Fuel Cells

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2008 DOE Hydrogen Program
Merit Review and Peer Evaluation Meeting

June 9, 2008
GOAL: Develop and demonstrate fuel cell technologies for transportation, stationary, and portable power applications.

- **Transportation applications**
  - By 2010, develop a 60% peak-efficient, direct hydrogen fuel cell system at a cost of $45/kW with 5000 hours of durability; by 2015, a cost of $30/kW.

- **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.
Budget

FY2009 Budget Request = $79.3M
FY2008 Appropriation = $62.1M

FY08 Emphasis
- Develop high-temperature, low-relative humidity membranes; assess progress against interim targets
- Increase catalyst activity and reduce platinum group metal (PGM) loading to lower fuel cell cost
- Design strategies to mitigate stack component degradation
- Continue/complete stationary fuel cell system projects
- Develop models relating performance loss to impurity concentration
- Optimize GDL properties and pore structure
FY 2008 Budget by Topic

- Membranes: $10.4M
- Water Transport & BOP: $7.6M
- Characterization & Analysis: $7.0M
- Impurities: $4.9M
- Stack Components: $7.6M
- Portable / APU / Off-road: $4.8M
- Catalysts: $13.3M
- Distributed Energy Systems: $6.5M
Challenges to Fuel Cell Commercialization

- Durability
- Cost
- Performance
- Air Management
- System Thermal and Water Management
- Water Transport within the Stack
- Start-up/Shut-down Operation
Three Strategies for High-Temperature Membrane Research:

- **Phase segregation control (polymer & membrane)**
  - Polymer - Separate blocks of hydrophobic and hydrophilic functionality incorporated within the same polymer molecule
  - Membrane – Two-polymer composites. One polymer provides mechanical strength while the other polymer enables proton conduction

- **Non-aqueous proton conductors**
  - Membranes that use inorganic oxides, heteropolyacids, or ionic liquids, rather than water, for proton conductivity

- **Hydrophilic additives**
  - Membranes with additives that maintain water content and conductivity at higher temperature

Importance to Goals:

- *Fuel cell stack performance and durability depend on membrane properties*
- *Membranes are a significant contributor to the fuel cell cost at low manufacturing volumes*
- *Membrane limitations add complexity to the fuel cell system*
Strategies – Catalysts and Supports

Importance to Goals:
- Platinum (Pt) cost is ~55% of total stack cost
- Catalyst durability needs improvement

Four Strategies for Catalysts & Supports R&D:
- Lower PGM Content
  - Improved Pt catalyst utilization and durability
- Pt Alloys
  - Pt-based alloys that maintain performance compared to Pt and cost less
- Non-Pt catalysts
  - Non-precious metal catalysts that maintain performance and durability compared to Pt
- Novel Support Structures
  - Non-carbon supports and alternative carbon structures

Stack Cost - $51/kW

- Catalyst 55%
- GDL 10%
- Membrane 7%
- Balance of MEA 9%
- Bipolar Plate 10%
- Balance of Stack 9%
- Bipolar Plate 10%

DTI, 2007 analysis, scaled to high volume production of 500,000 units/yr
Strategies for Water Transport Research:
- Advanced imaging of pore volume within GDL structures, ice and water droplet formation, and water movement in fuel cells
- Computational Fluid Dynamics (CFD) modeling
- Experimental determination of gas diffusion media properties

Importance to Goals:
- Understanding water transport key to operation in cold climates, preventing flooding, and preventing membrane dry-out
3M MEA exceeds 2010 Durability Target

Mechanically stabilized membrane electrode assembly achieves over 7,300 hours durability with voltage cycling (DOE 2010 target is 5,000 hours).

Membrane Durability for Automotive Fuel Cells

7 Dispersed MEAs
A/C Catalyst: Pt/Carbon: 0.4 mg-Pt/cm²
PEM: 3M, no chemical or mechanical stabilization
All 7 failed in 200 - 600 hrs

2- NSTF MEAs
A/C Catalyst: 0.2 mg-Pt/cm² PtCoMn
PEM: modified
1st Still running > 7300 hrs
2nd started later, still running

4 - NSTF MEAs
A/C Catalyst: 0.2 mg-Pt/cm² PtCoMn
PEM: 3M, no chemical or mechanical stabilization
Av. Lifetime ~ 3500 hrs

Shiva all NSTF Data 021808 - graph 3
Nano-Capillary Membranes meet Interim Proton Conductivity Milestone

- Nano-fiber mat created through electrospinning
- Very fine morphology, good mechanical properties
- Membranes meet interim proton conductivity milestone of 70 mS/cm at room temperature and 80% RH, exceeding Nafion® performance under the same conditions

Sulfonated poly(arylene ether sulfone) nano-capillaries in NOA (inert polymer resin)
Ternary Alloy Catalyst shows Improved Performance

Ternary Alloy Catalyst with higher mass activity than conventional Pt catalyst

Platinum Total Content—**for Automotive Fuel Cells**

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Neutron Images validate Water Transport Models

- Calculated water volume closely matches water measured via neutron imaging during operation below freezing
- CFD results for water transport in diffusion media show accumulation at the lands, matching observed results through neutron imaging
Automotive Fuel Cell System Cost reduced to $94/kW

- Based on DTI DFMA 2007 cost analysis
- Projected to manufacturing volume of 500,000 units per year.

80 kW, direct-hydrogen automotive PEM fuel cell system

- Membrane 4%
- Catalyst 30%
- GDL 5%
- Bipolar Plate 5%
- Balance of Stack 5%
- Balance of Plant 19%
- Water Management 4%
- Air Management 10%
- Thermal Management 7%
- Fuel Management 6%

Automotive Fuel Cell System Cost

- $275/kW in 2000
- $107/kW in 2005
- $94/kW in 2010
- $45/kW in 2015
- $30/kW in 2015

Graph showing the projected cost reduction from 2000 to 2015.
Key Fuel Cell Subprogram Milestones & Future Plans

* subject to Congressional Appropriations and Direction
## Future Plans for Transportation, Stationary, and Portable Applications

### Addressing Cost, Durability, and Performance

#### Membranes
- Operate at higher temperature, lower RH to reduce BOP size and cost
- Lower cost by eliminating fluorine
- Identify degradation mechanisms and mitigate effects

#### Catalysts/Supports
- Carry out Pt and non-PGM studies in parallel
- Identify degradation mechanisms and mitigate effects
- Increase OCV and performance of non-PGM catalysts
- Test catalysts in fuel cells

#### Water Management
- Improve tolerance to freeze / thaw conditions
- Prevent membrane flooding or dehydration

#### Early Market
- Develop structure / manufacturing / performance relationships
- Expand early adoption activities

#### MEAs
- Develop characterization tools, understanding of material behavior

#### Impurity effects
- Characterize effects of impurities on membranes and catalysts

#### SOFCs
- Improve fuel processors / system integration for small-scale applications
For More Information

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