
U.S. Department of Energy Hydrogen Program

Fuel Cells

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**2008 DOE Hydrogen Program
Merit Review and Peer Evaluation Meeting**

June 9, 2008





Goal and Objectives

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.

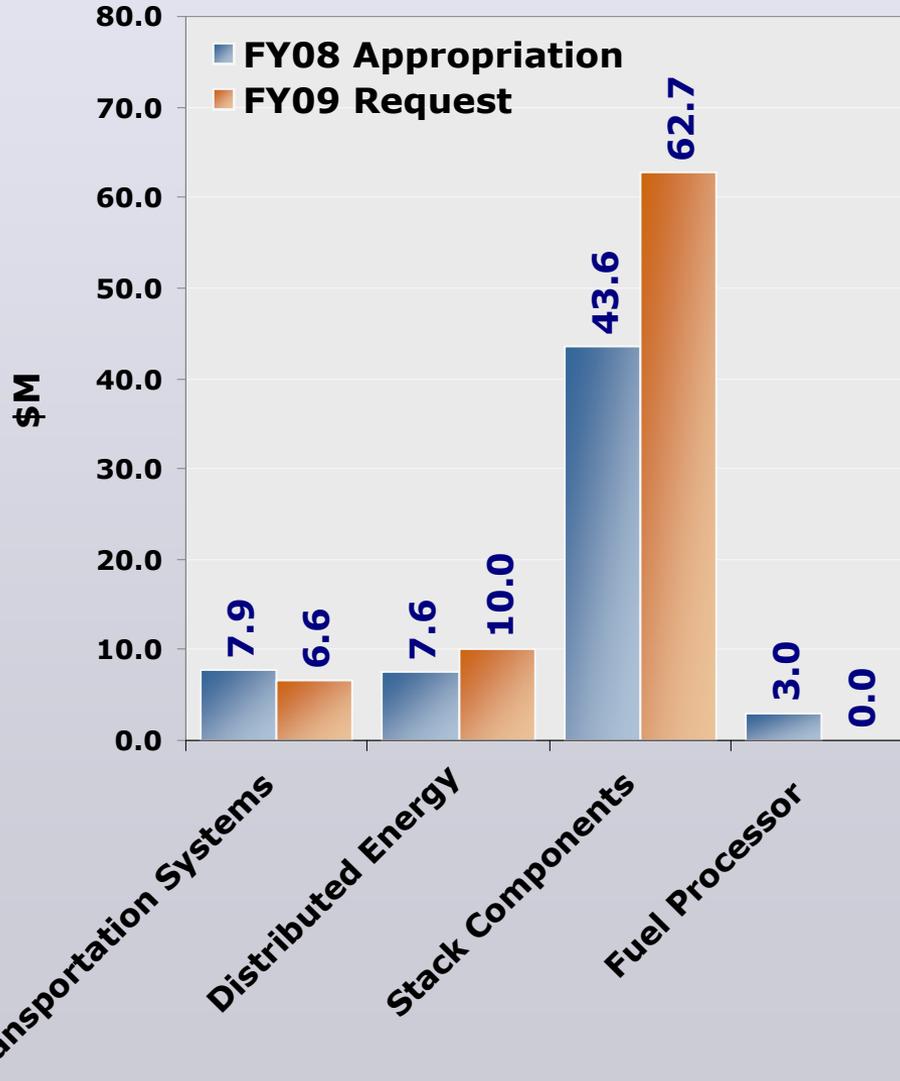
- **Stationary power and other early market fuel cell applications**

- 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

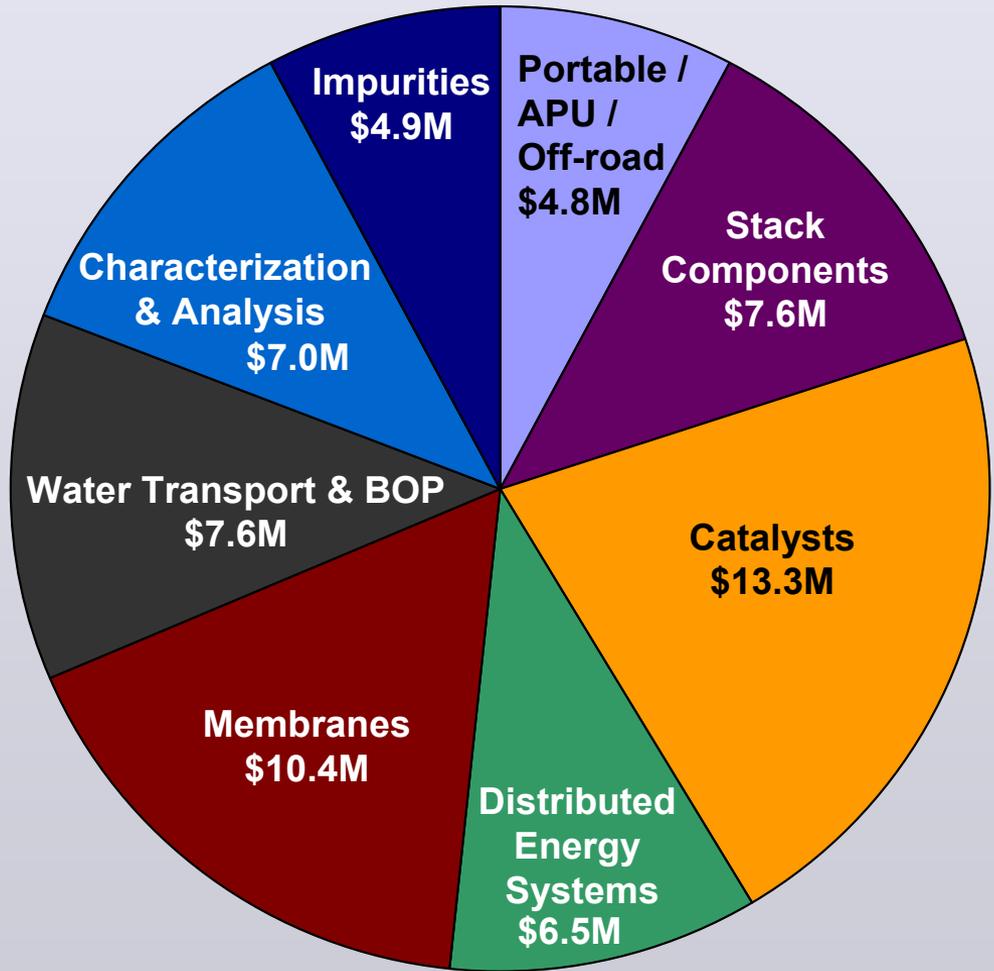


FY08 Emphasis

- 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



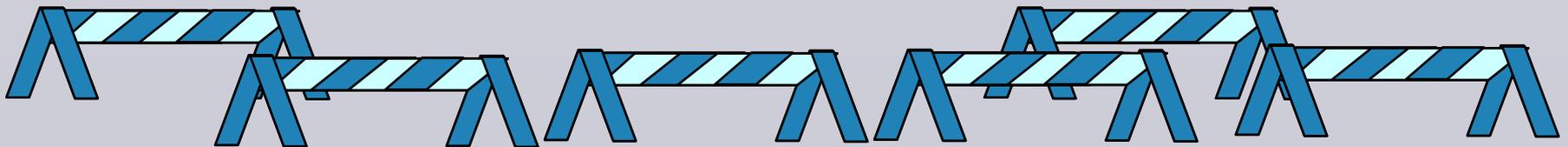
FY 2008 Budget by Topic





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





Strategies – Membrane R&D

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**

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



Strategies – Catalysts and Supports

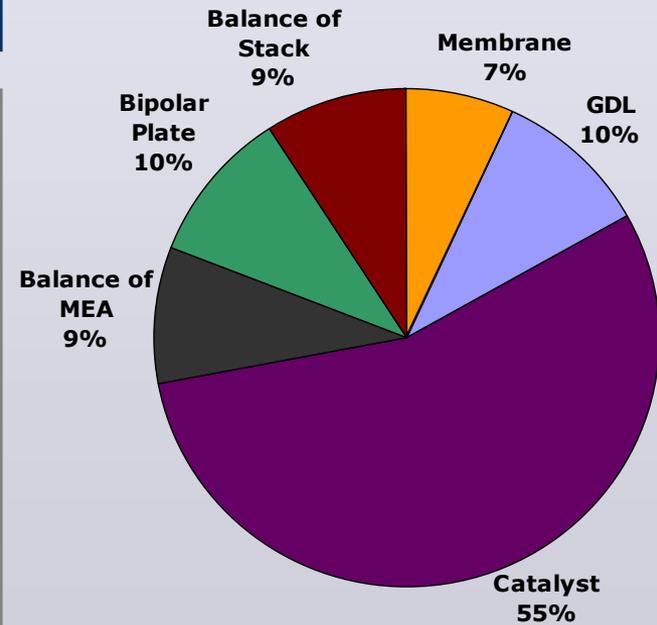
Importance to Goals:

- **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



DTI, 2007 analysis, scaled to high volume production of 500,000 units/yr



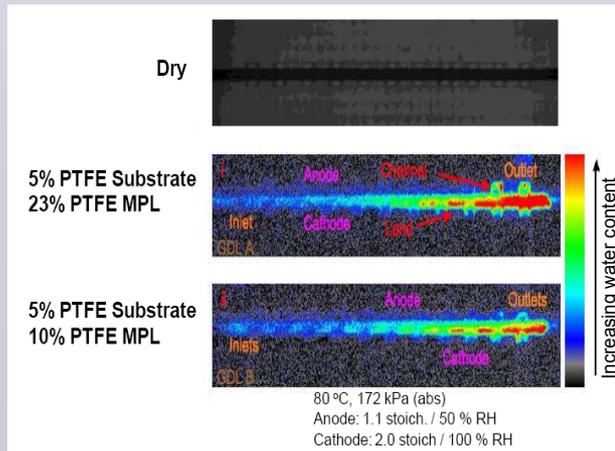
Strategies – Water Transport

Importance to Goals:

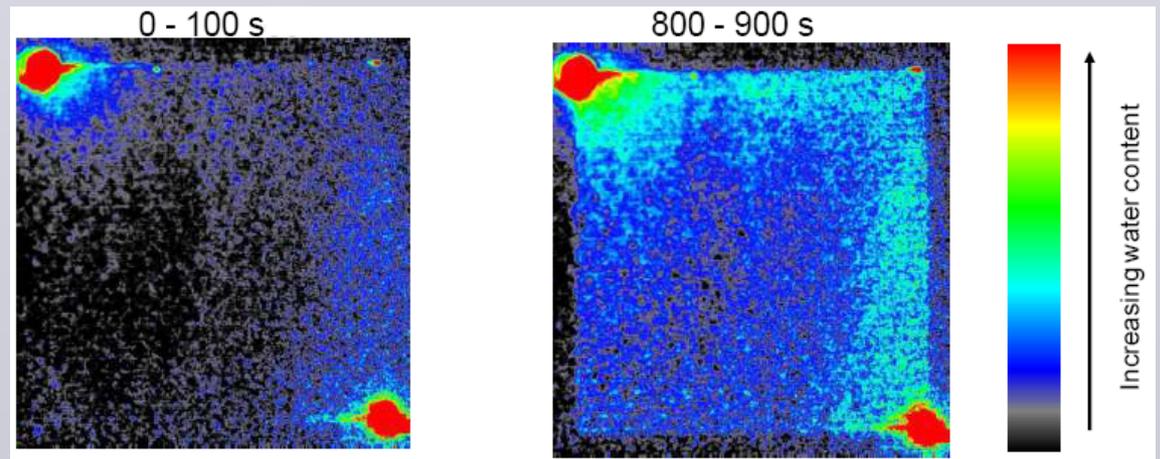
- **Understanding water transport key to operation in cold climates, preventing flooding, and preventing membrane dry-out**

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



Neutron Imaging of Fuel Cell Operation



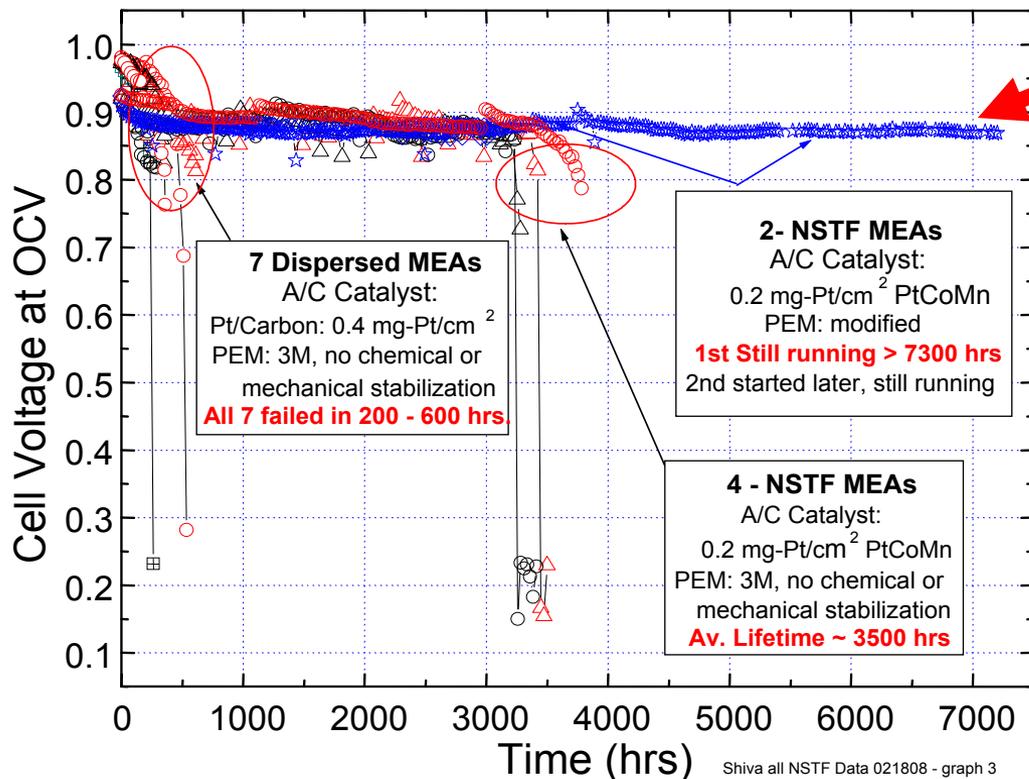
Neutron Imaging of Ice Formation During Operation at -10°C



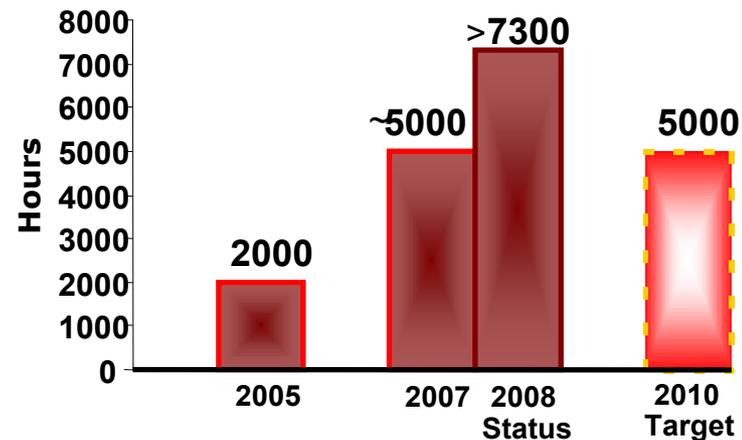
3M MEA exceeds 2010 Durability Target

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

MEA still running



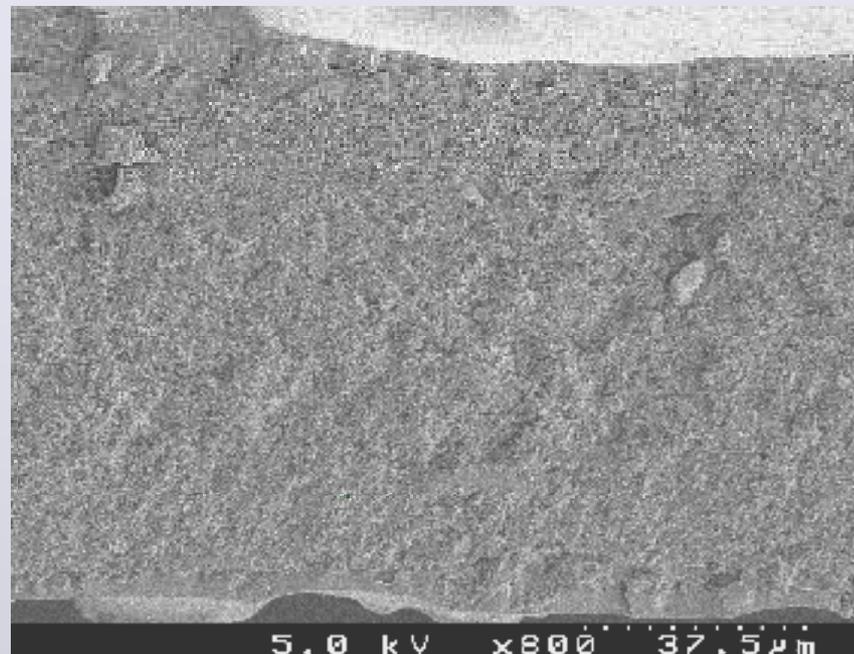
Membrane Durability for Automotive Fuel Cells



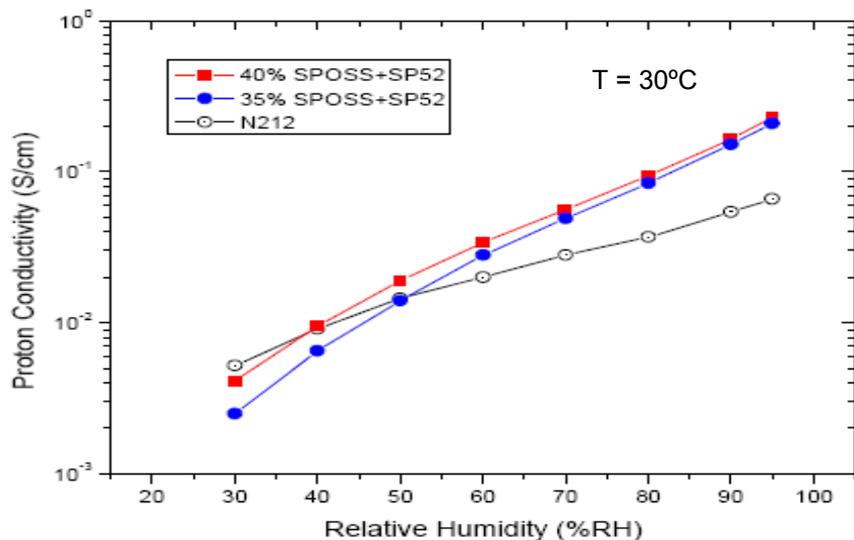


Nano-Capillary Membranes meet Interim Proton Conductivity Milestone

- 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**



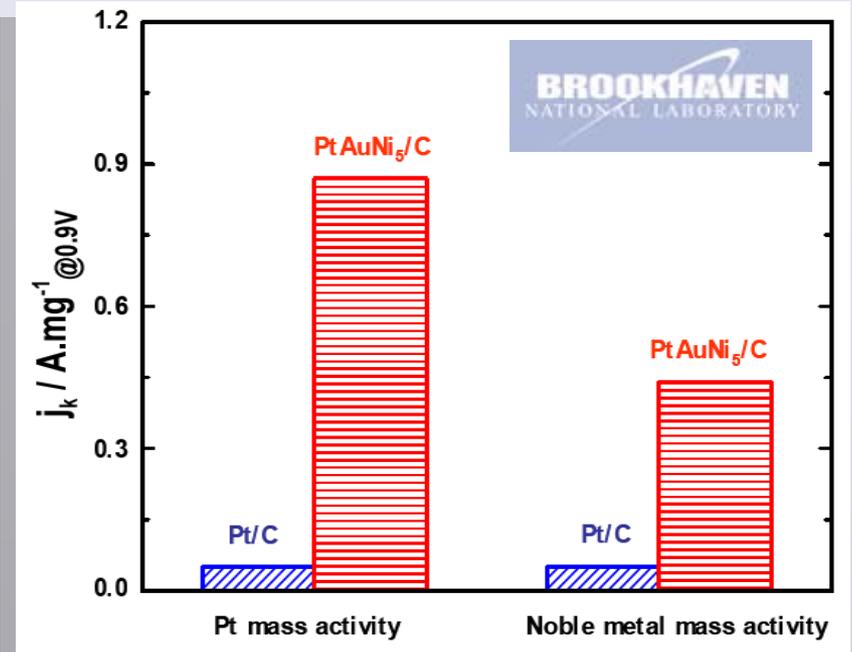
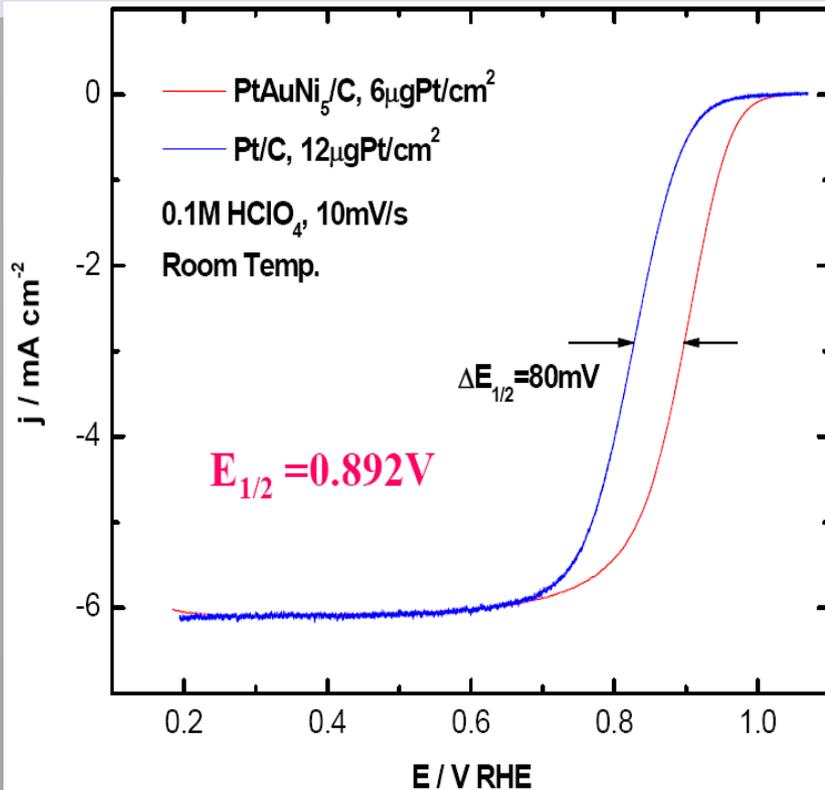
Sulfonated poly(arylene ether sulfone) nano-capillaries in NOA (inert polymer resin)



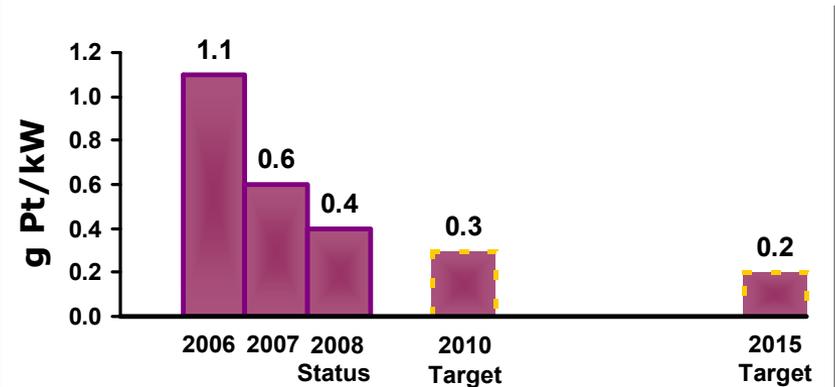


Ternary Alloy Catalyst shows Improved Performance

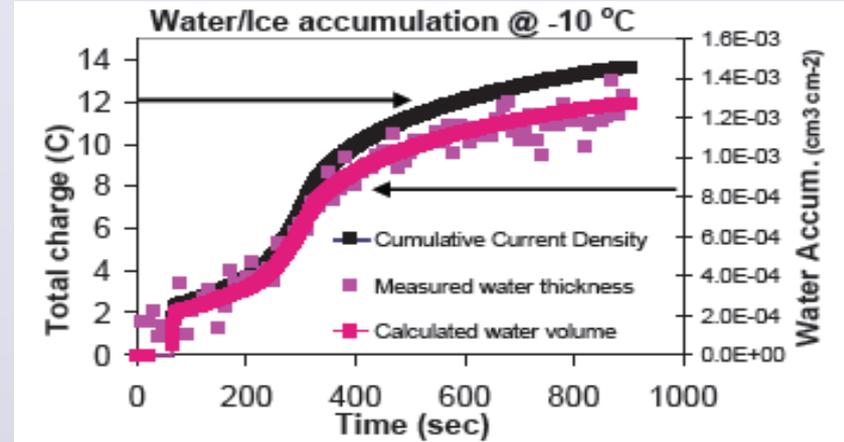
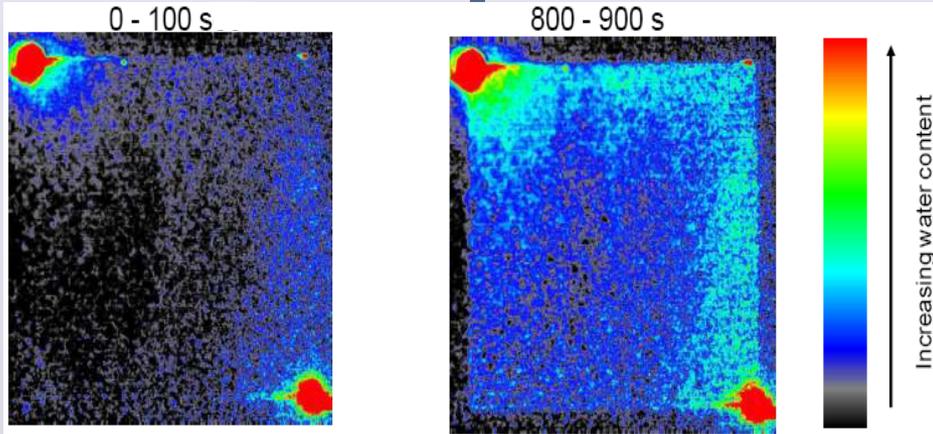
Ternary Alloy Catalyst with higher mass activity than conventional Pt catalyst



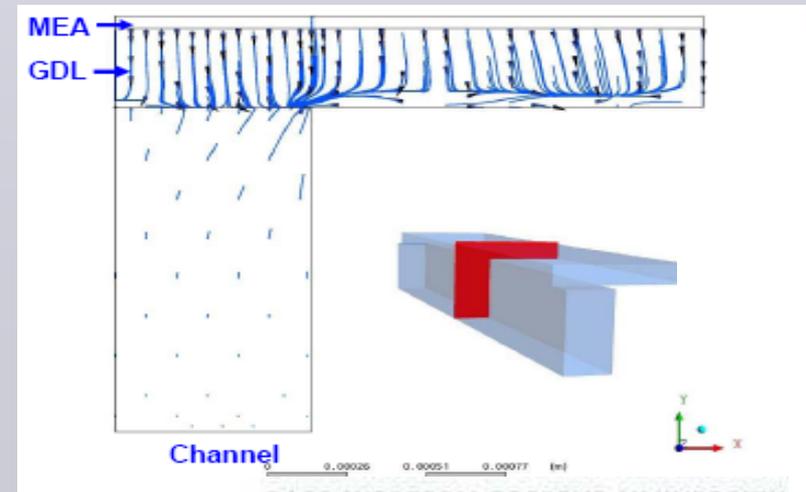
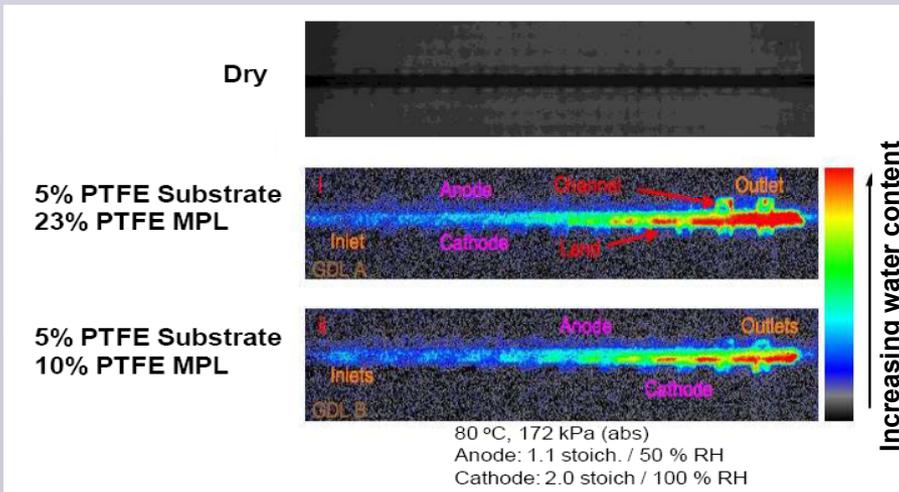
Platinum Total Content—for Automotive Fuel Cells



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

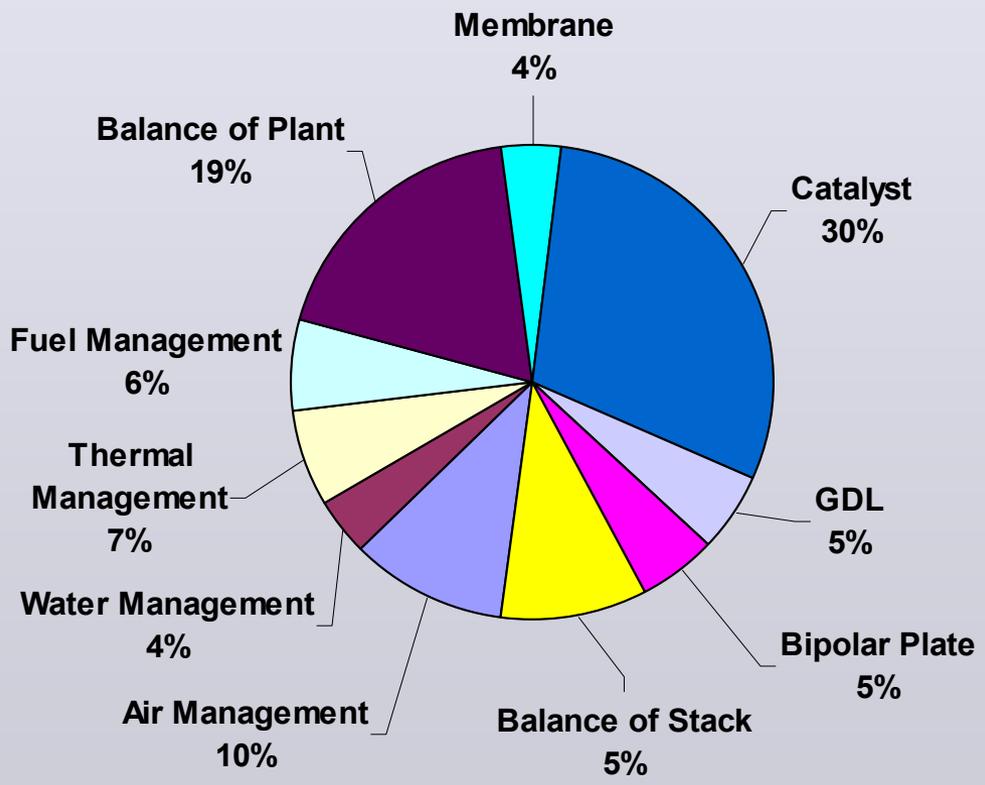
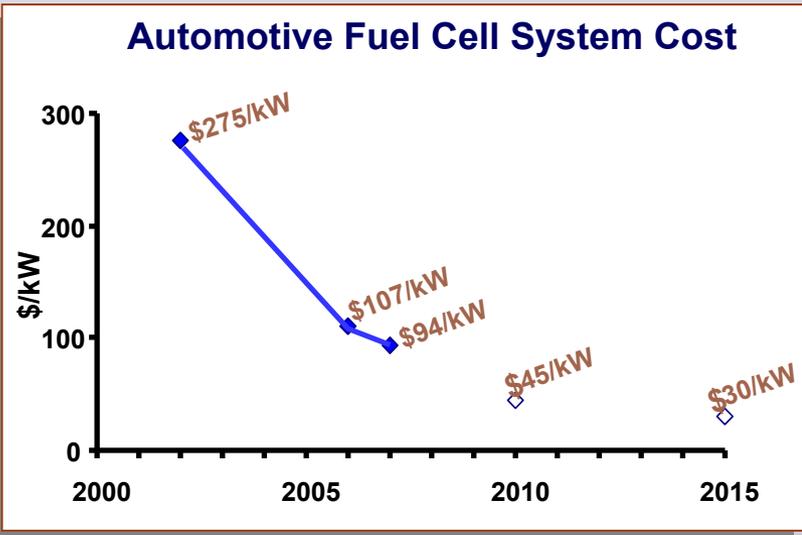




Automotive Fuel Cell System Cost reduced to \$94/kW

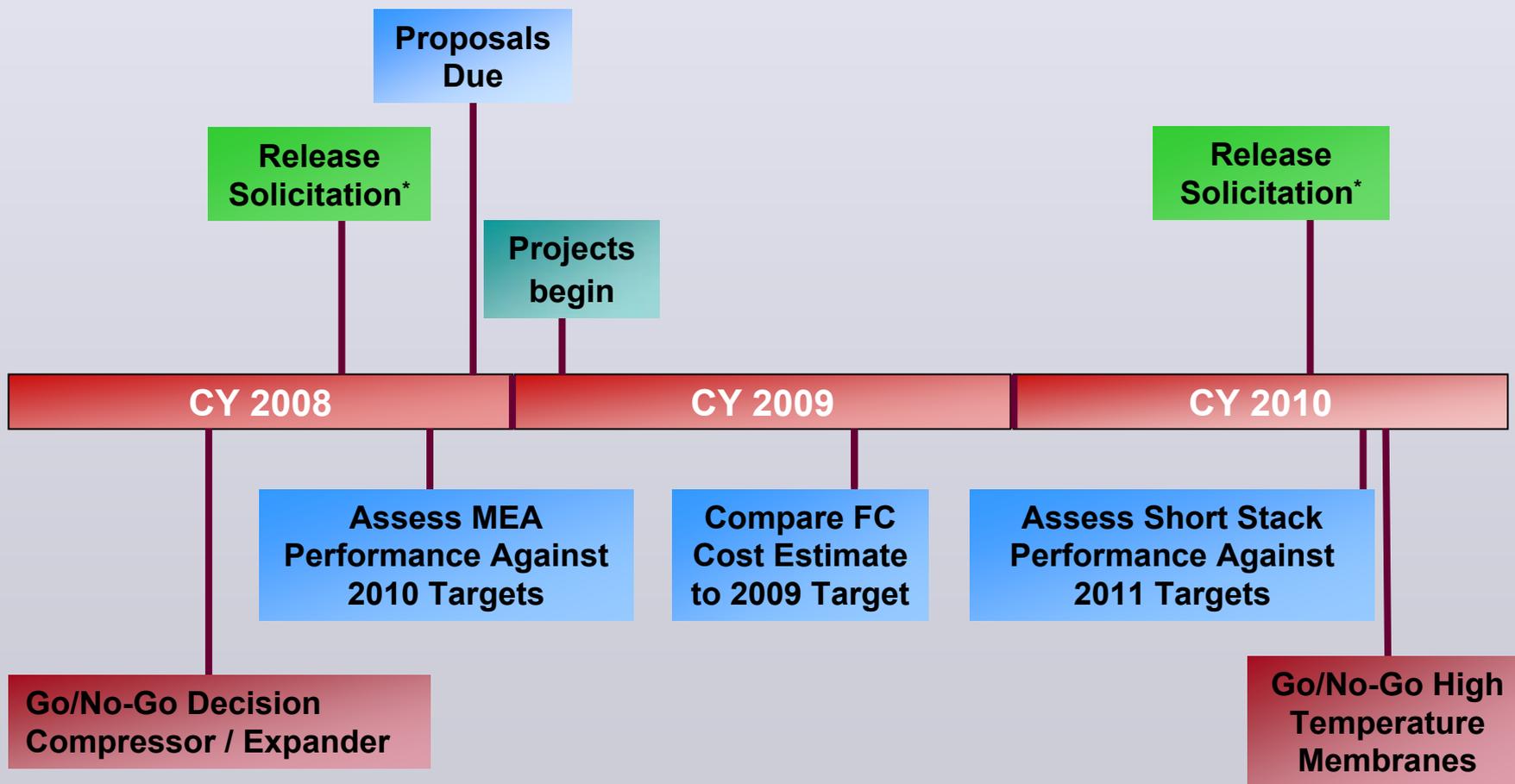
- Based on DTI DFMA 2007 cost analysis
- Projected to manufacturing volume of 500,000 units per year.

80 kW, direct-hydrogen automotive PEM fuel cell system





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

Early Market

- Develop structure / manufacturing / performance relationships
- Expand early adoption activities

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

Impurity effects

- Characterize effects of impurities on membranes and catalysts

Water Management

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

MEAAs

- Develop characterization tools, understanding of material behavior

SOFCs

- Improve fuel processors / system integration for small-scale applications



For More Information

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