Fuel Cells Program Area
- Plenary Presentation-

Dimitrios Papageorgopoulos
Fuel Cell Technologies Office

2016 Annual Merit Review and Peer Evaluation Meeting
June 6 - 10, 2016
Objectives

• By 2020, develop a **transportation fuel cell power system** with 65% peak efficiency, 5,000 hours durability and a mass-produced cost of $40/kW

• By 2020, develop a **DG/CHP fuel cell system** at a cost of $1,000 to $1,500/kW and durability of 60,000 to 80,000 hours, depending on size and application

• Other specific objectives are in the Fuel Cells MYRD&D Plan

**GOAL:** Advance fuel cell technologies for transportation, stationary and early market applications
FUEL CELL TECHNOLOGIES OFFICE  

Fuel Cells MYRD&D Plan updated in 2016


The Fuel Cells program supports R&D of fuel cells and fuel cell systems with goals of reducing cost and improving durability.
Automotive Fuel Cell Targets
Cost: $40/kW by 2020 and $30/kW ultimate
Durability: 5,000 hours by 2020 and 8,000 hours ultimate

Durability and Cost are the primary challenges to fuel cell commercialization and must be met concurrently.

FC system cost targets allow competition with incumbent technology on a lifecycle cost basis.
Strategic Technical Analysis Guides Focus Areas for R&D and Priorities

Lowering PGM content and improving activity key to lowering cost

PEMFC Stack Cost Breakdown*

500,000 stacks/year

Bipolar Plates

Catalyst and Application

Membranes

GDLs

MEA Frames/Gaskets

Balance of Stack

Platinum Group Metals

Key Focus Areas for R&D

Pt Loading
Power Density
Air Loop Cost (including CEM)
Bipolar Plate Cost
Air Stoichiometry
Hydrogen Recirculation System Cost
Active to Total Area Ratio
Bipolar Plate Welding Speed
Q/DT Constraint
EPTFE Cost
Ionomer Cost
GDL Cost
Membrane Humidifier Cost
JM Catalyst Synthesis Processing Cost

Sensitivity Analysis helps guide R&D

Pt Loading
0.125mg/cm²
0.3mgPt/cm²

Power Density
1119mW/cm²
634mW/cm²

Air Loop Cost (including CEM)
$555
$1,231

Bipolar Plate Cost
$3/kW
$10/kW

• Improvements in multiple components are required to meet the 2020 cost target

• Advances in PEMFC materials and components could benefit a range of applications

Meeting guideline component level targets could pave path to $40/kW
Fuel Cells Program Budget

FY 2017 Request = $35.0 M
FY 2016 Appropriation = $35.0 M

EMPHASIS

- Increase activity and utilization of low-PGM catalysts and develop PGM-free catalysts for long-term applications
- Develop membranes with enhanced performance and stability at reduced cost
- Advance fuel cell performance and durability by addressing transport and degradation issues
- Improve PEM MEAs through integration of state-of-the-art MEA components

Full-upfront funding for non-lab financial assistance projects selected from FOAs
**Fuel Cell Cost**

### Fuel Cell Cost Reductions

- **50%** from 2006
- **30%** from 2008
- **5X** Platinum Catalyst

### Fuel Cell Cost Status

- **$53/kW** for 500,000 units/year
- **$60/kW** for 100,000 units/year
- **$280/kW** (for current technology at 20,000 units/year) - expected cost for initial FCEV commercialization

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* SA, bottom-up analysis of model system manufacturing cost, high volume manufacturing with next-gen lab technology
† ORNL, top-down analysis based on OEM input
Fuel Cell Durability Assessment: Voltage Degradation Results by Application

Data from **lab tested**, full active area PEMFC and SOFC short stacks and systems with full stacks. Data generated from constant load, transient load, and accelerated testing and include 23 U.S. and international fuel cell developers.

10% voltage degradation metric is used for assessing voltage degradation; it may not be the same as end-of-life criteria and does not address catastrophic failure modes.

* Preliminary DOE Target

J. Kurtz et al., NREL
Fuel Cell Durability Assessment: Comparison with On-Road FCEV voltage durability

State-of-the-art lab durability projections higher than on-road projections

Continued durability improvements for fuel cell technology yet to be deployed
FC-PAD: Consortium for Fuel Cell Performance And Durability

Approach:
- Couple national lab capabilities with funding opportunity announcements (FOAs) for an influx of innovative ideas and research

Objectives:
- Improve component stability and durability
- Improve cell performance with optimized transport
- Develop new diagnostics, characterization tools, and models

Core Consortium Team
Lab Lead: LANL
Deputy Lead: LBNL
Partners: ANL, NREL, ORNL

FOA*
- University/Non-Profit
- Company
- National Lab

Consortium will foster sustained capabilities and collaborations

*Partners to be added by DOE DE-FOA-0001412

Established Consortium to advance fuel cell performance and durability
FC-PAD: Structural Approach

FC-PAD

Fuel Cell Consortium for Performance and Durability

FC-PAD structured across six component and cross-cutting thrusts

The FC-PAD website is now online!

www.fcpad.org
Accomplishments: Platinum Monolayer Catalysts

Nitriding core components can facilitate the development of high-performance Pt-ML catalysts with low- or no-noble metal cores

NiPd calcined at 250 °C in N₂ and 510 °C in NH₃

- Pd content is reduced by 50% in comparison with Pt/Pd/C.
- Ni nitride formation stabilizes Ni.

Niobium nitride as a core

- Non-optimized Pt/NbN/C shows promising activity.
- Future studies will focus on improving synthesis and durability.

BNL demonstrated potential to develop low-cost Pt monolayer catalysts with noble metal free cores

*R. Adzic et al., BNL*
Accomplishments: New Membranes

3M developed 10 µm supported Perfluoro Imide Acid membrane with chemical additive:

- meets the resistance target at 80 °C for all humidities and at 120 °C only for the highest humidity; and
- meets mechanical and chemical durability targets

3M PFIA membranes meet most 2020 DOE targets

M. Yandrasits et al., 3M
Accomplishments: MEA Integration

Improved MEAs produce $6.8 \text{ kW/g}_{\text{PGM}}$ under conditions that satisfy $Q/\Delta T$ target (2008 baseline $2.8 \text{ kW/g}_{\text{PGM}}$; 2014 status $6.2 \text{ kW/g}_{\text{PGM}}$; 2015 status $6.5 \text{ kW/g}_{\text{PGM}}$)

- Further work required to meet performance, durability, and robustness targets simultaneously.

A. Steinbach et al., 3M

3M MEA integration R&D leads to improved performance and decreased PGM content
Accomplishments: Contamination Detection Study

- NREL and GM investigated system material-driven contamination of the fuel cell stack.
- Included structural plastics, hoses, lubricants, adhesives, seals.
- Correlated a “leaching index” to MEA degradation and cost.
- The project identified a cleaner PPA structural material with no significant increase in material cost and higher performance.
- Developed a publicly available material screening data tool and extensive database.*

* www.nrel.gov/hydrogen/system_contaminants_data/

• ~1400 site visits since May 2013

H. Dinh et al., NREL

Study of system contaminants led to public dataset of materials, with leaching index, identity and quantity of contaminants, and recommended common test procedures.
Accomplishments: Molten Carbonate Fuel Cells

“Smart Matrix” project targets technology advancement toward meeting stationary fuel cell durability of 80,000 hours

Improved porous ceramic matrix formulation resulted in:

- stable pore size during AST;
- high phase stability (<3% phase transformation);
- low particle growth (3.5x reduction in coarsening);
- >80% reduction in gas crossover;
- >40% increase in mechanical strength;
- **5,000 h AST durability demonstrating projected 80,000 h stack durability.**

C. Yuh et al., FuelCell Energy

**Novel MCFC electrolyte matrix projected to hit 80,000 hours target for stationary applications**
SNL developed AEM/PEM technologies with a focus on commercialization.
# FY15 FOA & Lab Call Awards

## Catalysts & Supports topic of Funding Opportunity Announcement DE-FOA-0001224

<table>
<thead>
<tr>
<th>Recipient</th>
<th>Location</th>
<th>Project Title</th>
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<tbody>
<tr>
<td>3M Company</td>
<td>St. Paul, MN</td>
<td>Highly Active, Durable, and Ultra-low PGM NSTF Thin Film ORR Catalysts and Supports</td>
</tr>
<tr>
<td>General Motors</td>
<td>Pontiac, MI</td>
<td>Highly-Accessible Catalysts for Durable High-Power Performance</td>
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<tr>
<td>National Renewable Energy Laboratory</td>
<td>Golden, CO</td>
<td>Extended Surface Electrocatalyst Development</td>
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<tr>
<td>Illinois Institute of Technology</td>
<td>Chicago, IL</td>
<td>Corrosion-resistant non-carbon electrocatalyst supports for PEFCs</td>
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## AEMFC and Catalyst R&D Lab Call

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<thead>
<tr>
<th>Lab</th>
<th>Location</th>
<th>Project Title</th>
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<tbody>
<tr>
<td>LANL (RPI, SNL, ANL)</td>
<td>Los Alamos, NM</td>
<td>Advanced Materials for Fully-Integrated MEAs in AEMFCs</td>
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<tr>
<td>NREL (CSM, LBNL, ORNL)</td>
<td>Golden, CO</td>
<td>Advanced Ionomers and MEAs for AEMFCs</td>
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<tr>
<td>ANL (LANL, LBNL, ORNL)</td>
<td>Argonne, IL</td>
<td>Tailored High Performance Low-PGM Cathode Catalysts</td>
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<tr>
<td>BNL (LANL)</td>
<td>Upton, NY</td>
<td>Platinum Monolayer Electrocatalysts</td>
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*New awards fill gaps in Fuel Cell R&D portfolio*
### ElectroCat (Electrocatalysis Consortium) Established

<table>
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<tr>
<th>Goal</th>
<th>Mission</th>
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<tr>
<td>Accelerate the deployment of fuel cell systems by <strong>eliminating the use of PGM catalysts</strong></td>
<td>Develop and implement PGM-free catalysts by:</td>
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<tr>
<td></td>
<td>• streamlining access to unique synthesis and characterization tools across national labs</td>
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<td>• developing missing strategic capabilities</td>
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<td>• curating a public database of information</td>
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### Leads

- **Argonne National Laboratory**
  - High-throughput materials discovery, characterization, and testing
- **Los Alamos National Laboratory**
  - Design and synthesis of PGM-free catalysts and electrodes

### The Bigger Picture

Save The Date: ElectroCat Workshop

WORKSHOP: July 26, 2016

@ Argonne National Laboratory

An Outreach Event on
PGM-free Catalyst Development, Characterization, Modeling, and High Throughput Approaches

Outlining capabilities
Assessing stakeholder needs

More info to follow
Summary of Activities and Upcoming Milestones

- Projects address cost reduction, performance and durability enhancement of stack components including catalysts, membranes and MEAs
- FC-PAD Consortium established to advance fuel cell performance and durability
- ElectroCat launched to coordinate PGM-free catalyst development and gather state-of-the-art tools at the national labs under one umbrella for easy access by stakeholders and the research community.

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<tr>
<th>FY 2016</th>
<th>FY 2017</th>
<th>FY 2018</th>
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<tr>
<td>1Q 2016: Released FCTO R&amp;D FOA</td>
<td>1Q 2017: Release FCTO R&amp;D FOA (ElectroCat)*</td>
<td>4Q 2017: Demonstrate MEA with 7.2 kW/g_pgm at rated power</td>
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<td>3Q 2016: Released updated MYRDD Plan</td>
<td>3Q 2017: Project selection from FCTO R&amp;D FOA (ElectroCat)*</td>
<td>4Q 2018: Demonstrate MEA with 7.5 kW/g_pgm at rated power</td>
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<tr>
<td>4Q 2016: FC-PAD project selection from FCTO R&amp;D FOA</td>
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*Subject to appropriations
Collaborations

INTERNATIONAL ACTIVITIES
- International Energy Agency – Hydrogen Implementing Agreement

DOE-EERE Fuel Cells Program
- Vehicle Technologies Office
- Small Business Innovative Research (SBIR)
- 36 projects

INDUSTRY
- U.S. DRIVE Partnership: Fuel Cell Tech Team
- Codes & Standards Organizations

TECHNOLOGY VALIDATION

National Collaborations (inter- and intra-agency efforts)
- DOE - FE SOFC Program
- DOE - BES Catalysts and Membranes
- DOE – ARPA-E REBELS and IONICS Programs
- DOT/FTA Fuel Cell Buses
- DOD DOD/DOE MOU
- DOC/NIST Neutron Imaging

*Applied R&D is coordinated among national and international organizations*
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**Bahman Habibzadeh** (on detail from BTO)