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

plug power

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 NOx, CO, SOx, hydrocarbon, particulates)	g/MWhr	< 1.5	< 1.5	< 1.5

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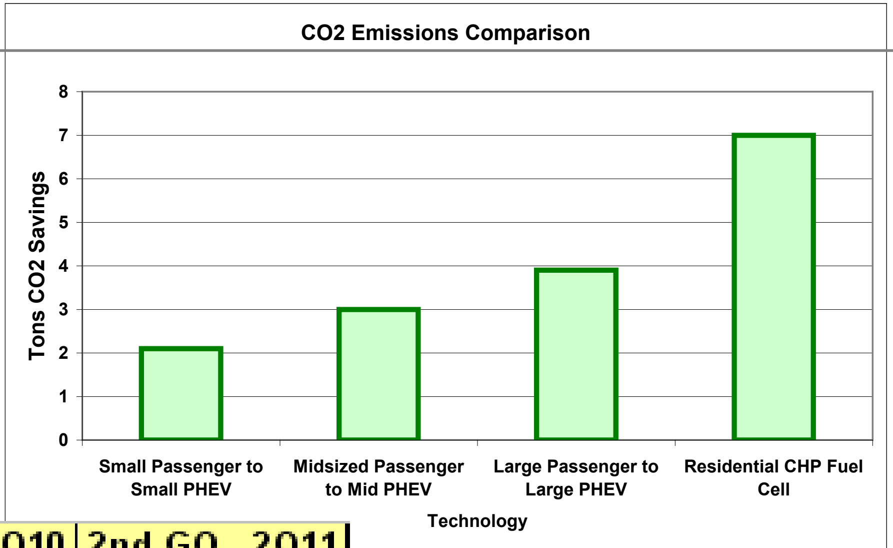

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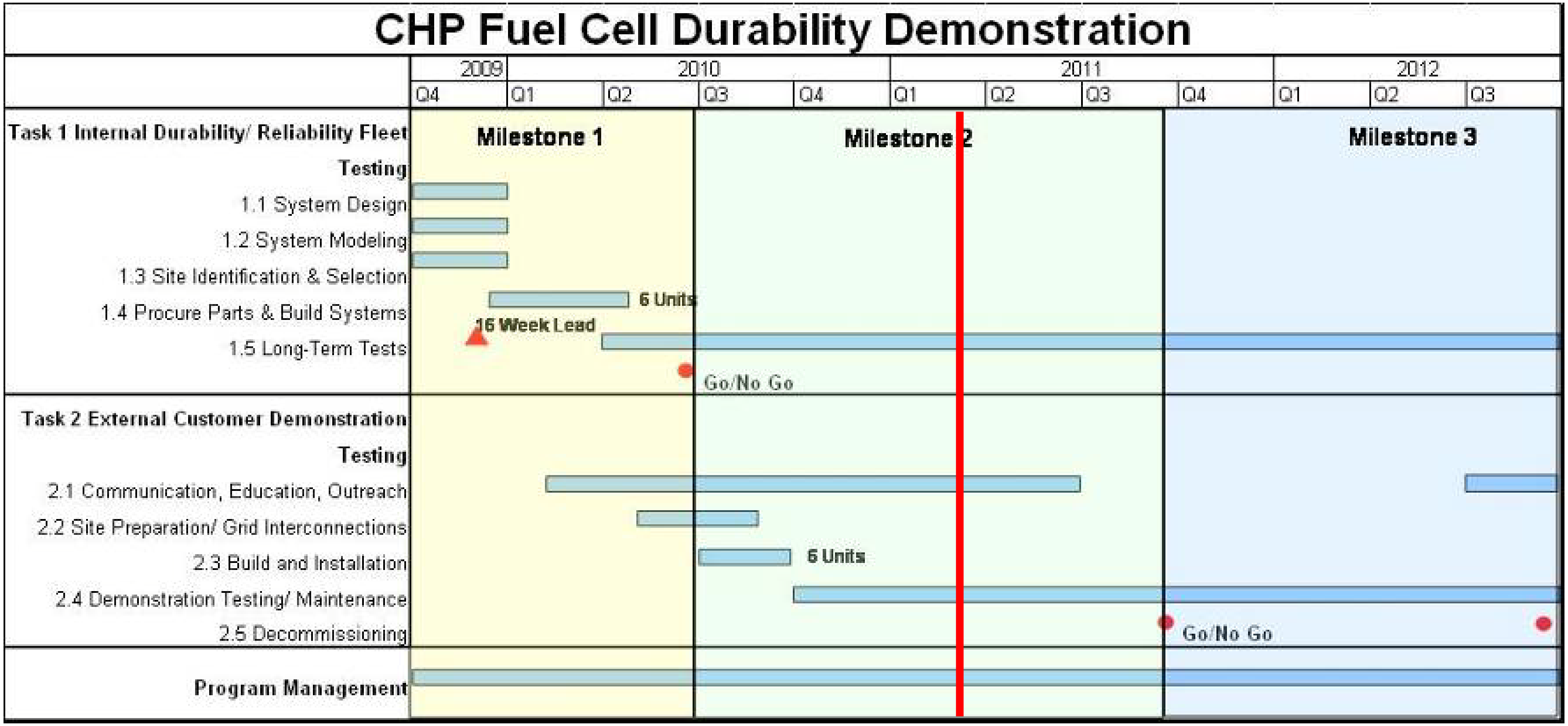
In 2Q10 the team held its first GO/NO decision.

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.

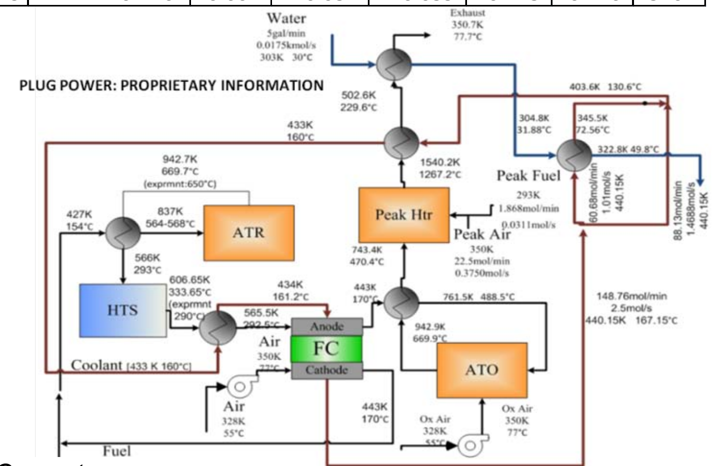
UCI is leading the system modeling effort. The team is correlating data generated by the model with data from the reliability fleet.

TASK 1.2: SYSTEM MODELING

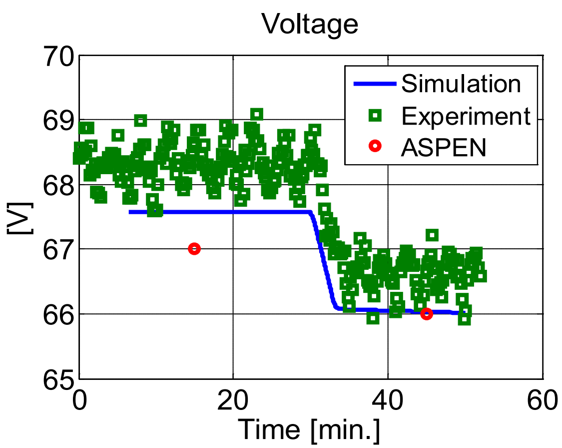
- Completed Work
  - Fuel Processor Model Modifications

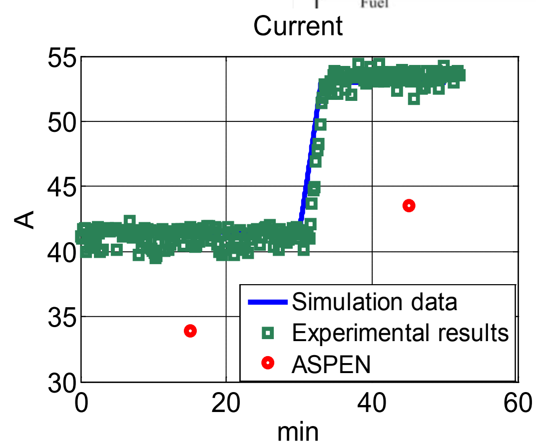
	Molar flow rate [kmol/s]	CH_4	CO	CO_2	H_2	H_2O	T [K]
ASPEN model	2.14E-04	0.002	0.008	0.077	0.246	0.111	626.7
New HTS	2.01E-04	0.001	0.006	0.086	0.271	0.112	604.3
Previous HTS	2.01E-04	0.001	0.034	0.059	0.243	0.140	570.1

  - 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





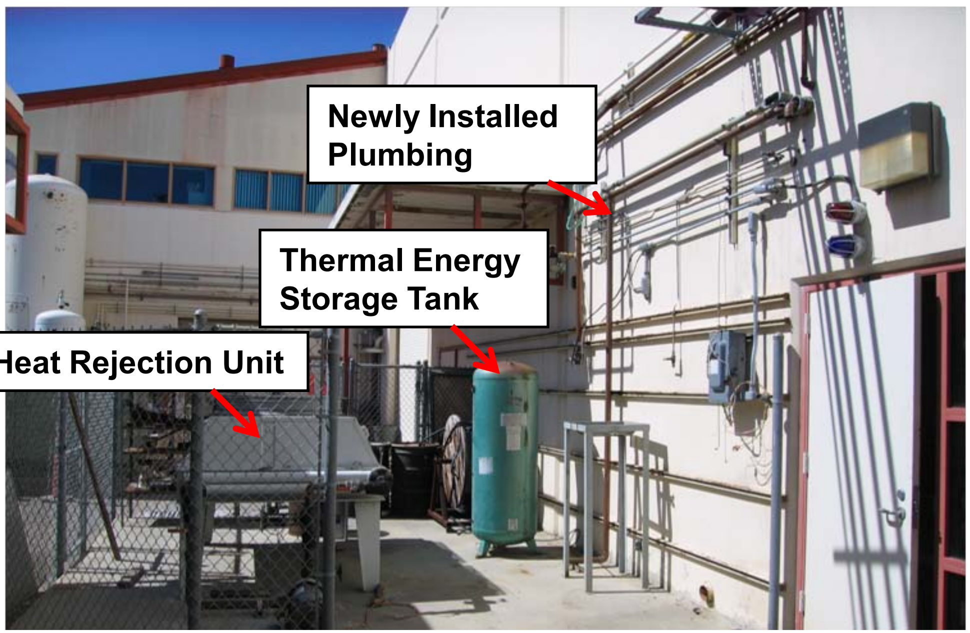
TASK 1.3: SITE IDENTIFICATION AND SELECTION

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

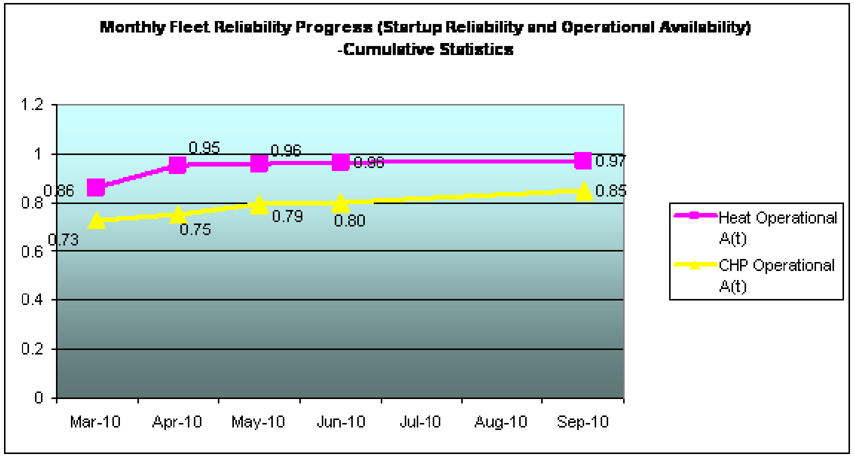
- Ongoing installation work
  - Exterior Plumbing/Electrical
  - Interior exhaust duct
  - Battery installation
  - CHP rig installation
  - Estimated Completion Date: Mid April

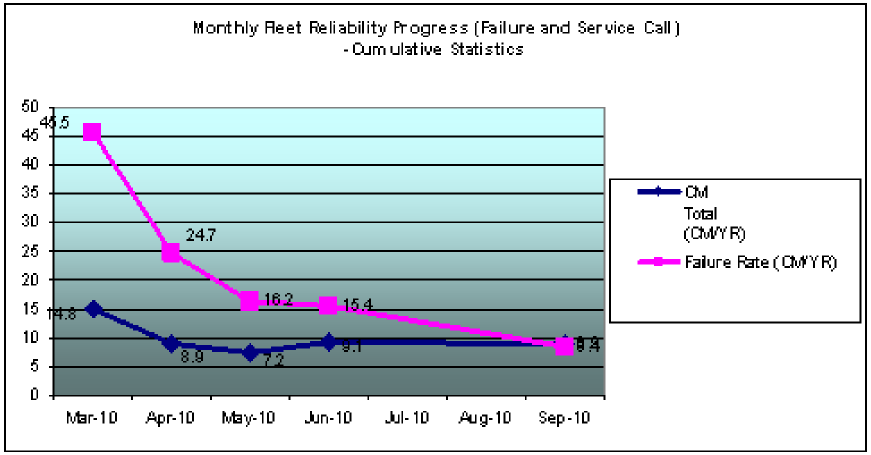


TASK 1.5: LONG TERM TESTING

Internal fleet dashboard metrics:

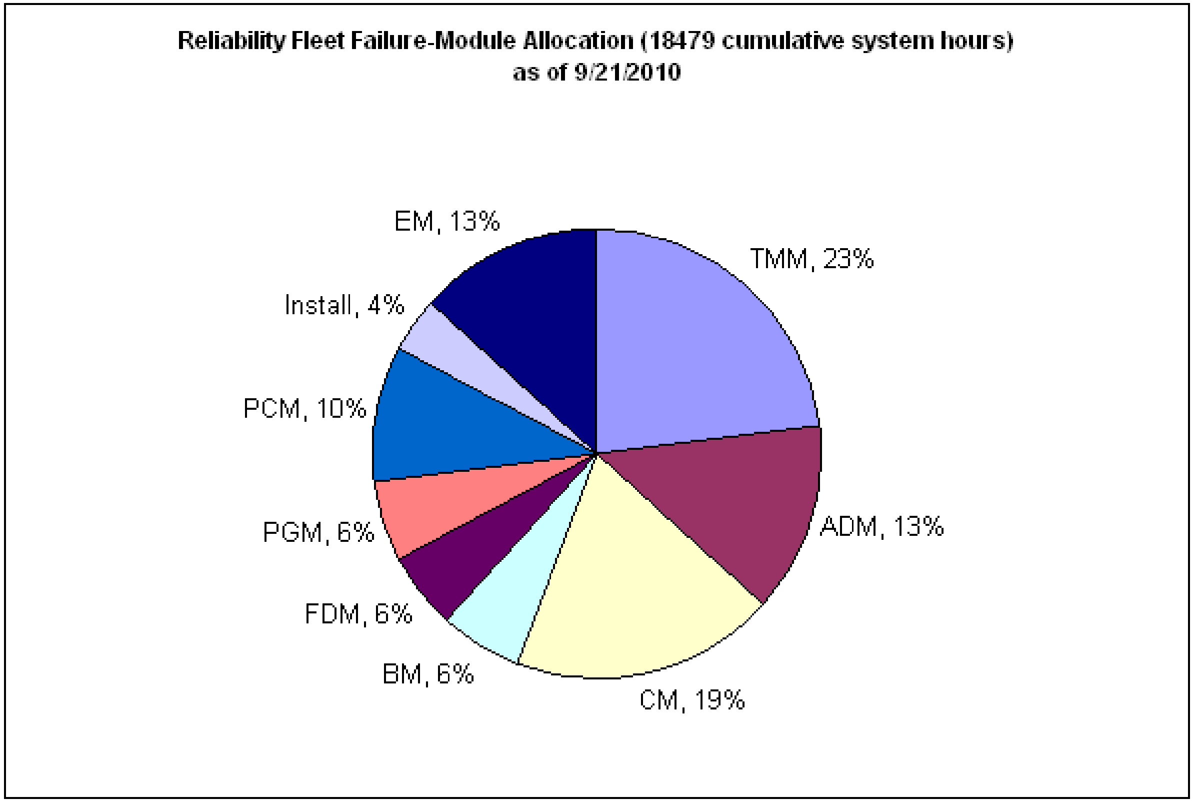
- **6** systems commissioned in Plug Power labs
- Over **18,000** run hours
- **32 MWhrs** of electricity and **163 MWhrs** of heat produced
- Unadjusted heat availability of **97%**
- Unadjusted CHP availability of **85%**
- CHP availability (supplier delivery issues removed) of **94%**





TASK 1.5: LONG TERM TESTING

Fleet failure mode allocation:



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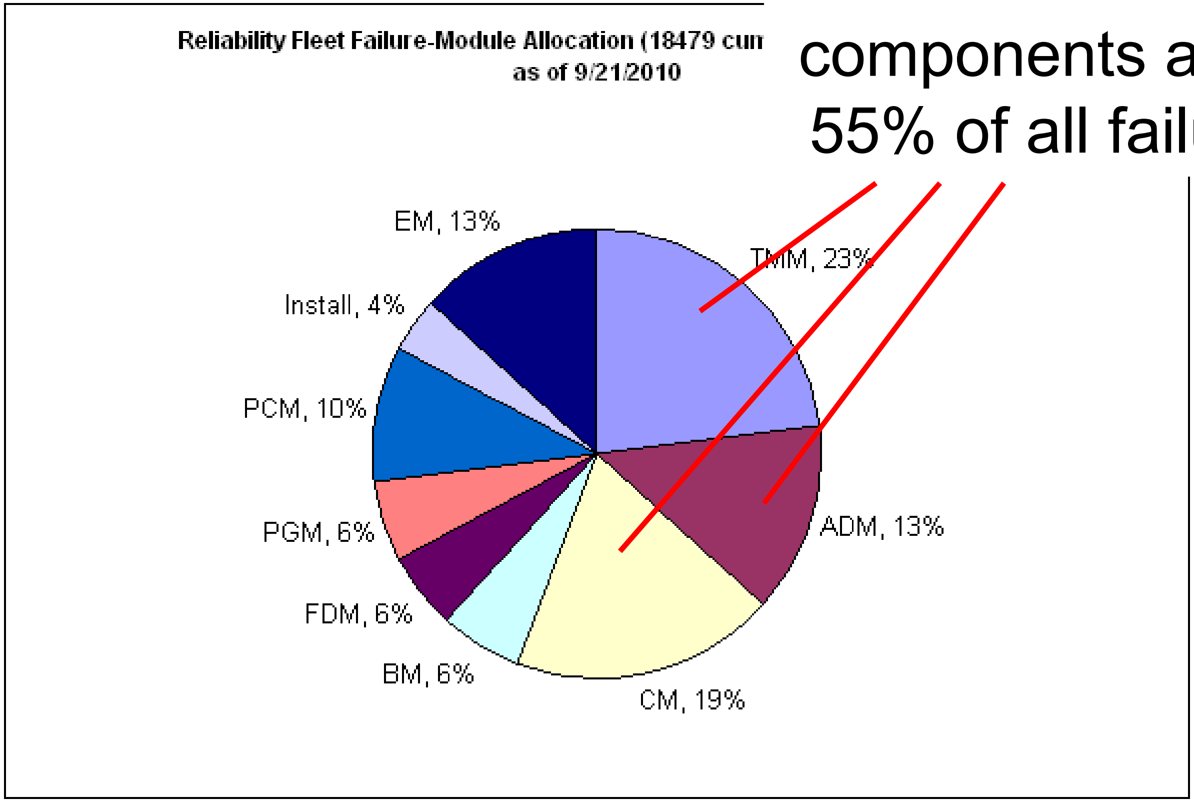


A small number of components account for 55% of all failures seen

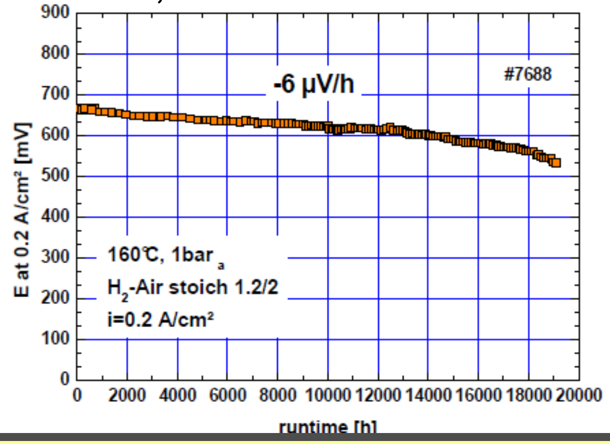
TASK 1.5: LONG TERM TESTING

- Current stack life in system is:
  - 3000-5000 h (6-12 months)

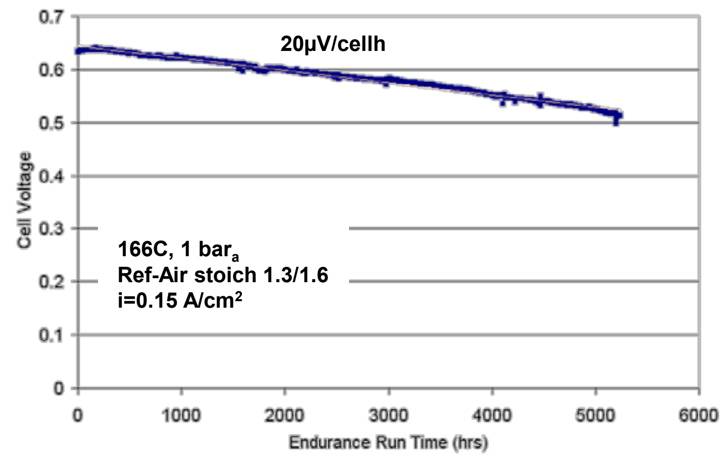
	Before April 2010		After April 2010
	Hrs		Hrs
Epsilon 8	1045		4073
Epsilon 9	580		3801
Epsilon 10	1778		
Foxtrot 2	2068		4742
Foxtrot 3	1913		3098
Foxtrot 4	#N/A		3206
Avg	1476.8		3784

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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Noise	dB(A)	<55 at 10m	<55 at 10m	55 at 1m	<55 at 10m
Emissions (combined NOx, CO, SOx, hydrocarbon, particulates)	g/MWhr	< 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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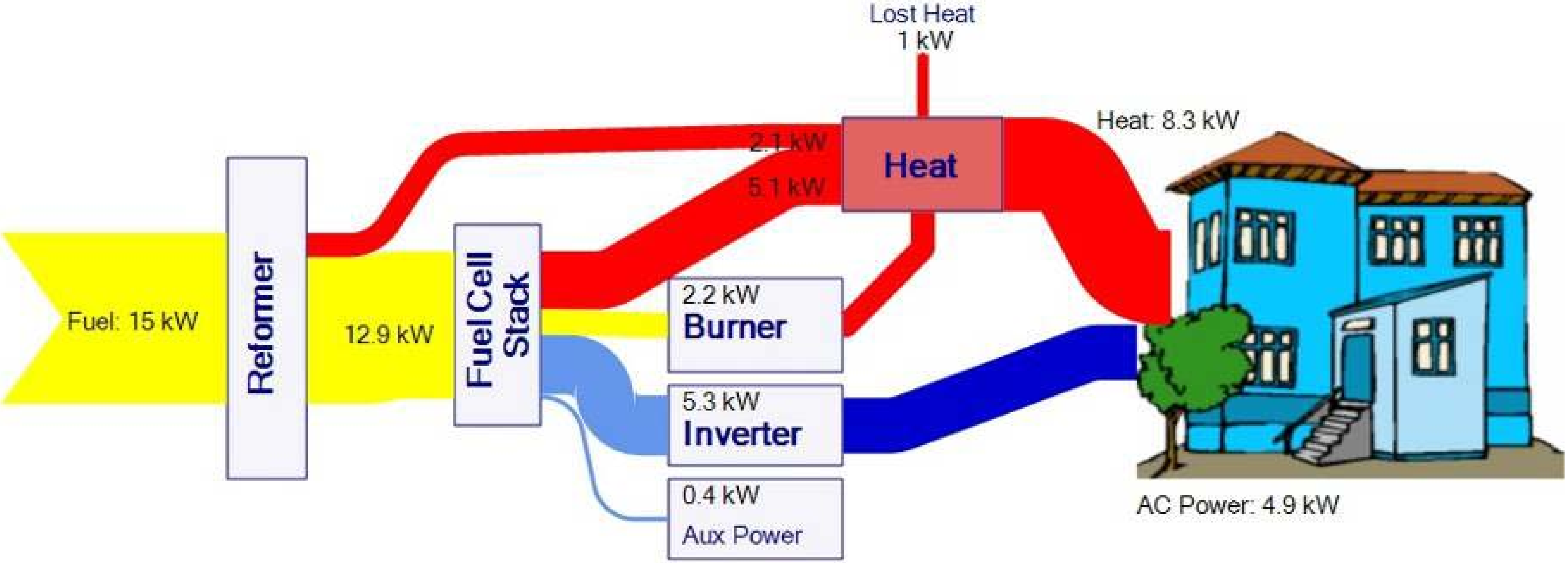
Technical Backup Slides

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