
U.S. DEPARTMENT OF ENERGY

# Fuel Cell Technologies

*Dimitrios Papageorgopoulos*

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## 2009 DOE Hydrogen Program & Vehicle Technologies Program

## Merit Review and Peer Evaluation Meeting

*May 19, 2009*

# Goal and Objectives

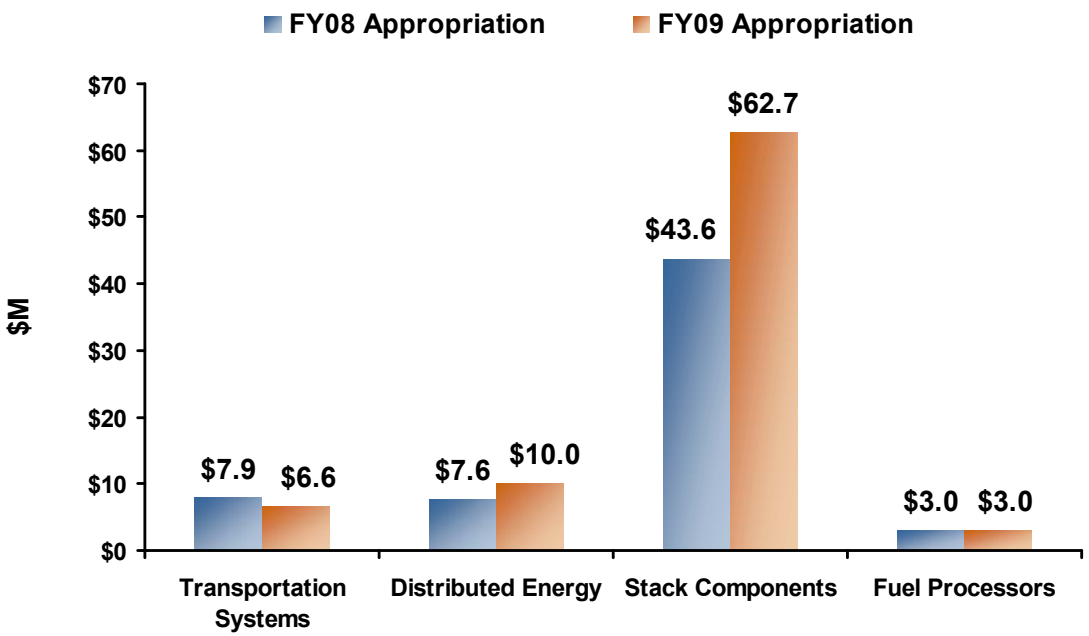
***Goal:* Develop and demonstrate fuel cell technologies for transportation, stationary, and portable power applications.**

- **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**



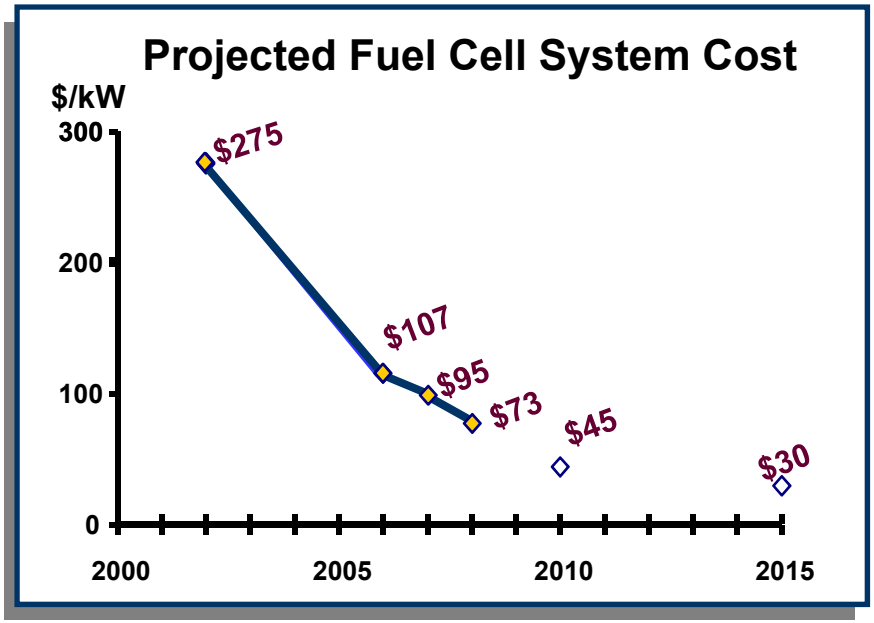

## EMPHASIS

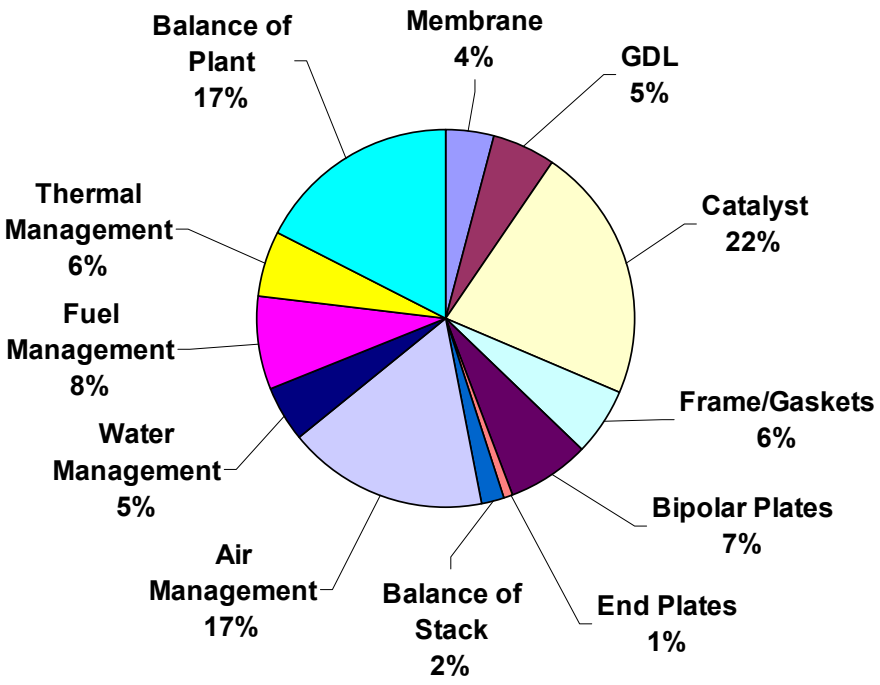
- Develop membranes for high-temperature, low-relative humidity operation; assess progress against interim targets.
- Increase catalyst activity and reduce platinum group metal loading to lower fuel cell cost.
- Design strategies to mitigate stack component degradation.
- Use quantitative performance 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)

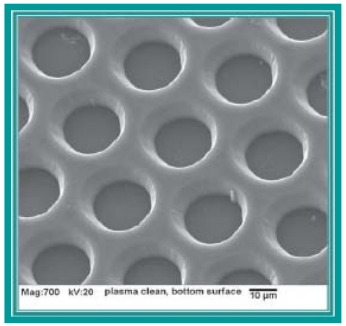


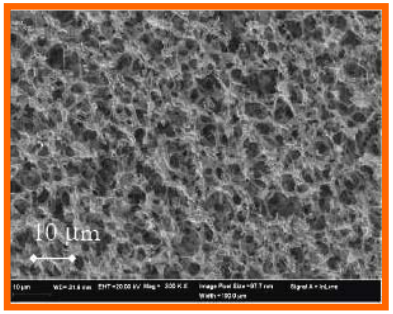

80 kW, direct-hydrogen PEM fuel cell system

# 2009 Progress & Accomplishments

## *Membranes achieve high conductivity at high temperature*




2D Support



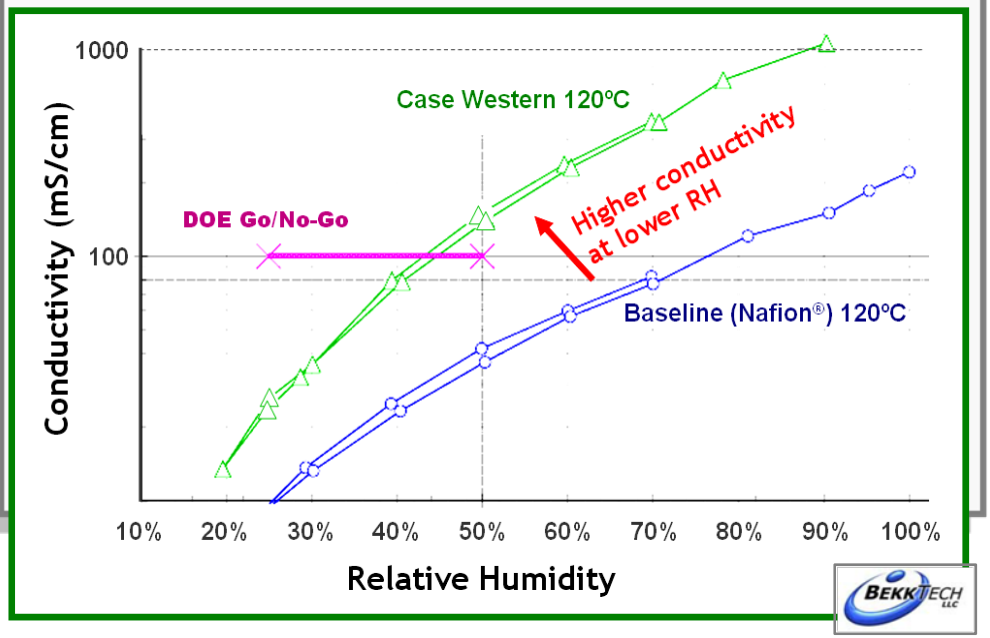

3D Support

## 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***

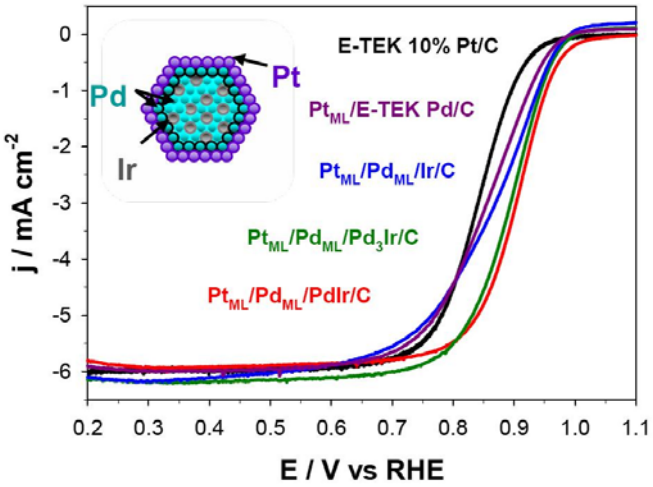


# 2009 Progress & Accomplishments

***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

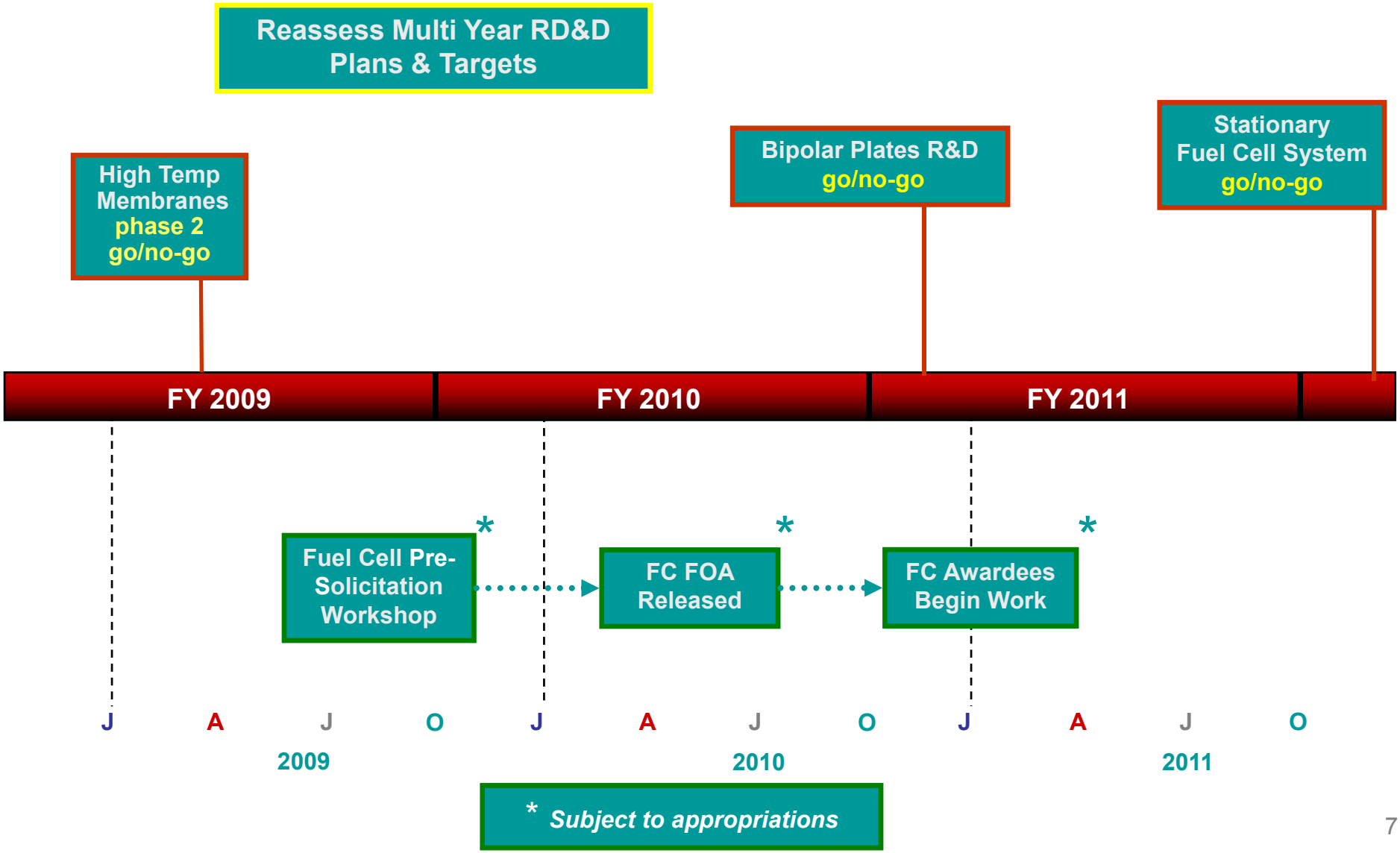



## 3M *MEAs*

- 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

## Fuel Cell Team

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*Larry Blair (Consultant)*

***Golden Field Office Project Officers:***
*Jesse Adams*
*Greg Kleen*
*Dave Peterson*
*Reg Tyler*
*Lea Yancey*

# 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 |