2012 DOE Hydrogen Program Annual Merit Review

Development and Demonstration of a New Generation High Efficiency 10kW Stationary PEM Fuel Cell System

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Overview

Timeline

Start Date: July 2007

End Date: June 2012

Percent Complete: 94%

Budget

Total : $4,998,938

Total DOE obligation: $2,404,863

Planned Funding for FY12: $0

Metric	2011 Status	2015 Target	2020 Target
Electrical Efficiency	34-40%	42.5%	>45%
CHP Energy Efficiency	80-90%	87.5%	90%
Equipment Costs $10kW_{avg}$ system	NA	$\$1900/kW_{avg}$	$\$1700/kW_{avg}$
Operating Lifetime	12,000 hours	40,000 hours	60,000 hours

Project Partners

- California Polytechnic University, Pomona
- University of South Carolina
- Sandia National Labs
- Intelligent Energy Ltd.
- Scottish Southern Energy

Relevance

- **Project: To Develop a High Efficiency 10kW PEM Fuel Cell CHP System and Demonstrate in IPHE Country (UK)**
- **Project Objectives for 2012 to Progress Towards DOE Targets**

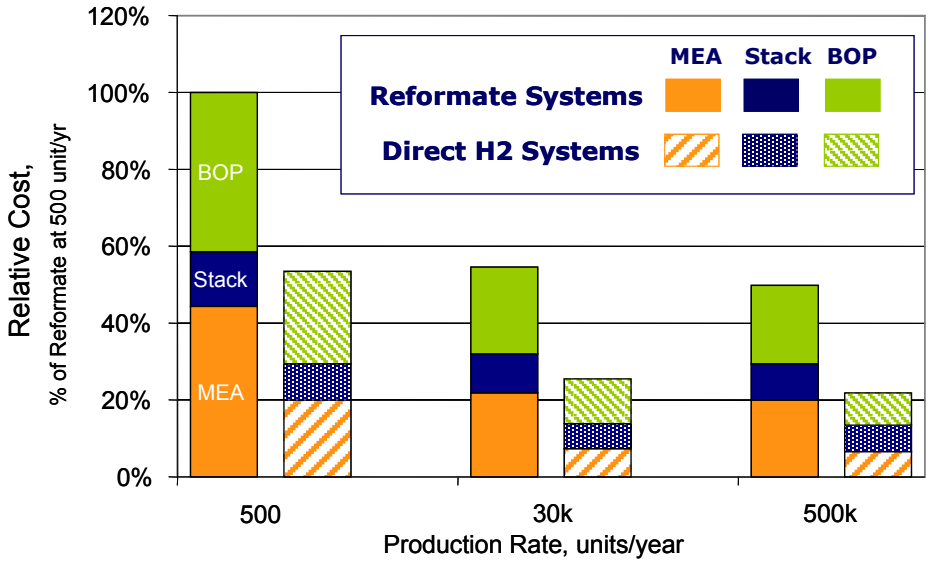
DOE 2011 Target	Project Objectives	2012 Objectives
34-40% electrical efficiency	40% electrical efficiency	37% (SMR)
80-90% overall efficiency	>70% efficiency	78% (SMR)

- Parallel development of alternative fuel processor (AER)
- Pure hydrogen, high efficiency PEM FCs suitable for multiple applications
- Volume cost reduction strategy "design once, deploy many times"

Approach

Phased Development of an Open Architecture System with a Pure H_2* Interface Between the Fuel Cell & Fuel Processor

- Advantages
  - Improved fuel cell performance
  - Increased fuel cell lifetime
  - Lower fuel cell cost
  - Smaller reformer
  - High fuel utilization
  - Simplified integration
  - Independent operation of fuel cell, fuel processor
  - "Plug and Play"



- **Task 1**-Technology Building Blocks Development and Evaluation (100% Complete)
- **MILESTONE: GO/NO-GO #1 DECISION ACHIEVED**
- **Task 2**-CHP Prototype Engineering Design and Configuration (100% complete)
- **Task 3**-CHP Prototype Construction and Validation Testing (100% complete)

  MILESTONE: GO/NO-GO #2 DECISION ACHIEVED
- **Task 4**-CHP system retrofit, optimization and field demonstration (94% complete)

*99% or greater

Approach

- Model-based systems engineering using industry standard software
  - **Address trade-offs for optimization at both subsystem and system level**
- End-to-end system integration with prototype test and validation unit (SMR + PSA 2010/11)
  - **Real data for model inputs**
  - **Automated controls development**
  - **Multiple level safety systems**
- CE certification (SMR + PSA 2012)
  - **Addresses safety and manufacturability**
- Pure hydrogen PEM FC
  - **Addresses durability**
  - **Addresses high electrical efficiency**
  - **Addresses lower costs**

- Low cost, highest efficiency hydrogen generator will plug into existing architecture (*AER 2012/13- Proposal submitted for funds-FOA-0000360*)

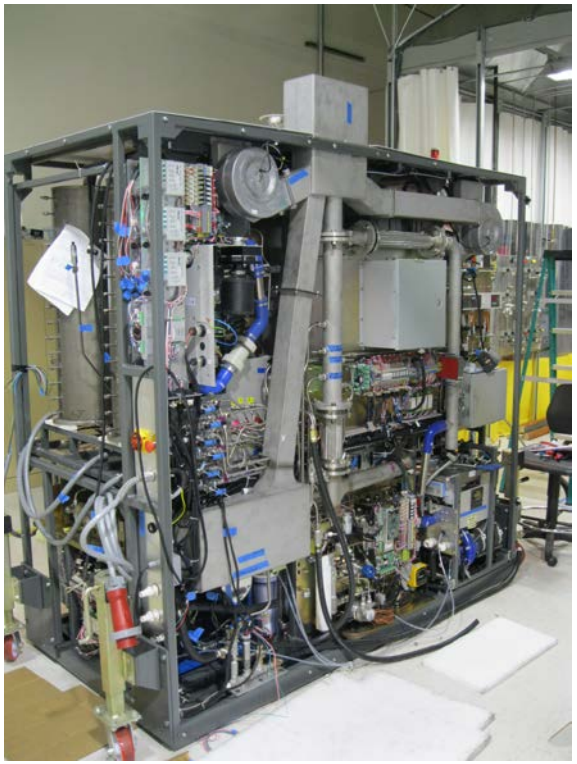
Technical Accomplishments

Prototype-previous work [Tasks 1-3]

	Expected Initial Performance @ 10kW	Achieved with Prototype @ 11kW	Projected Performance of Demonstrator (Task 4)
Pure Hydrogen Produced (SLPM)		135	
Natural Gas Fed to Reformer (SLPM)		54	
Natural Gas Fed to Combustor (SLPM)		6.3	
Hydrogen fed to Combustor (Proxy for PSA off-gas) (SLPM)		5	
Pure Hydrogen generation LHV efficiency	72%	68.2%	73%
Fuel cell Gross power (W)		11540	
Hydrogen Consumed by Fuel Cell (SLPM)		120	
Gross Efficiency of Fuel Cell	53%	53.4%	59%
Fuel cell parasitic power (W)	720	620	620
Hydrogen production parasitic power (W)	850	610	610
Percentage of DC Power Available to Customer	89.4%	89.4%	89.4%
End-to-End Electrical Efficiency (Electricity Out / LHV Fuels In)*	**34.1%**	32.6%	**38.5%**
Thermal Power Recovered from Hydrogen Generator (W)	4200	2732	3500
Thermal Power Recovered from Fuel Cell (W)	4200	6640	9000
End-to-End Thermal Efficiency	**27.6%**	30.1%	41.1%
Overall Combined Heat and Power Efficiency	**61.7%**	**62.7%**	**79.6%**

Technical Accomplishments

Demonstration Unit-previous work [Tasks 4]



Commissioning and initial field operation

CHP Unit	I (UK)	II (US)
Hot Hours	1370	863
Reforming Hours	531	625
Fuel cell Hours	25	62
Cold Starts	70	48
Warm Starts	107	172

- CH_4 conversion: ~82%
- PSA H_2 recovery: ~67%
- H_2 Generated/CH_4 feed: ~2.04
- LHV efficiency for H_2 Generation: ~61%
- Fuel cell gross efficiency ~59% (FC Net efficiency ~55%)
- Overall electrical efficiency ~33%*

*NG compression and DC/AC inversion demands not factored in and system not yet optimized

Technical Accomplishments

Demonstration Unit-previous work [Task 4]

- EMC pre-scan for CE mark completed
- Unit tested grid-tied in Long Beach
- Produces FCS grade hydrogen after new PSA/methanator were installed
  - FCS is operating with 500ppm methane
- Shipped to Scotland and recommissioned
- Site safety assessment completed (PUWER)* and municipal sign-off for operation
- Second identical unit commissioned and running grid-tied in Long Beach IE facility
- Optimization and CE unit certification in progress

Demonstration Unit Installed in Scotland

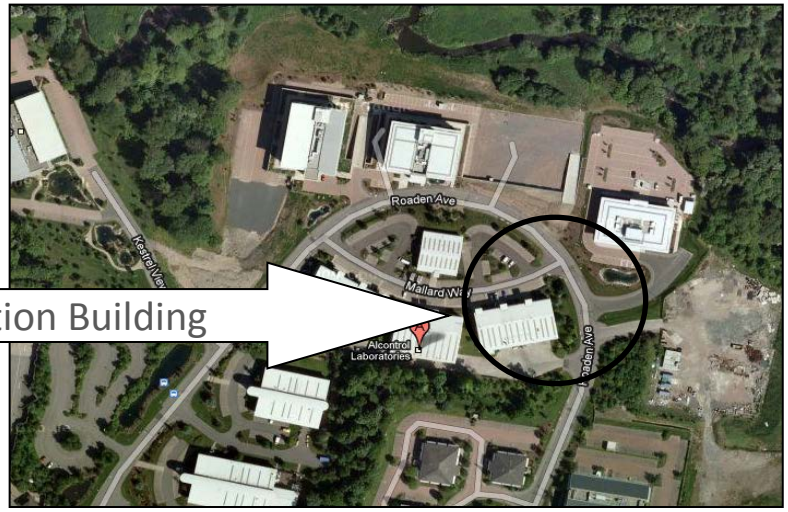
*The Provision and Use of Work Equipment Regulations

Technical Accomplishments

Site Selection (change from previous year)

Bellshill Scotland

- Located 20 minutes from Glasgow Scotland
- Received exclusion from NEPA site requirement
- Facility owned by IE partner IE-CHP
- Unit will be operated past the end of current DOE contract and data will be provided as it comes available



Demonstration Building

Technology Transfer

- Additional investment beyond DOE program to establish strong CHP presence in the UK/IRE market
  - Joint venture with Scottish and Southern Energy (UK)
  - System installer and maintenance subcontractor UPS Systems PLC
  - Site modeling and controls subcontractor Element Energy (UK)
  - Technology Strategy Board (UK)
- California State Polytechnic University Pomona
  - Helping develop future professionals who will possess knowledge of green technologies

Future Work Through 2012

- Complete CE testing
- Obtain CE mark
- Field Trial
  - Expected operation is for 24/7
  - Data streamed in real-time to IE Knowledge Room via SHM
  - Testing will be witnessed by SSE (owners of electrical grid) periodically
- Program Closure

Summary

- 2012 field demonstration of system carrying the CE mark
  - Approximately 30% smaller than prototype
  - FCS operating with hydrogen from SMR+PSA/methanator containing 500ppm methane
  - Use of higher efficiency twin stack configuration with additional long-term cost benefit
- Strong corporate commitment to CHP markets and technology development
  - Joint venture with Scottish and Southern Energy
- 2013/14 development of integrated AER+FC CHP system with the potential to achieve 40% electrical efficiency, ~$750/kW and 40,000 hours durability
  - Proposal submitted for funding to DOE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