

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

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May 15, 2013
H2RA003



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Today's Fuel Cells for proven, reliable power.

OVERVIEW



UNIVERSITY of
CALIFORNIA
IRVINE



SOUTHERN CALIFORNIA
EDISON



ClearEdge | POWER®

Timeline

- Project start – October 2009
- Project end – September 2013
- 85% complete

Budget

- Total project funding - \$6.7M
 - DOE - \$3.35M / PP - \$3.35M
- Funding in FY09 - \$2.50M
- Funding in FY10 - \$2.56M
- Funding in FY11 - \$0.80M
- Funding in FY12 - \$0.67M
- Status: 97% Complete

Barriers

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

Partners

- Interactions/collaborations
 - University of California Irvine
 - Southern California Gas
 - ClearEdge Power
- Project Leads
 - Dr. Jack Brouwer
 - Randy Brown

RELEVANCE

- **ARRA Objectives Over Project Life**
 - Create new jobs as well as save existing ones; spur economic activity
 - Invest in long-term economic growth
 - Accelerating the commercialization and deployment of fuel cells, fuel cell manufacturing, installation, maintenance, and support services
 - **Use demonstrations to overcome the fuel cell development hurdles of durability, cost, system complexity, and temperature**
 - **Substantiate the durability of Plug Power's 5 kW stationary (PEM) fuel cell system and verify its commercial readiness for the marketplace.**
 - **Task 1 - internal fleet testing**
 - **Task 2 - external customer demos in real-world locations in California**
- **Specific Project Objectives During 2013**
 - **Support ClearEdge as a fuel cell leader in the CHP market to demonstrate it technology in a commercial setting**

APPROACH

Task 1 Internal Durability / Reliability Fleet Testing		Status
Task 1.1	System Design	100%
Task 1.2	System Modeling	90%
Task 1.3	Site Identification and Sselection	100%
Task 1.4	Procure Parts and Build Systems	100%
Task 1.5	Long Term Tests	100%
Go/No Go Decision		Go

Plug Power met the durability testing requirements to proceed to External Test (Task 2)

Task 2 External Customer Demonstration and Testing		Status
Task 2.1	Communication, Education, and Outreach	90%
Task 2.2	Site Prep, NG and Grid Interconn.	100%
Task 2.3	Build and Installation	100%
Task 2.4	Demonstration Testing and Maintenance	50%
Go/No Go Decision		No Go for Plug Go for ClearEdge
Task 2.5	Decommissioning	0%

Plug Power ceased plans for GenSys ECAT

- Stack MEA quality issues
- Continuity of supply issues

Task 3 Project Management		Status
Task 3.0	Project Management	90%
Task 3.1	Cost Analysis	0%

Subcontracted ClearEdge to carry out 1-year demos at two sites

ACCOMPLISHMENTS (PRE-2012)

- **Fleet of 6 systems located at Plug Power**
- 31,000+ run hours; 53 MW-hrs elec, 633 MW-hrs heat

Plug Power CHP System Performance Metrics (Through December 2011)

System S/N	E8	E9	E10	F2	F3	F4	Totals	Average
Commissioned Date	Jan-10	Jan-10	Apr-10	Jan-10	Mar-10	Jun-10		
System Runtime (Hours)	7,823	4,381	1,777	8,977	5,011	3,249	31,219	5,203
Current Stack Runtime	6,058	3,802	1,777	1,651	3,098	3,249	19,635	3,273
Burner Runtime	11,443	9,910	8,344	7,958	11,191	8,264	57,109	9,518
Electrical kWh	15,247	7,349	2,520	15,109	6,679	6,002	52,905	8,818
Thermal kWh	117,862	101,859	95,252	112,070	122,348	83,607	632,998	105,500
Startup Reliability	60.0%	70.0%	71.4%	64.0%	56.3%	54.5%		62.7%
Heat Operational	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%
CHP Operational	71.9%	39.2%	55.7%	70.4%	53.8%	46.9%		56.3%

Plug Power Systems Lab



- **Fleet of 3 systems located at UC-Irvine**

Design Improvements

- **Efficiency: 89% total peak to 94%**
- **Manuf: Build reduced from >120 to <50 hr**
- **DMC Reduction: ~\$90k to \$53k in volumes < 20**

University of California - Irvine



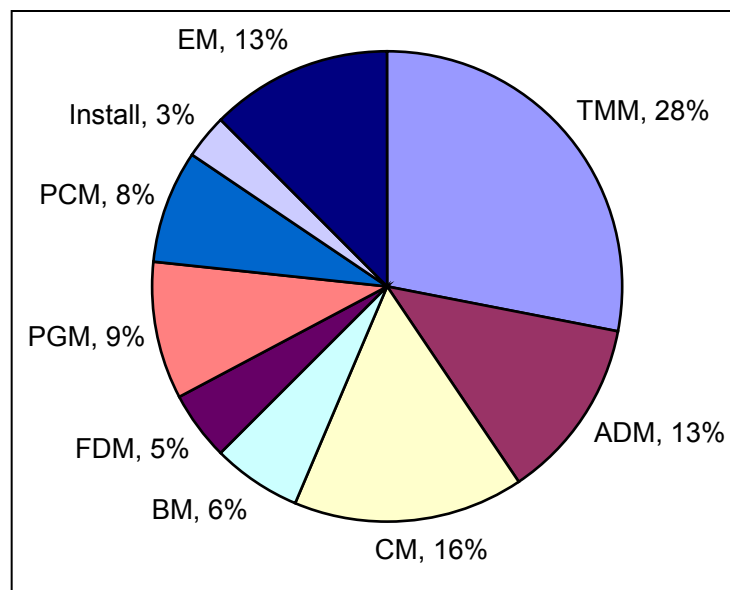
ACCOMPLISHMENTS (PRE-2012)

Defining the Top Problem Set

- PGM: Stack life less than 8000 hours
- PGM: Stack cell variability
- TMM: Pump - seal, seizing, electronics
- TMM: Oil leaks - stack gasket leaks
- TMM valve seizing and coupling failure
- ADM: manifold material warping
- ADM: valve seizing, controls
- BM: Igniter failure – materials / temp
- CM: Sola failure due to voltage
- CM: valve position drift/loss
- FDM: Reformer temperature too high

Module Acronyms

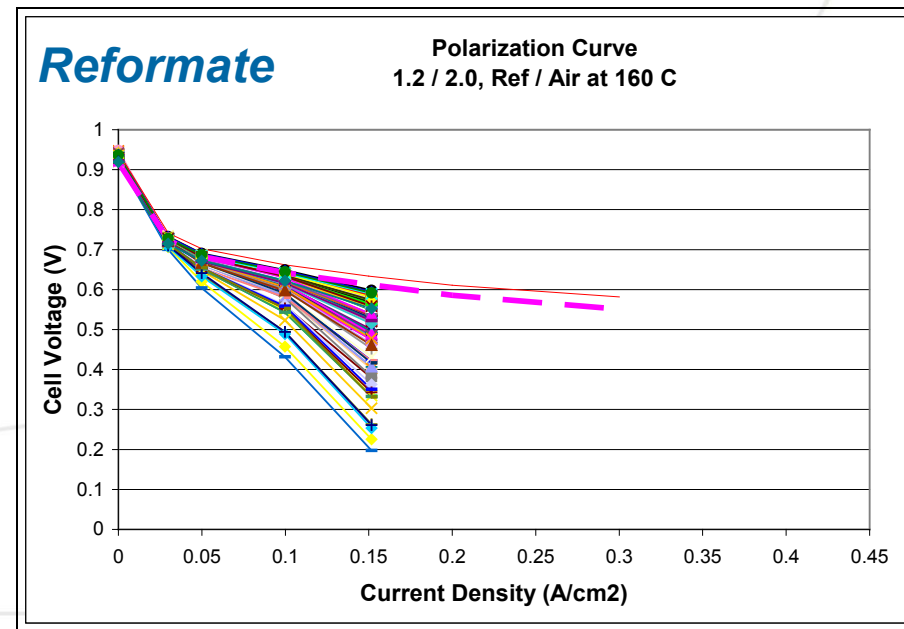
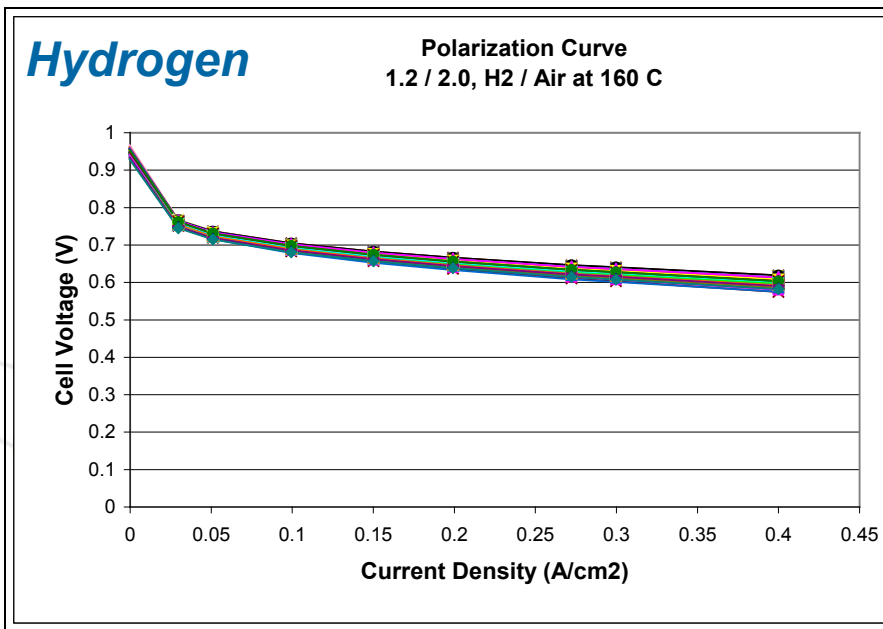
TMM	Thermal Management
ADM	Air Delivery
CM	Controls
BM	Burner
FDM	Fuel Delivery
PGM	Power Generation
PCM	Power Controls
Install	Installation
EM	Electronics



APPROACH – PRE-2012

Stack Quality Issues

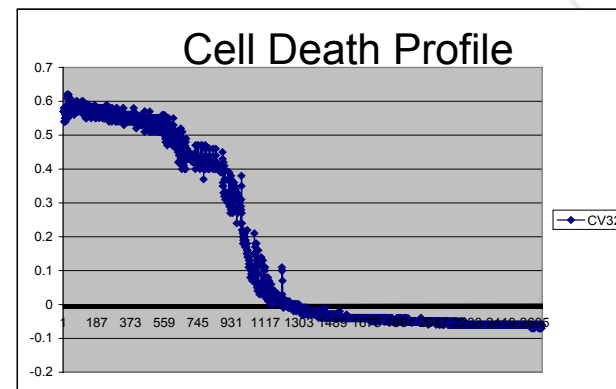
- **GenSys Blue MEA production was moved to another manuf. process**
- **Hydrogen tests looked strong**
- **Reformate test- cell-to-cell variability**
- **Stacks would have multiple weak cells**



APPROACH – PRE-2012

Stack Failure Signature

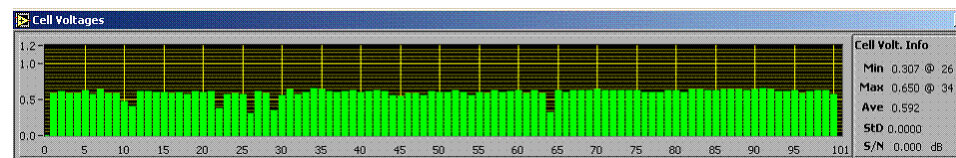
- Cells looked weak then dropped off rapidly
- Cell went negative, forced shutdown
- Stack failures within 1 week of operation



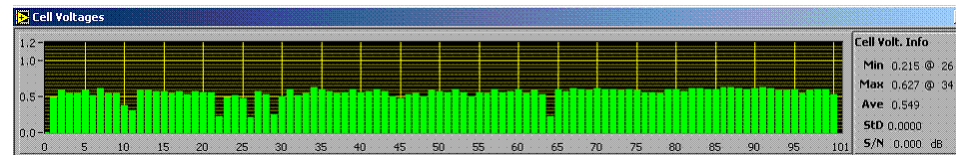
Changes to Operating Points

- High stoic conditions did not improve weak cells
- Additional cells crashing at 1.6 anode stoic

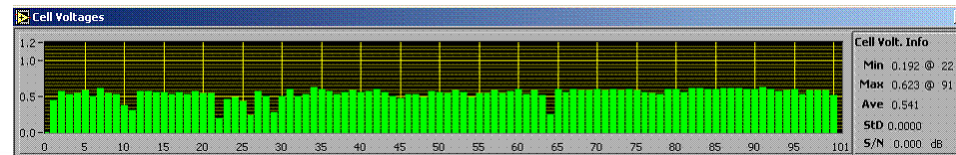
1.91 Anode Stoichs 30A on Reformate



1.63 Anode Stoichs 35A on Reformate



1.58 Anode Stoichs 36A on Reformate



APPROACH – 2011/2012

- **Discussions held with BASF - troubleshooting sessions over many months**
 - Catalyst issues
 - Over Compression
 - Phos Acid Blinding of Catalyst
 - Prototype Consistency
 - Raw Materials
 - Stack Assembly
- **BASF offered a standard format MEA design to substitute Plug Power's custom configuration**
 - Would require prohibitive stack redesign
 - Did not want home customers to experience early stack failures
 - Decided risk was too great to move forward
- **Decision: Go with ClearEdge Units**

APPROACH

- Go / No Go Decisions

6A Target Performance and Go/No-Go Decision Chart					
Characteristic	Units	Goal	1st GO - 2Q10	1st GO Actual	2nd GO - 2Q11
Electrical efficiency at rated power	%	40	>30	32%	>30
CHP efficiency at rated power	%	90	>80	90%	>80
Cost (qnty < 15)	\$/kWe	10,000	20,000	10,400	20,000
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 NOx, CO, SOx, hydrocarbon, particulates)	g/MW hr	< 1.5	< 1.5	< 1.5	< 1.5
				GO	NO GO

APPROACH

- Over the past 4+ years, Plug Power has remained determined to use the program to move the fuel cell market forward in the face of changes within the company and fuel cell industry.



Plug Power Development

2009-2012: Plug Power lead on Internal Customer Acceptance Testing (Task 1)

5/10: PP “focus commercial activity on material handling market”

Subcontracting with ClearEdge

2012-2013: Plug Power subcontracts ClearEdge to demo ClearEdge CHP units in commercial opportunity



ACCOMPLISHMENTS (2012 – 2013)

- **2 ClearEdge 5 units installed, commissioned, running**

UCI Irvine (7/25/12)

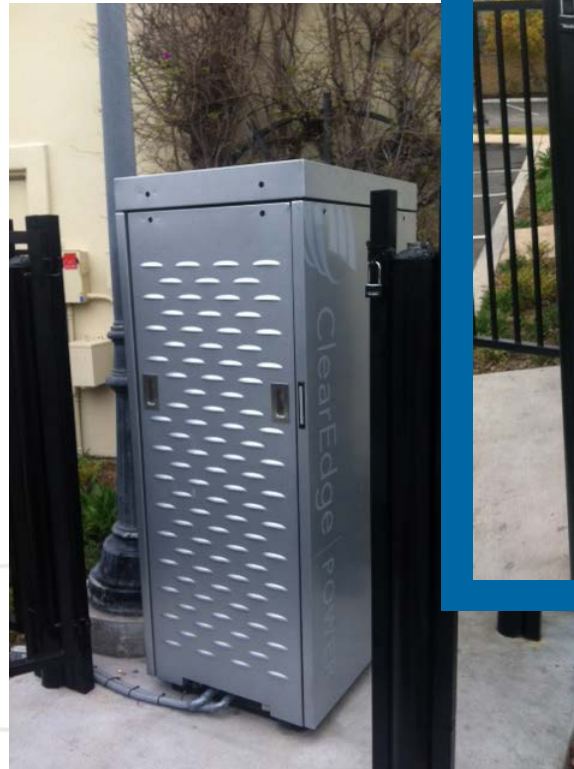
Irvine, CA

- **Availability: 98.2%**
- **Run Time: 5,134 hrs.**
- **Elec: 20,532 kW-hr (36% Eff.)**
- **Heat: 23,269 kW-hr (78% Eff.)**

• Taco Bell (9/28/12)

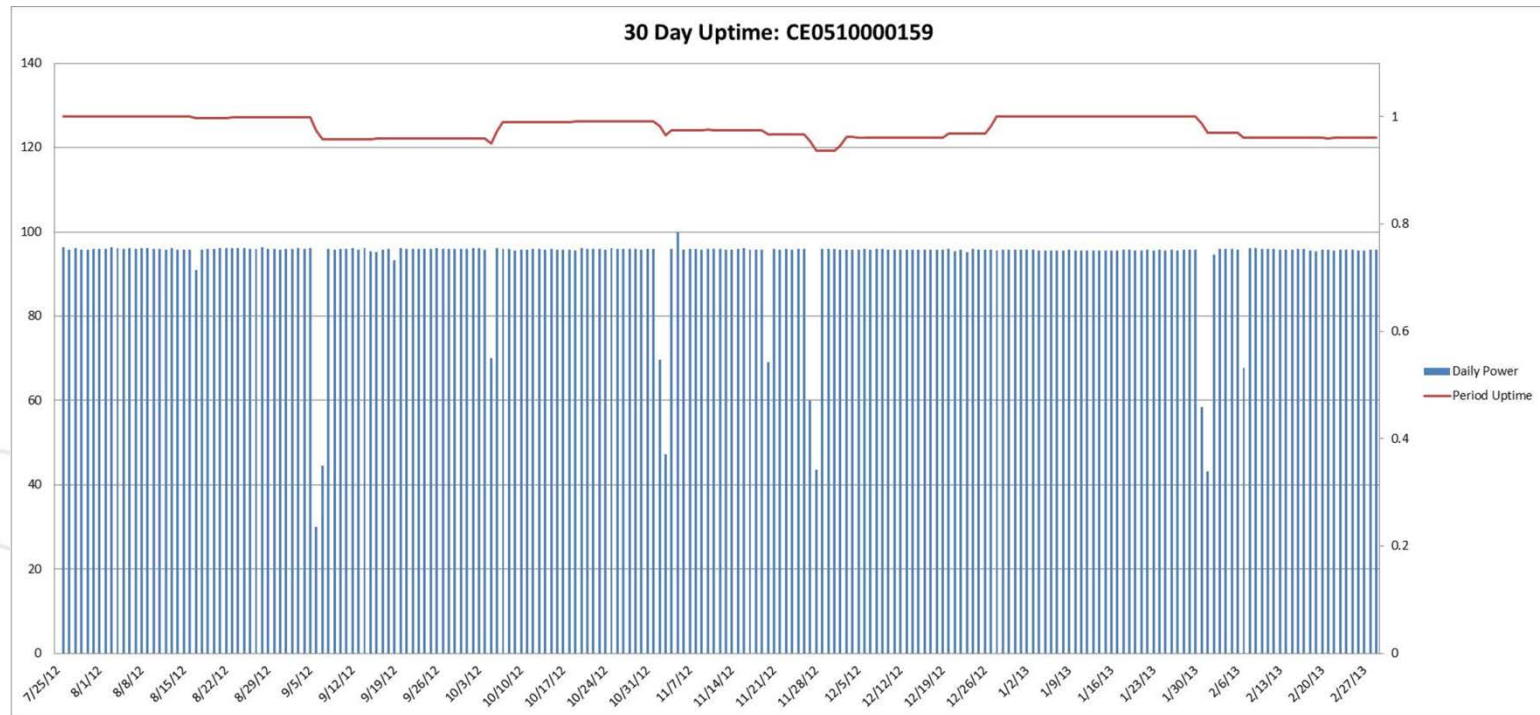
San Juan Capistrano, CA

- **Availability: 95.6%**
- **Run Time: 3,482 hrs.**
- **Elec: 13,962 kW-hr (35% Eff.)**
- **Heat: 15,825 kW-hr (76% Eff.)**



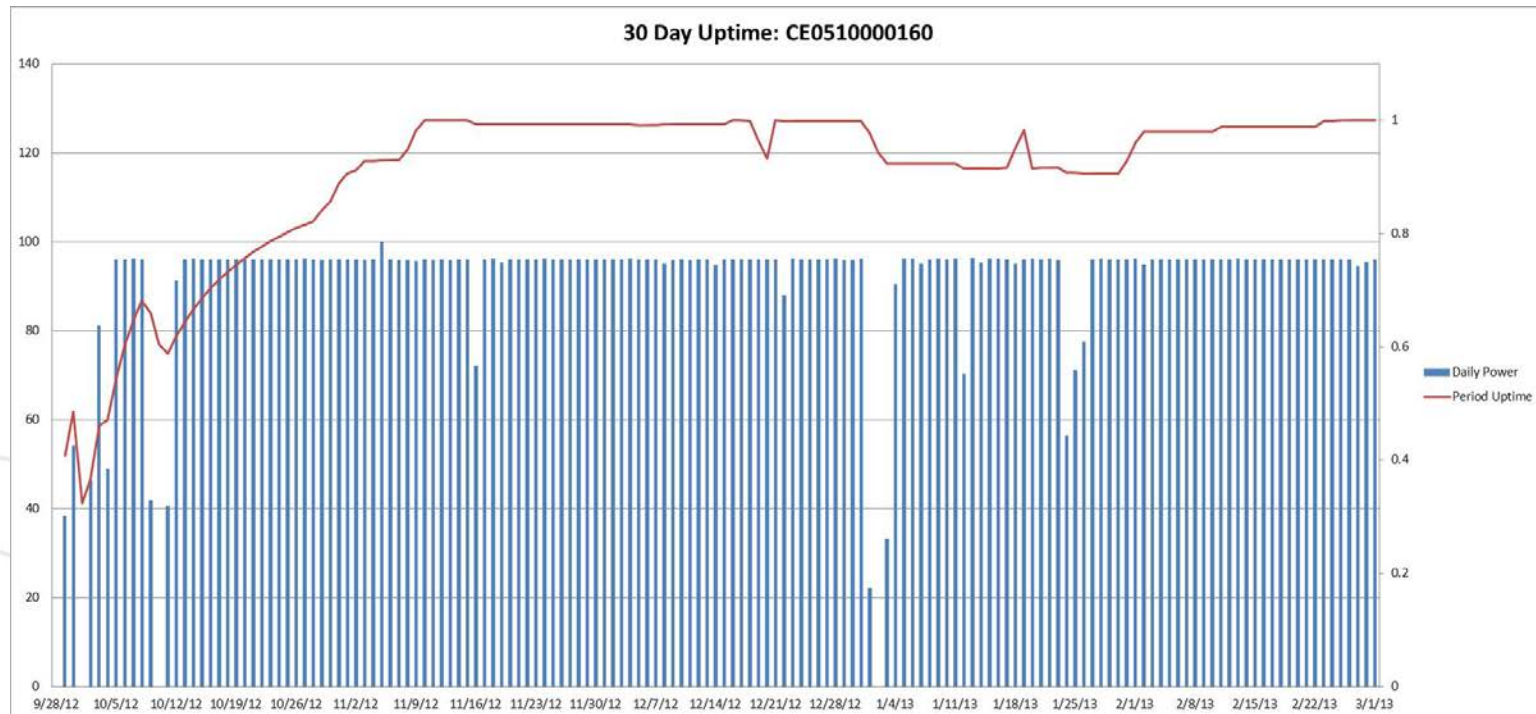
ACCOMPLISHMENTS (2012 – 2013)

- **System Commissioned: 7/25/12**
- **% of Demo Complete: 60%**
 - Availability: 98.2%
 - Run Time: 5,134 hrs.
 - Elec: 20,532 kW-hr (36% Eff.)
 - Heat: 23,269 kW-hr (78% Eff.)



ACCOMPLISHMENTS (2012 – 2013)

- **System Commissioned: 9/28/12**
- **% of Demo Complete: 42%**
 - Availability: 95.6%
 - Run Time: 3,482 hrs.
 - Elec: 13,962 kW-hr (35% Eff.)
 - Heat: 15,825 kW-hr (76% Eff.)



COLLABORATION



**GenSys Blue Fuel Cell Development
Task 1 Testing (Internal Customer Acceptance Testing)
Program Management**

**California Utility Partner
Cost-share Partner**



**Subcontracting with ClearEdge – 2012 / 2013
Demonstration of two ClearEdge CHP units in
commercial opportunity**

**Task 1/Task 2 Testing Location / Cost-share Partner
Model for Refining Controls and Improving Operation**



Data Reduction and Publishing

FUTURE WORK

- **Continue running the two ClearEdge demonstration units**
- **Decommission of UCI system in July (2 more months from May)**
- **Decommission of Taco Bell system in September (4 more months from May)**
- **Quarterly reports – Q1 (in April 2013), Q2 (in July 2013)**
- **Cost analysis**
- **Final report – Sept/Oct 2013**

SUMMARY

Topic 6A	2009	2010	2011	2012
Q1		7.4	2.7	0.6
Q2		6.5	1.7	0.3
Q3	12.0	3.1	1.4	0.05
Q4	8.0	2.0	0.4	0.3
Total	20.0	19.0	6.1	1.3

Relevance:

- **Jobs Created: 13.25 person-years**
- **Continued investment into CHP fuel cells, even outside of Plug Power**

Approach:

- **Task 1 testing successfully completed**
- **Stack supply led to No Go for Plug; Go for ClearEdge for Task 2**

Collaborations:

- **ClearEdge, University of California – Irvine, Southern California Edison, NREL**

Future Work:

- **Finish ClearEdge demonstrations**
- **Cost analysis**
- **Quarterly and final reporting**