U.S. DEPARTMENT OF ENERGY

Fuel Cell Technologies

Dimitrios Papageorgopoulos

2009 DOE Hydrogen Program & Vehicle Technologies Program

Merit Review and Peer Evaluation Meeting

May 19, 2009

Goal and Objectives

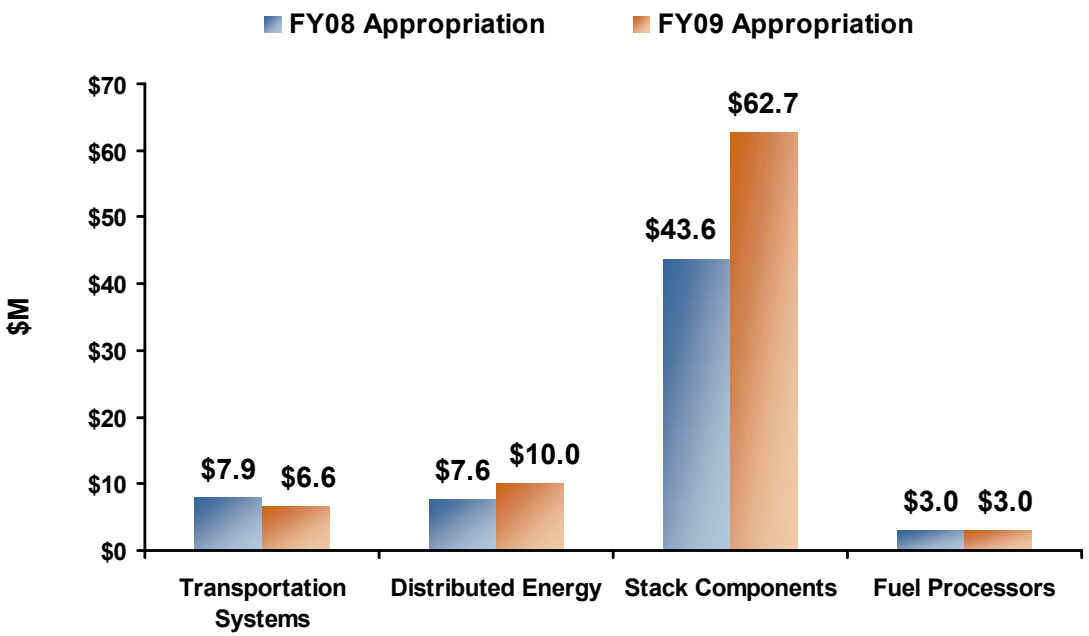
***Goal:* Develop and demonstrate fuel cell technologies for transportation, stationary, and portable power applications.**

- **Stationary power and other early market fuel cell applications**
  - By 2011, develop a distributed generation PEM fuel cell system operating on natural gas or LPG that achieves 40% electrical efficiency and 40,000 hours durability at $750/kW.
  - By 2010, develop a fuel cell system for consumer electronics (<50 W) with an energy density of 1,000 Wh/L.
  - By 2010, develop a fuel cell system for auxiliary power units (3-30 kW) with a specific power of 100 W/kg and a power density of 100 W/L.
- **Transportation applications**
  - By 2010, develop a 60% peak-efficiency, direct-hydrogen fuel cell system at a cost of $45/kW with 5,000 hours of durability; by 2015, a cost of $30/kW.

Budget

FY 2009 Appropriation = $82.3M

FY 2008 Appropriation = $62.1M



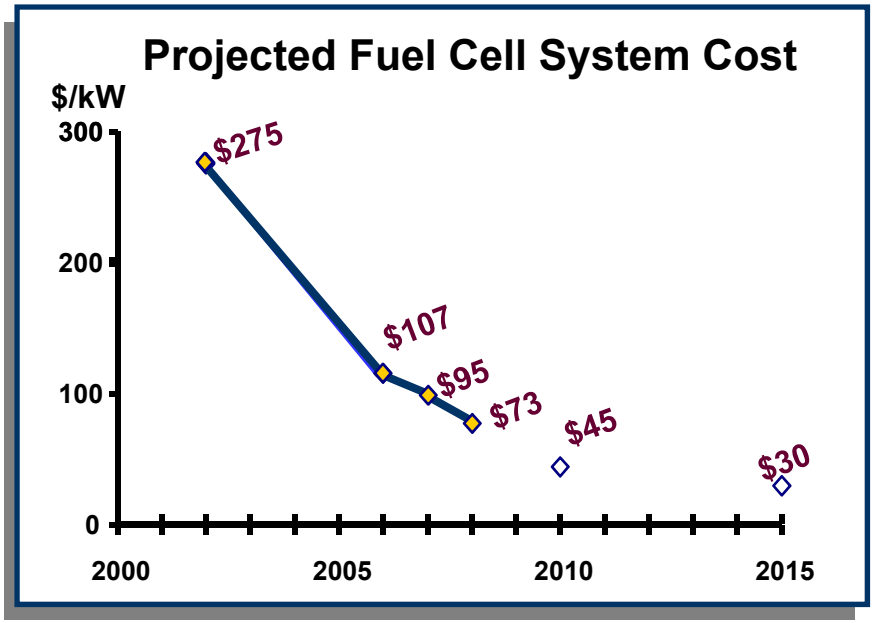
EMPHASIS

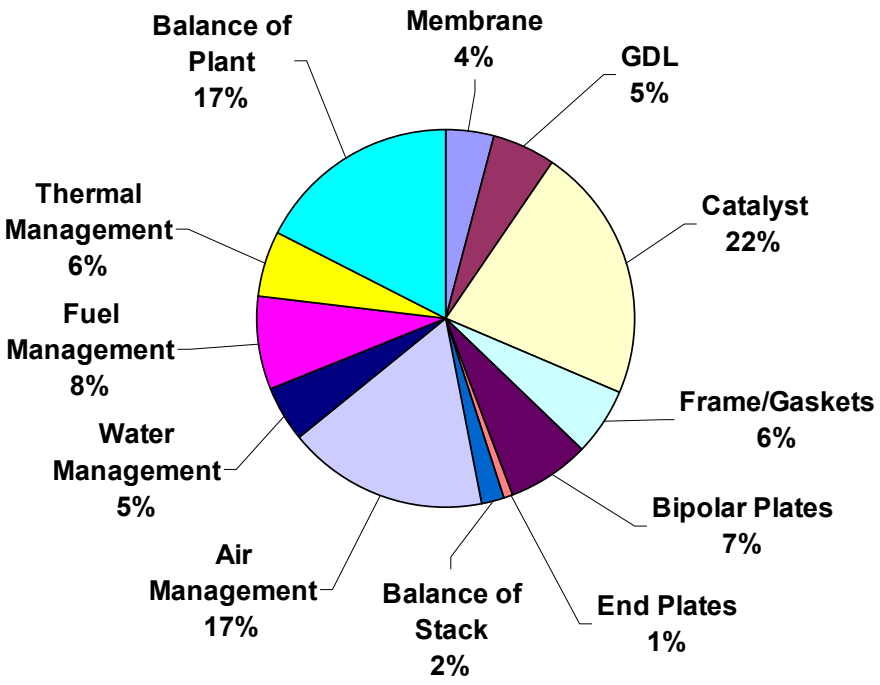
- Develop membranes for high-temperature, low-relative humidity operation; assess progress against interim targets.
- Increase catalyst activity and reduce platinum group metal loading to lower fuel cell cost.
- Design strategies to mitigate stack component degradation.
- Use quantitative performance degradation measurements to prepare ISO Hydrogen Fuel Product Specification Draft International Standard.
- Optimize water management properties.

Reducing Cost and Improving Durability are Major Challenges

Projected 80 kW Fuel Cell System Cost Reduced to $73/kW

- Based on DTI DFMA 2008 cost analysis
- Projected to a manufacturing volume of 500,000 units/year
- Independent panel validates cost projection ($60 - $80/kW)

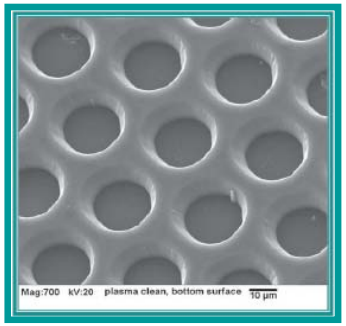




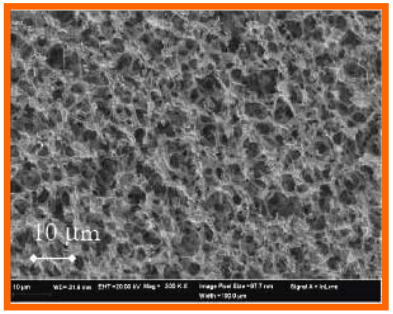
80 kW, direct-hydrogen PEM fuel cell system

2009 Progress & Accomplishments

Membranes achieve high conductivity at high temperature



2D Support



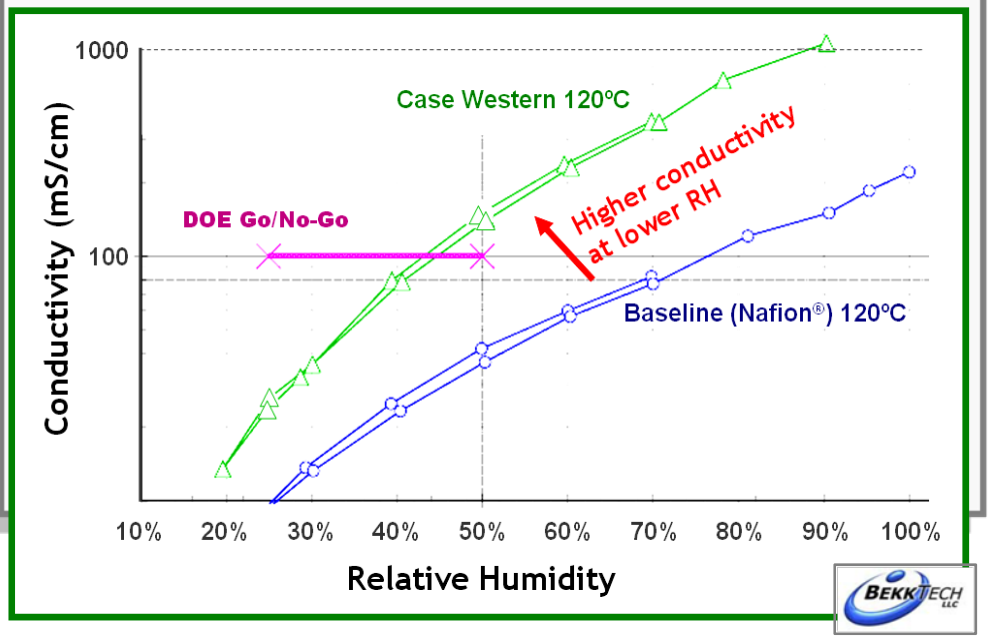
3D Support

GINER *HI-TEMP MEMBRANES*

- ***Giner addressed membrane durability with dimensionally stabilized membrane - demonstrated no x-y swelling***
- ***Met DOE conductivity milestones at 30ºC/80%RH and 120ºC/50%RH; > 2x conductivity of Nafion® over the entire RH range***
- **Benefits**
  - ✓ **Provides mechanical stability and allows lower equivalent weight ionomers**
  - ✓ **Results in better conductivity under low relative humidity**

CASE WESTERN RESERVE UNIVERSITY *HI-TEMP MEMBRANES*

- ***Developed innovative rigid-rod structure that holds water at low RH***
- ***Demonstrated highest conductivity (>140 S/cm) of all membrane projects under high-temperature, low-RH conditions***

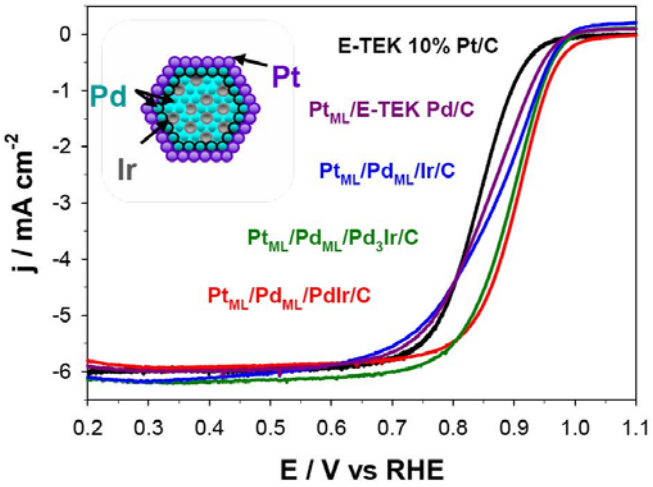


2009 Progress & Accomplishments

Catalysts and MEAs exhibit enhanced performance at lower PGM loading

BROOKHAVEN NATIONAL LAB *CATALYSTS*

- Demonstrated 2.5x activity of baseline Pt/C with Pd interlayer core-shell cathode catalysts (0.34 A/mg_{PGM}), approaching 2015 target of 0.44 A/mg_{Pt}
- Successful industrial scale-up of BNL's $Pt_{ML}/Pd/C$ catalyst in gram quantities accomplished by Cabot

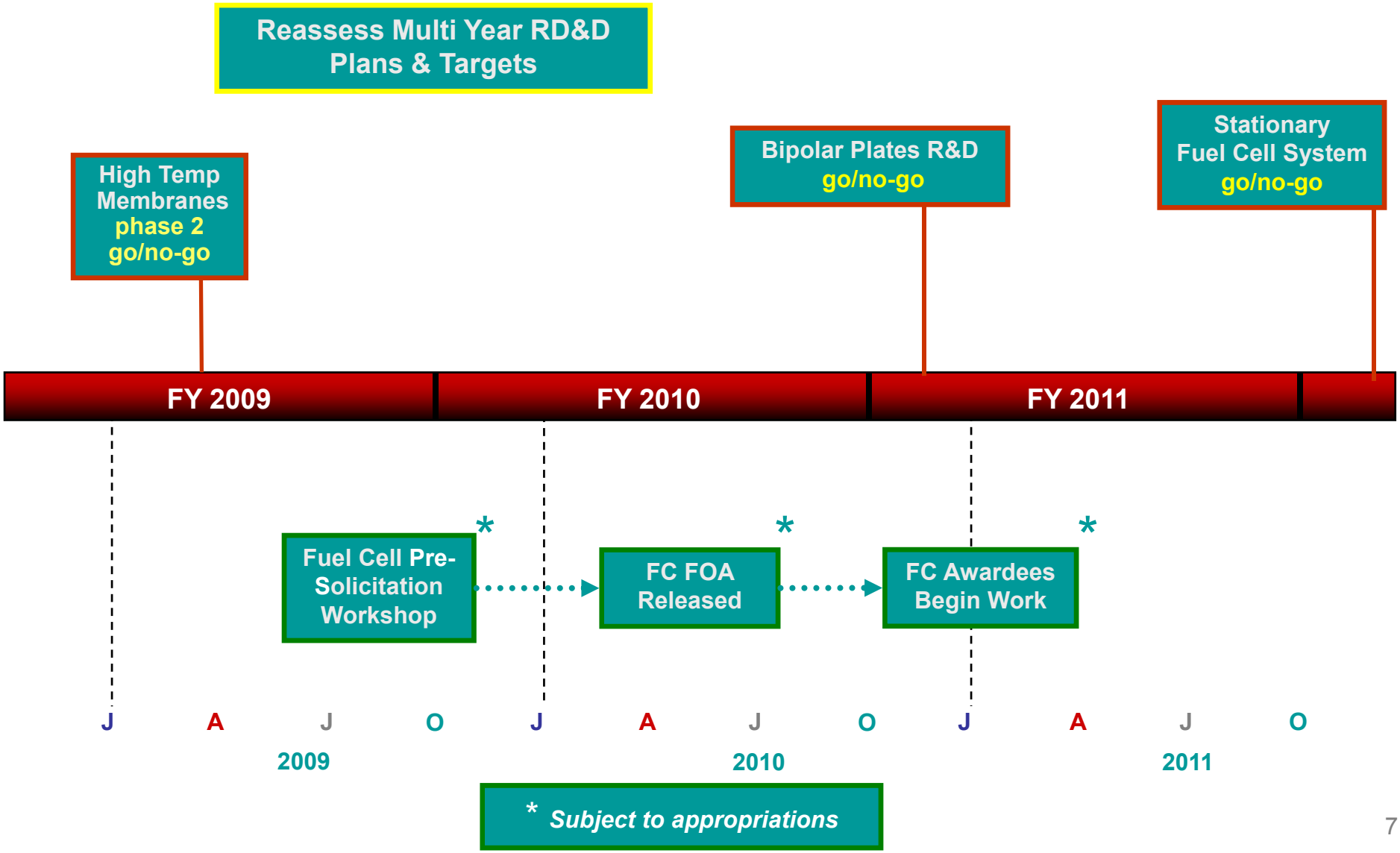


3M *MEAs*

- New baseline MEA has PGM loading of 0.15 mg_{PGM}/cm^2 and 0.18 g_{PGM}/kW, exceeding DOE 2015 targets (0.2 mg_{PGM}/cm^2 and 0.2 g_{PGM}/kW) in single cell testing
- Demonstrated improved durability, exceeding a DOE accelerated stress test protocol runtime by a factor of > 4
- Produced over 45,000 linear ft combined of NSTF substrate, coated catalyst, and catalyst coated membrane for process development, qualification and use

Summary

Major Milestones & Future Solicitation



For More Information

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Tuesday Fuel Cell Presentations

Start	Presenter	Organization	Title
8:15	Dimitrios Papageorgopoulos	DOE	Fuel Cell Technologies
Membrane Research and Development			
8:30	James Fenton	U of Central Florida	Lead Research and Development Activity for DOE's High Temperature, Low Relative Humidity Membrane Program
9:00	Cortney Mittelsteadt	Giner	Dimensionally Stable Membranes
9:30	Serguei Lvov	Penn State	New Proton Conductive Composite Materials with Co-continuous Phases Using Functionalized and Crosslinkable VDF/CTFE Fluoropolymers
10:00	Jimmy Mays	U of Tennessee	Poly(cyclohexadiene)-Based Polymer Electrolyte Membranes for Fuel Cell Applications
10:30	**Break**		
11:00	James McGrath	Virginia Tech	Advanced Materials for Proton Exchange Membranes
11:30	Dominic Gervasio	Arizona State	Protic Salt Polymer Membranes: High-Temperature Water-Free Proton-Conducting Membranes
12:00	Stephen Creager	Clemson	Fluoroalkyl-phosphonic-acid-based proton conductors
12:30	**Lunch**		
1:45	Morton Litt	Case Western Reserve University	Rigid Rod Polyelectrolytes: Effect on Physical Properties Frozen-in Free Volume: High Conductivity at Low RH
2:15	Peter Pintauro	Vanderbilt University	NanoCapillary Network Proton Conducting Membranes for High Temperature Hydrogen/Air Fuel Cells
2:45	Ludwig Lipp	FuelCell Energy	High Temperature Membrane with Humidification-Independent Cluster Structure
3:15	Andy Herring	Colorado School of Mines	Novel Approaches to Immobilized Heteropoly Acid (HPA) Systems for High Temperature, Low Relative Humidity Polymer-Type Membranes
3:45	**Break**		
4:15	James Goldbach	Arkema	Improved, Low-Cost, Durable Fuel Cell Membranes
4:45	Steven Hamrock	3M	Membranes and MEA's for Dry, Hot Operating Conditions
5:15	John Kerr	LBNL	New Polyelectrolyte Materials for High Temperature Fuel Cells

Wednesday Fuel Cell Presentations

Start	Presenter	Organization	Title
8:30	Susanta Das	Kettering University	Novel PEM Membrane and Multiphase CFD Modeling of PEM Fuel Cells
		Catalysis	
9:00	Christina Johnston	LANL	Applied Science for Electrode Cost, Performance, and Durability
9:30	Mark Debe	3M Company	Advanced Cathode Catalysts and Supports for PEM Fuel Cells
10:00	Vivek Srinivasamurthi	UTC Power	Highly Dispersed Alloy Cathode Catalyst for Durability
10:30		**Break**	
11:00	Yong Wang	PNNL	Development of Alternative and Durable High Performance Cathode Supports for PEM Fuel Cells
11:30	Debbie Myers	ANL	Non-Platinum Bimetallic Cathode Electrocatalysts
12:00	Piotr Zelenay	LANL	Advanced Cathode Catalysts
12:30		**Lunch**	
		Impurities	
1:45	Fernando Garzon	LANL	Effects of Fuel and Air Impurities on PEM Fuel Cell Performance
2:15	James Goodwin	Clemson University	Effects of Impurities on Fuel Cell Performance and Durability
2:45	Trent Molter	University of CT	The Effects of Impurities on Fuel Cell Performance and Durability
		Stationary	
3:15	Durai Swamy	Intelligent Energy	Development and Demonstration of a New-generation High Efficiency 1-10 kW Stationary PEM Fuel Cell System
3:45		**Break**	
4:15	Eric Strayer	UTC Power	Stationary PEM Fuel Cell Power Plant Verification
4:45	Richard Chartrand	Plug Power Inc.	Intergovernmental Stationary Fuel Cell System Demonstration
5:15	Norman Bessette	Acumentrics Corp	Development of a Low Cost 10kW Tubular SOFC Power System – Phase II

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Thursday Fuel Cell Presentations

Start	Presenter	Organization	Title
		System and Cost Analysis	
8:30	Rajesh Ahluwalia	ANL	Fuel Cell Systems Analysis
9:00	Brian James	DTI	Mass Production Cost Estimation for Direct H2 PEMFC System for Automotive Applications
9:30	Jayanti Sinha	TIAX	Direct Hydrogen PEMFC Manufacturing Cost Estimation for Automotive Applications
		Catalyst and MEA Characterization	
10:00	Karren More	ORNL	Microstructural Characterization Of PEM Fuel Cell MEAs
10:30		**Break**	
		Platinum Group Metal Recycling	
11:00	Larry Shore	BASF	Platinum Group Metal Recycling Technology Development
		Water Management	
11:30	David Jacobson	NIST	Neutron Imaging Study of the Water Transport in Operating Fuel Cells
12:00	Rod Borup	LANL	Water Transport Exploratory Studies
12:30		**Lunch**	
1:45	Vernon Cole	CFD Research Corp	Water Transport in PEM Fuel Cells: Advanced Modeling, Material Selection, Testing, and Design Optimization
2:15	Satish Kandlikar	Rochester Institute of Technology	Visualization of Fuel Cell Water Transport and Performance Characterization Under Freezing Conditions
2:45	James Cross	Nuvera Fuel Cells	Subfreezing Start/Stop Protocol for an Advanced Metallic Open-Flowfield Fuel Cell Stack
3:15	Zia Mirza	Honeywell	Development of Thermal and Water Management System for PEM Fuel Cells
3:45		**Break**	
		Other Stack Components	
4:15	Peter Tortorelli	ORNL	Nitrided Metallic Bipolar Plates
4:45	Orest Adrianowycz	GrafTech International, Ltd.	Next Generation Bipolar Plates for Automotive PEM Fuel Cells
5:15	Jason Parsons	UTC Fuel Cells	Low Cost, Durable Seals for PEM Fuel Cells

Friday Fuel Cell Presentations

Start	Presenter	Organization	Title
Solid Oxide Fuel Cells			
8:30	Daniel Norrick	Cummins	Diesel Fueled SOFC System for Class 7/Class 8 On-Highway Truck Auxiliary Power
9:00	Gary Blake	Delphi	Solid Oxide Fuel Cell System Development for Auxiliary Power in Heavy Duty Vehicle Applications
9:30	Hau Duong	Superprotonic, Inc.	Solid Acid Fuel Cell Stack for APU Applications
10:00	Fred Mitlitsky	Bloom Energy Corp.	Low-cost Co-production of Hydrogen and Electricity
10:30	**Break**		
11:00	Greg Tao	Material & Systems Research	Development of Novel Efficient Solid-Oxide Hybrid for Co-Generation of Hydrogen & Electricity
11:30	Alan Ludwiszewski	Lilliputian Systems	Silicon Based Solid Oxide Fuel Cell for Portable Consumer Electronics
12:00	Praveen Cheekatamarla	Nanodynamics Energy	Biogass Fueled Solid Oxide Fuel Cell Stack