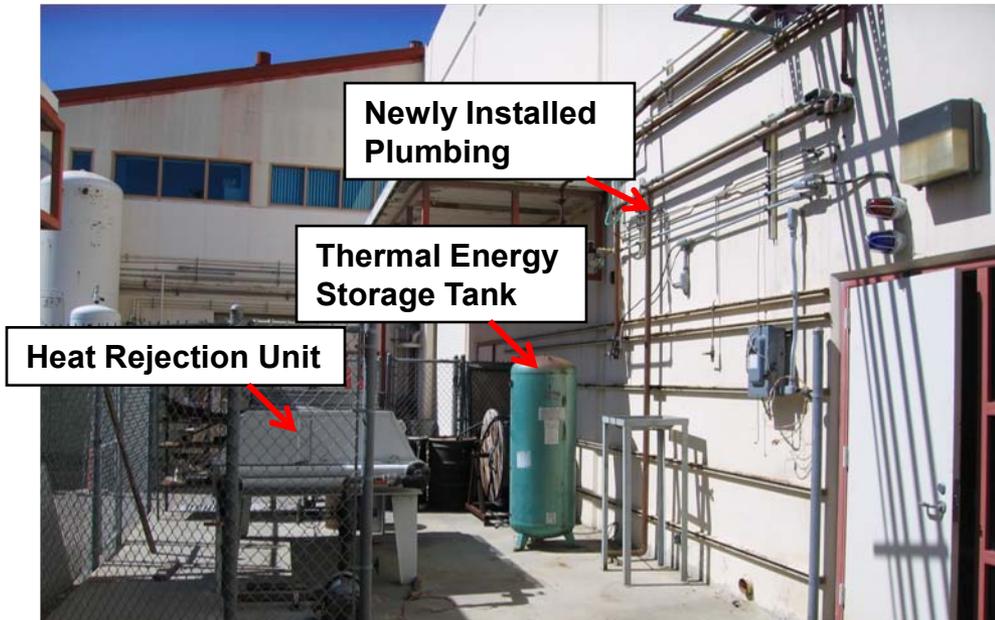
- NFCRC labs in Irvine, CA (3 systems)
- Sempra Energy sites (3 systems)



TASK 1.3: SITE IDENTIFICATION AND SELECTION

■ Ongoing installation work

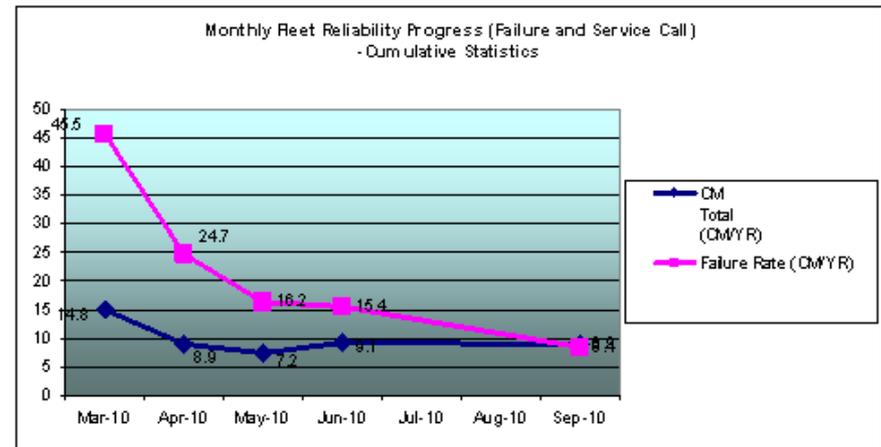
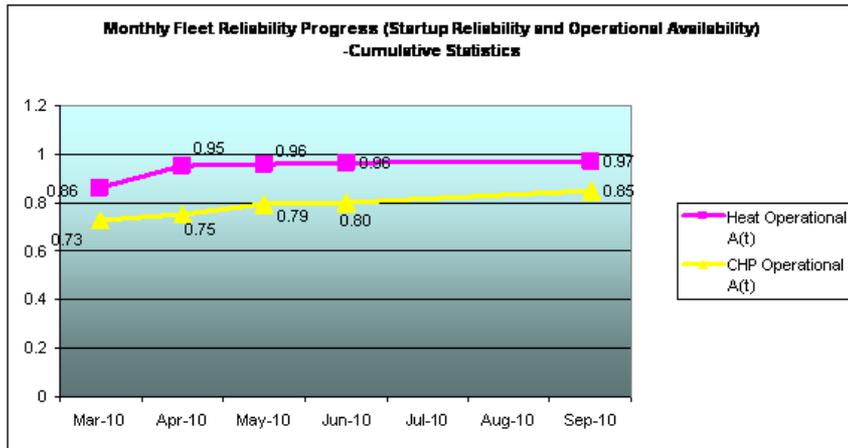
- Exterior Plumbing/Electrical
- Interior exhaust duct
- Battery installation
- CHP rig installation
- Estimated Completion Date: Mid April



TASK 1.5: LONG TERM TESTING

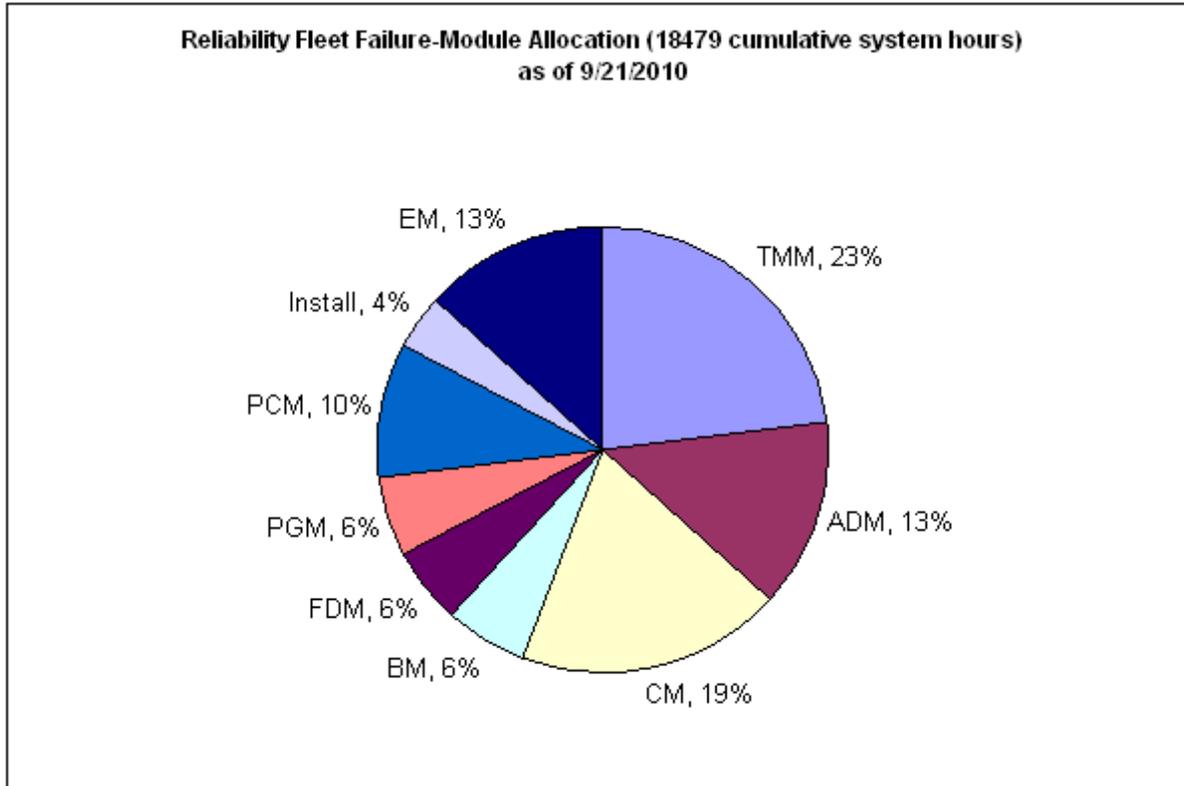
Internal fleet dashboard metrics:

- 6 systems commissioned in Plug Power labs
- Over **18,000** run hours
- **32 MWhrs** of electricity and **163 MWhrs** of heat produced
- Unadjusted heat availability of **97%**
- Unadjusted CHP availability of **85%**
- CHP availability (supplier delivery issues removed) of **94%**



TASK 1.5: LONG TERM TESTING

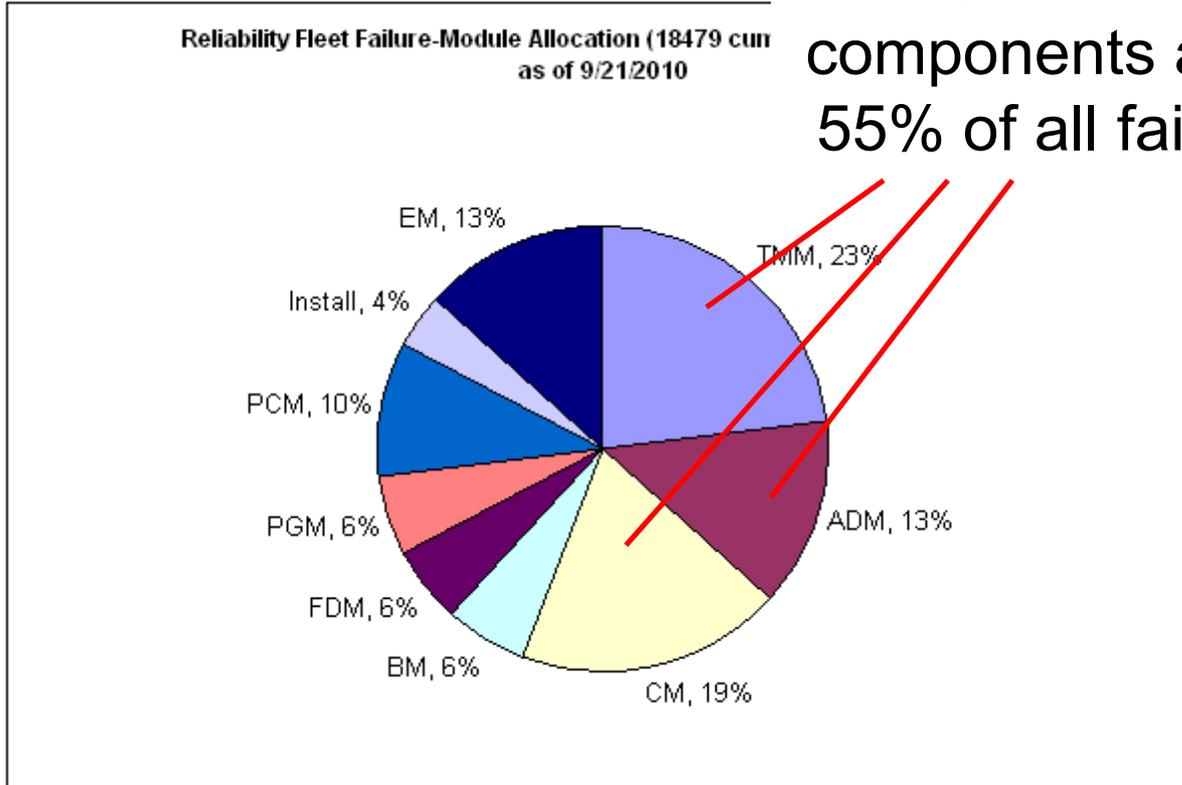
Fleet failure mode allocation:



TASK 1.5: LONG TERM TESTING

Fleet failure mode allocation:

A small number of components account for 55% of all failures seen



TASK 1.5: LONG TERM TESTING

- Current stack life in system is:

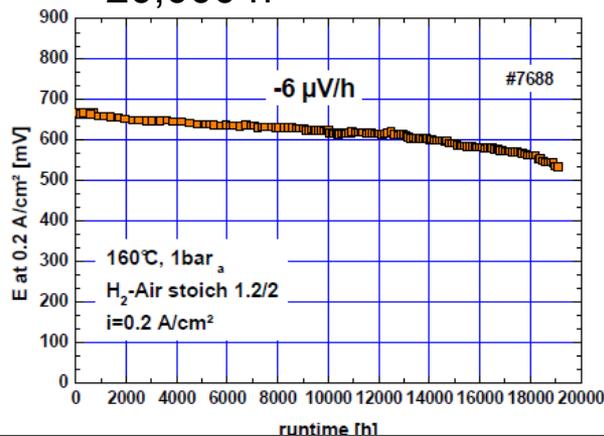
- 3000-5000 h (6-12 months)

	Before April 2010	After April 2010
	Hrs	Hrs
Epsilon 8	1045	4073
Epsilon 9	580	3801
Epsilon 10	1778	
Foxtrot 2	2068	4742
Foxtrot 3	1913	3098
Foxtrot 4	#N/A	3206
Avg	1476.8	3784

5500

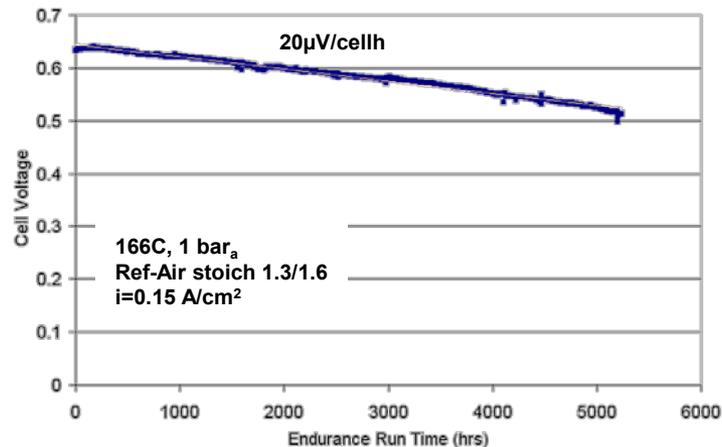
- BASF Laboratory Data:

- 20,000 h



- Current stack life on test station is:

- >5400h (12+ months) and running
- Projected 10,000h (18-24 months) at current rate



HT Technology Exceeds Requirements and HT Stack Lifetimes are Approaching Commercial Launch Requirements

1st GO/NO GO DECISION

Characteristic	Units	Goal	1st GO - 2Q10	1st GO Actual	2nd GO - 2Q11
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Durability at < 10% rated power degradation	hr	10,000	2,000	3,000	8,700
Noise	dB(A)	<55 at 10m	<55 at 10m	55 at 1m	<55 at 10m
Emissions (combined NO _x , CO, SO _x , hydrocarbon, particulates)	g/MW/hr	< 1.5	< 1.5	< 1.5	< 1.5

Based on data from the internal fleet the team believes the systems are ready for external deployment and made the decision to GO.

2.1: COMMUNICATION, EDUCATION AND OUTREACH

Events to date:

- Ribbon cutting ceremony for *GenSys Blue* installation at Union College in NY
- Alumni Day at Union College
- New York State Science, Technology, Engineering and Mathematics (STEM) Educational Collaborative at Ballston Spa High School in Ballston Spa, NY
- United States Fuel Cell Seminar in Palm Springs, California. *GenSys Blue: Fuel Cell Heating Appliance*
- Ballston Spa High School technology field trip
- Plans for system on display at the Schenectady Museum
- UCI takes over in California
- Co-taught Fuel Cell Seminar Course with UCI



NYS Assemblyman Jim Tedisco with Union College faculty, Plug Power and National Grid employees at ribbon cutting ceremony (DOE 7C)

2.2: SITE PREPARATION, NATURAL GAS AND GRID INTERCONNECTION

Site	Site Survey	NEPA Form	Application Engineering	Permits	Interconnect Application	Installation	Interconnect Approval	Commissioning
University of California, Irvine, California								
Installation 1	13-Sep	n/a	1Q11	1Q11	n/a	2Q11	n/a	2Q11
Installation 2	13-Sep	n/a	1Q11	1Q11	n/a	2Q11	n/a	2Q11
Installation 3	13-Sep	n/a	1Q11	1Q11	n/a	2Q11	n/a	2Q11
Sempra Energy Sites, California								
Woodbury Lagoon	14-Sep	n/a	2Q11	3Q11	2Q11	3Q11	3Q11	4Q11
Anthony Residence	14-Sep	n/a	2Q11	3Q11	2Q11	3Q11	3Q11	4Q11
Hentschel Residence	15-Sep	n/a	2Q11	3Q11	2Q11	3Q11	3Q11	4Q11
Huie Residence	14-Feb	n/a	2Q11	2Q11	2Q11	3Q11	3Q11	4Q11

Sites are identified and the team has begun detailed site work.

2.3: BUILD AND INSTALLATION



Three GenSys Blues sited at UC Irvine awaiting install



Woodbury Pool CHP injection loop proposed tie-in point

COLLABORATIONS

- **University of California Irvine – National Fuel Cell Research Center**
 - University, cost sharing partner within the program
 - NFCRC develops a system model for product development, refining controls and improving operation
- **Sempra Energy**
 - Industry, non-cost sharing partner within the program
 - Sempra Energy is providing sites for testing and will assist in interconnection and fleet evaluation
- **LPA**
 - Industry, non-cost sharing partner outside of the program
 - LPA will act as a site host and will assist in site design for the three systems installed on their campus
- **California Air Quality Management District (AQMD)**
 - State agency, non-cost sharing partner outside of the program
 - AQMD will evaluate fleet data against California air quality standards
- **National Renewable Energy Laboratory (NREL)**
 - National lab, non-cost sharing partner outside of the program
 - NREL will assist in fleet data analysis

FUTURE WORK

- **Installations at UCI California** **2Q11**
- **Installations in Sempra territory** **3Q11**
- **Begin External Reliability Fleet Testing** **3Q11**
- **Complete System Model** **2Q11**
 - UCI will verify system model against reliability fleet results
- **2nd GO/NO GO Decision** **3Q11**
 - Based on achievement of the program objectives the team will decide whether or not to invest in upgrading the fleet and continuing long term testing
- **Perform Economic Analysis** **4Q11**
 - Using fleet performance data, Plug Power will publish an economic analysis of the viability of this CHP technology
- **Complete Long Term Testing** **3Q12**



HEADQUARTERS

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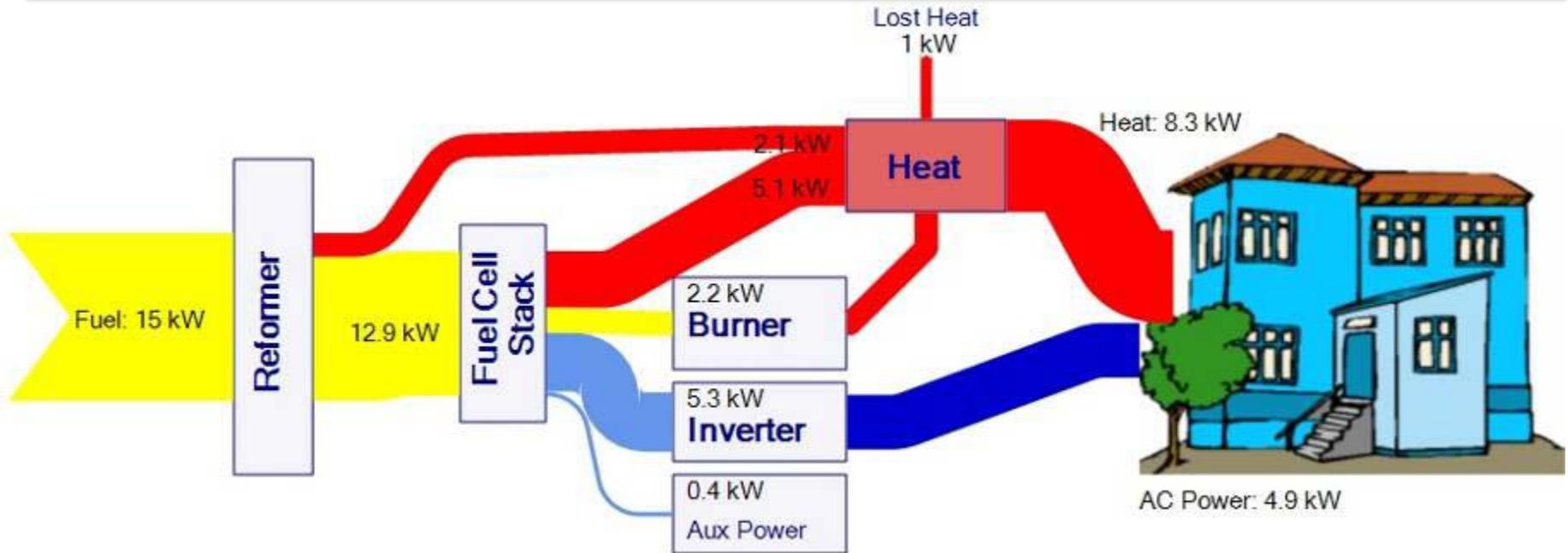
www.plugpower.com

Technical Backup Slides



POWER
POWER AHEAD

GenSys Blue: microCHP (<15kW)



- Increase household efficiency from ~45% to 85%
- **30%+** reduction in ultimate fuel usage and carbon footprint:
 - 3 - 7 tons/year (Equivalent to NOT driving for 6 months)
- Secure distributed generation with assured power