U.S. Department of Energy Hydrogen Program

Fuel Cells

Nancy L. Garland

2008 DOE Hydrogen Program
Merit Review and Peer Evaluation Meeting

June 9, 2008

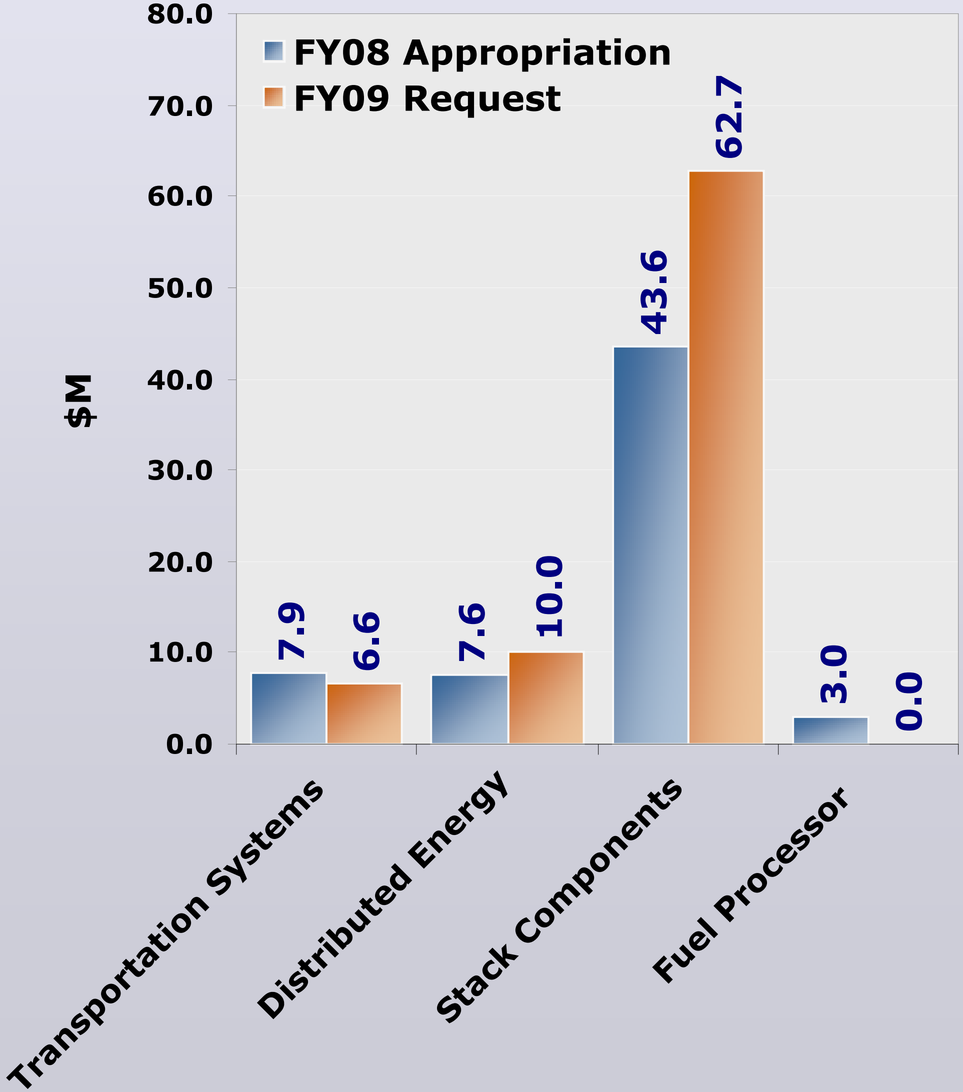
Goal and Objectives

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

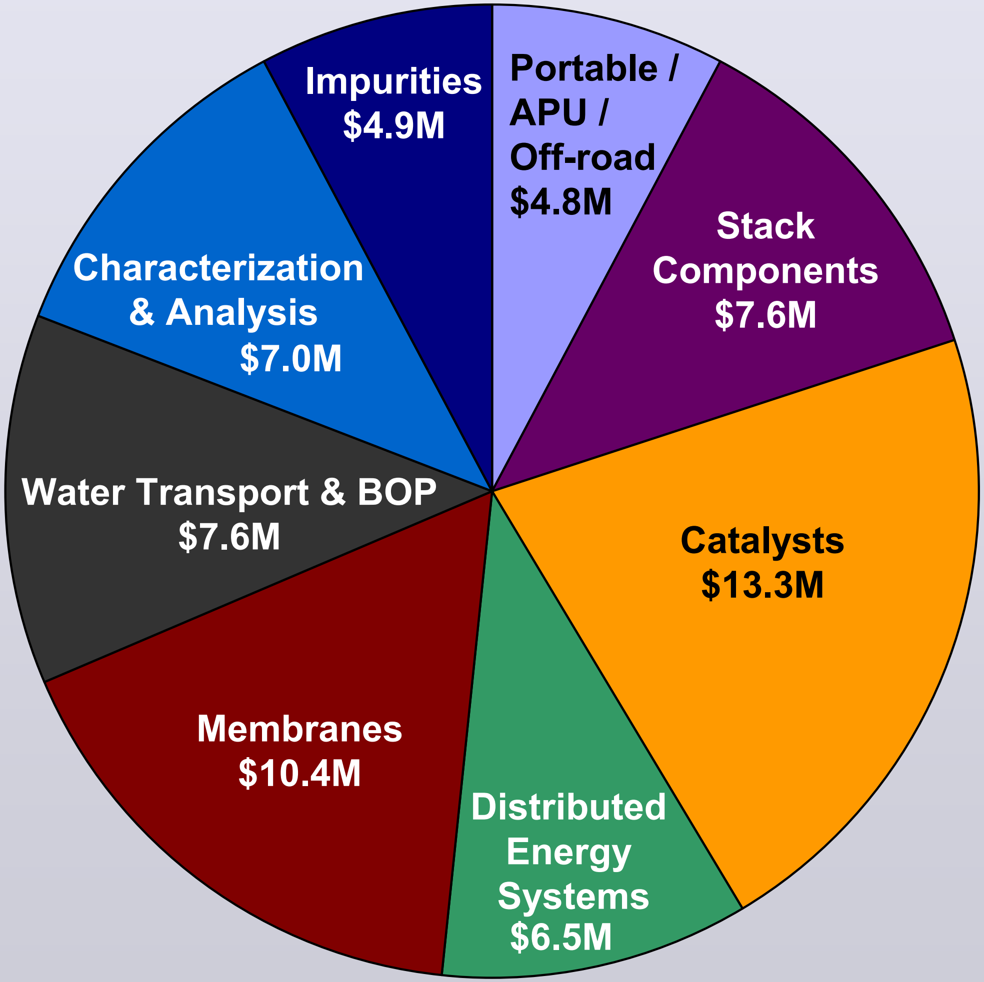
FY2009 Budget Request = $79.3M
FY2008 Appropriation = $62.1M



FY08 Emphasis

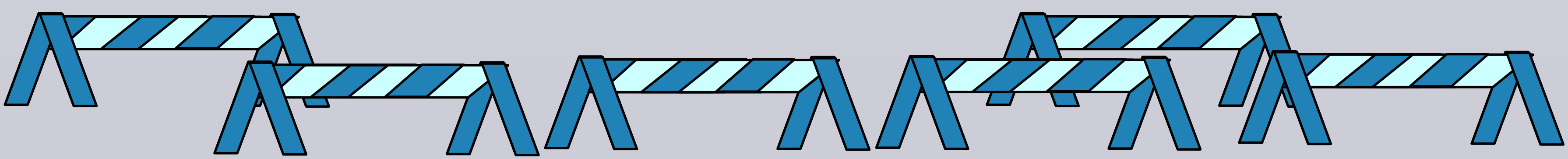
- Develop high-temperature, low-relative humidity membranes; assess progress against interim targets
- Increase catalyst activity and reduce platinum group metal (PGM) loading to lower fuel cell cost
- Design strategies to mitigate stack component degradation
- Continue/complete stationary fuel cell 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

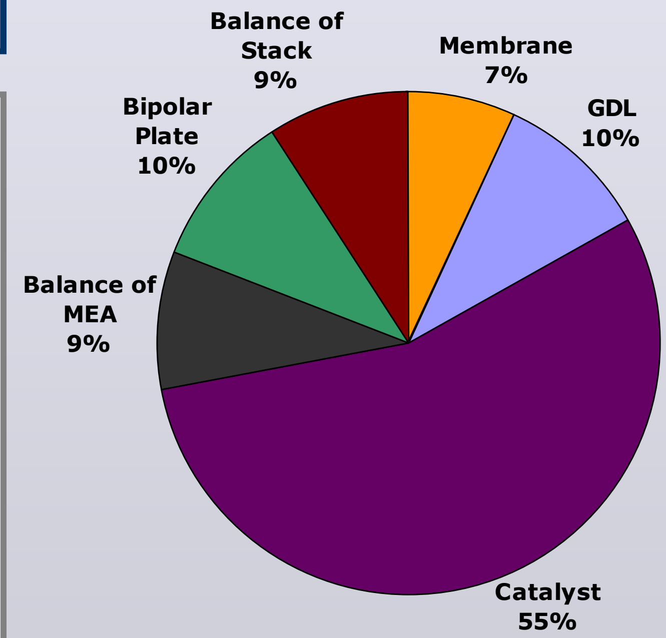
Importance to Goals:

- ***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

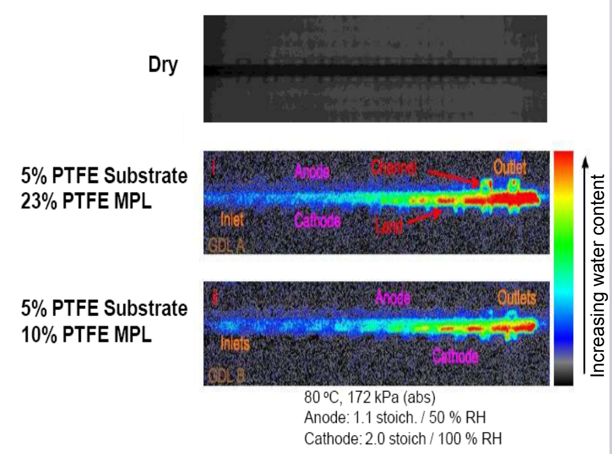
Strategies – Water Transport

Importance to Goals:

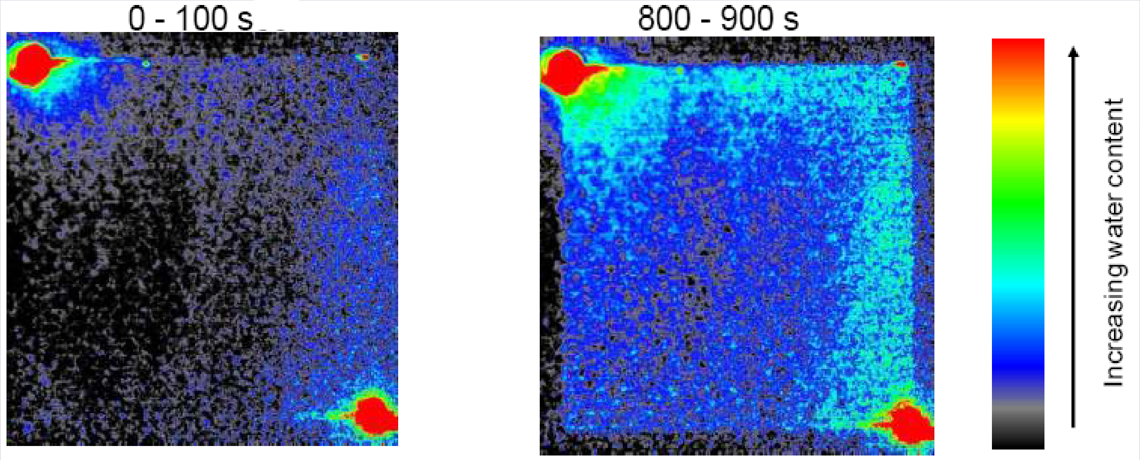
- ***Understanding water transport key to operation in cold climates, preventing flooding, and preventing membrane dry-out***

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

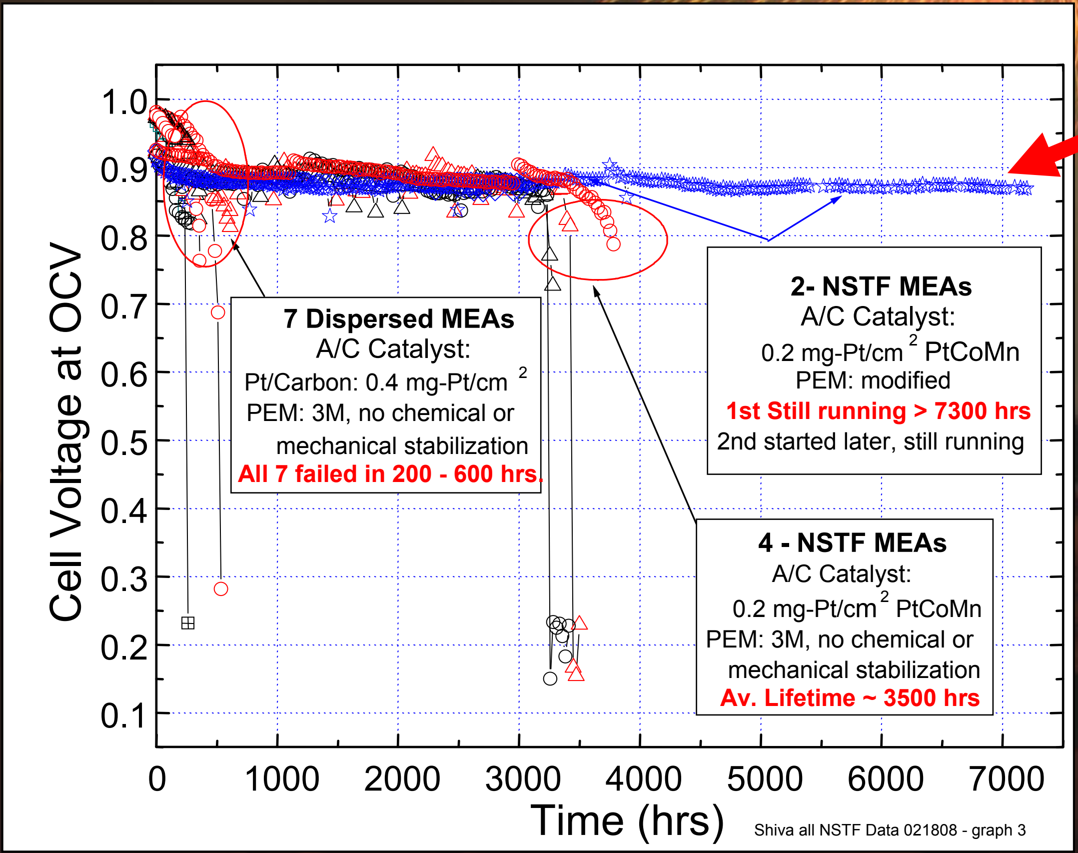


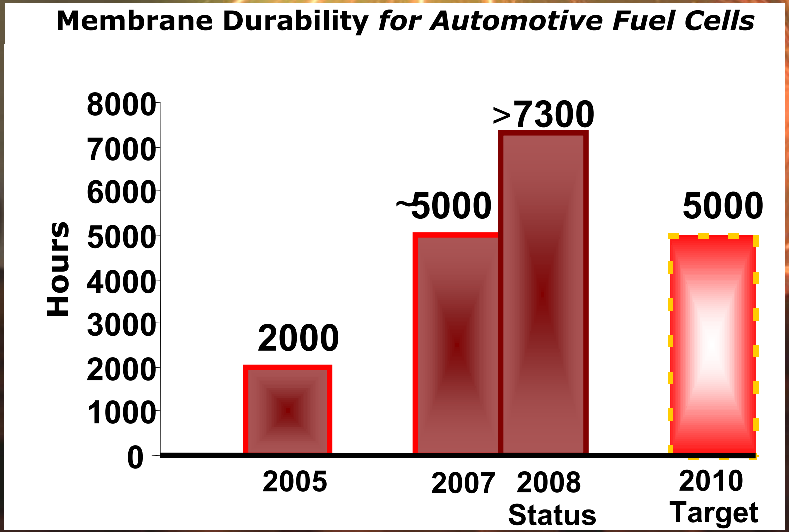
Neutron Imaging of Ice Formation During Operation at -10ºC

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).

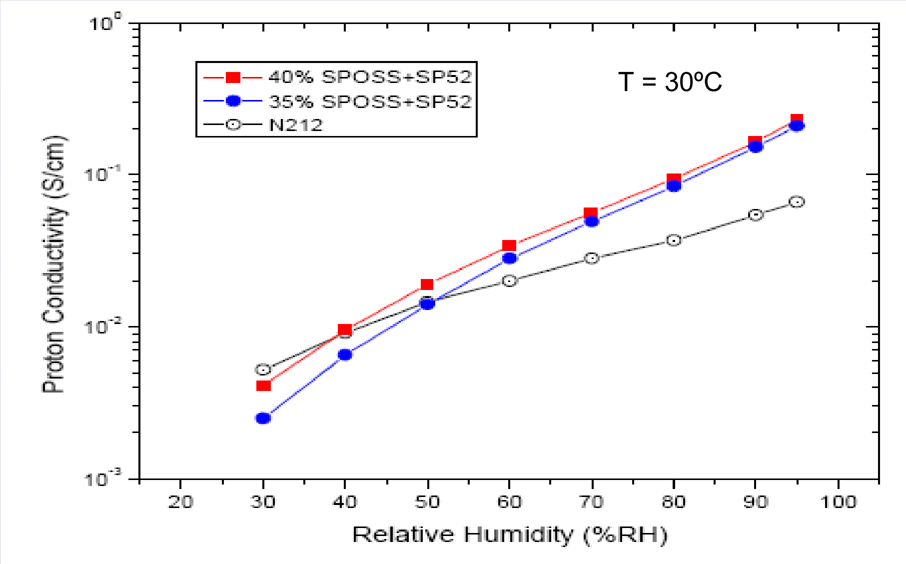
MEA still running

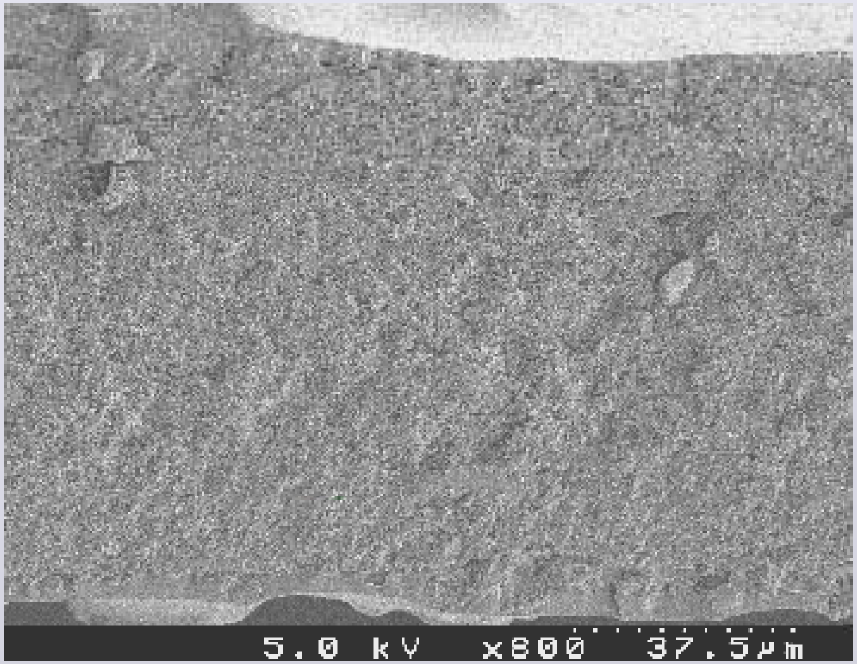




Nano-Capillary Membranes meet Interim Proton Conductivity Milestone

- 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

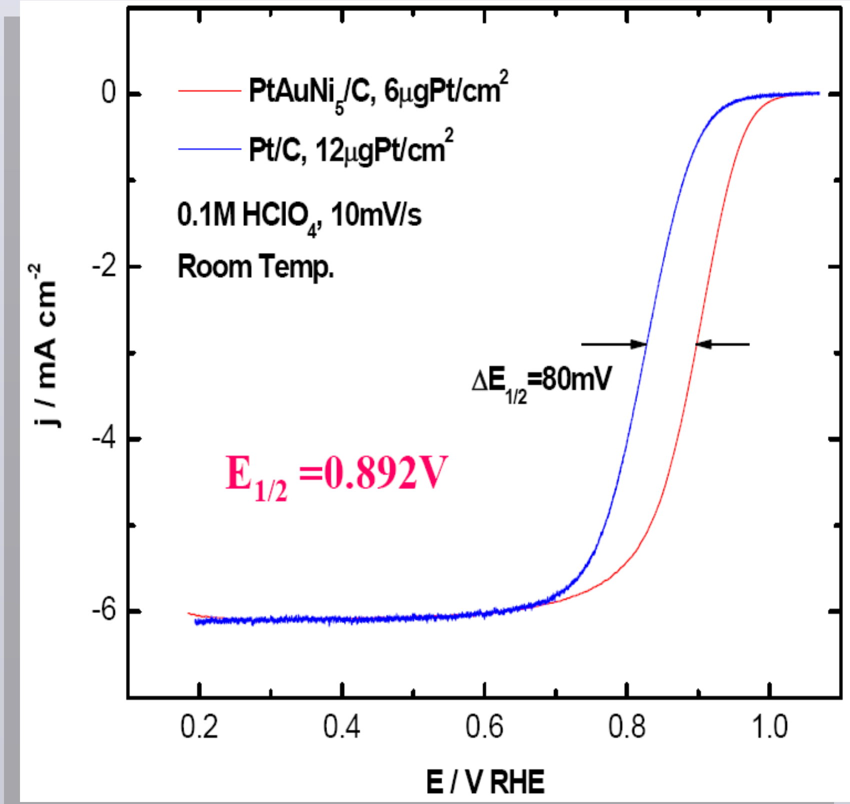


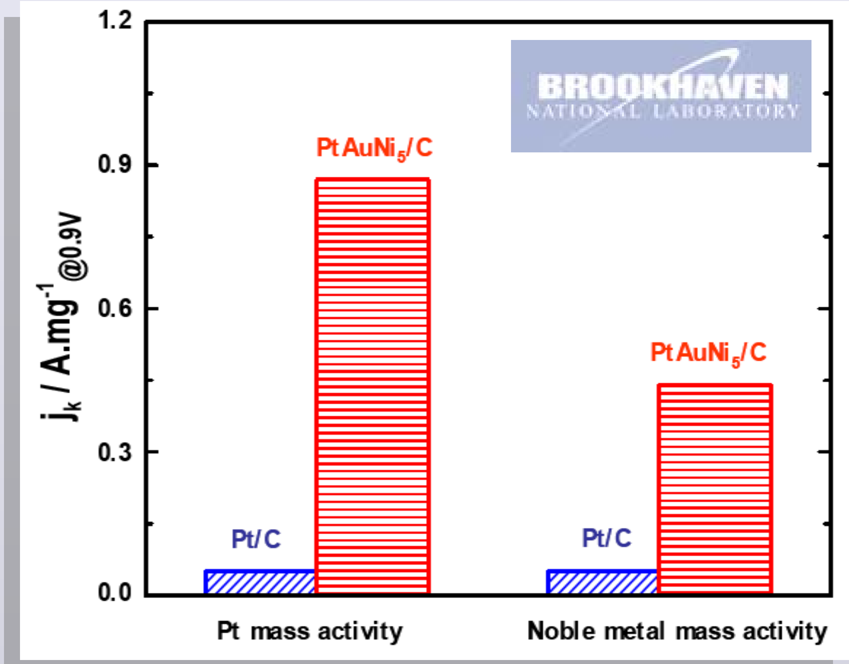


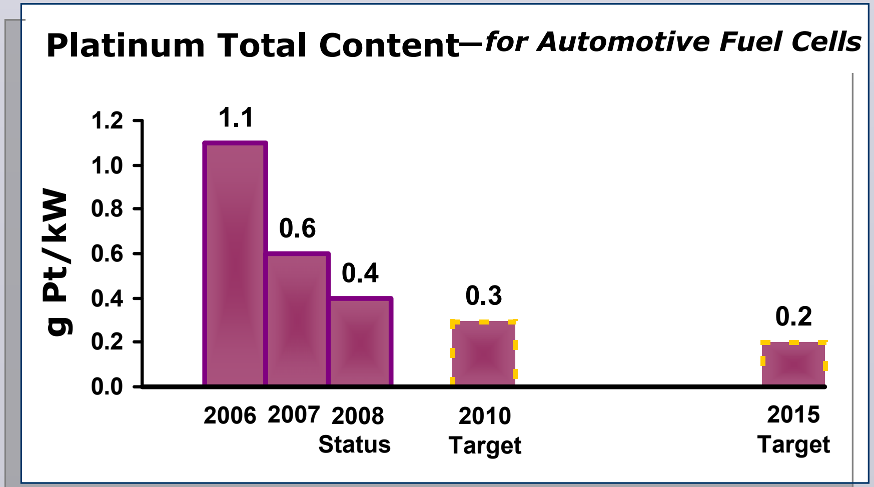
Sulfonated poly(arylene ether sulfone) nano-capillaries in NOA (inert polymer resin)

Ternary Alloy Catalyst shows Improved Performance

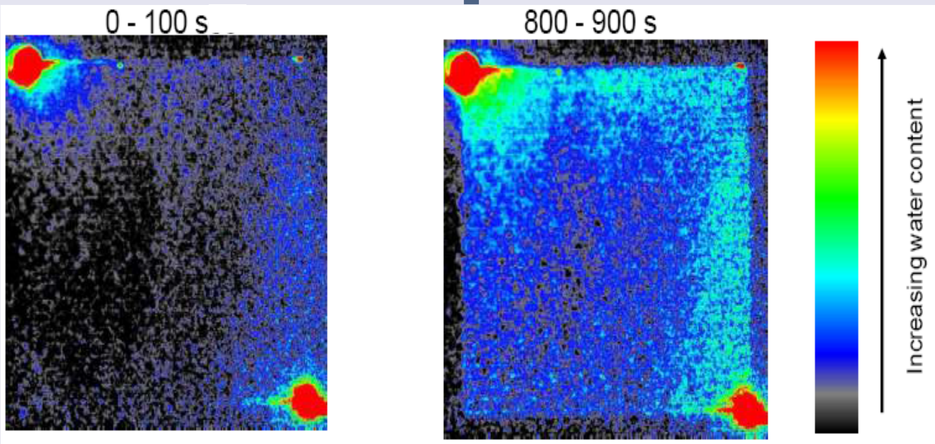
Ternary Alloy Catalyst with higher mass activity than conventional Pt catalyst

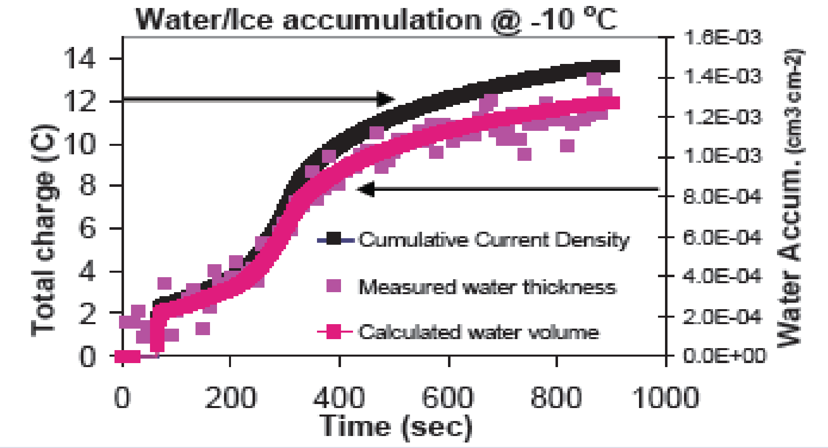




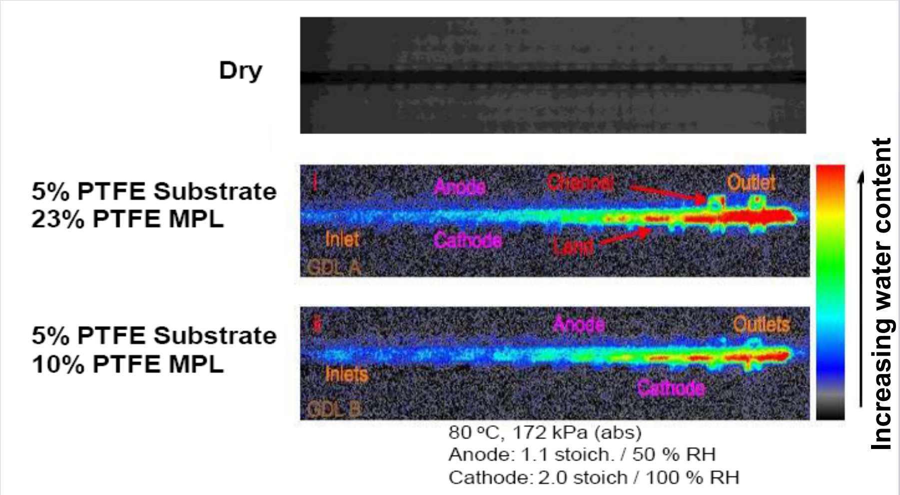


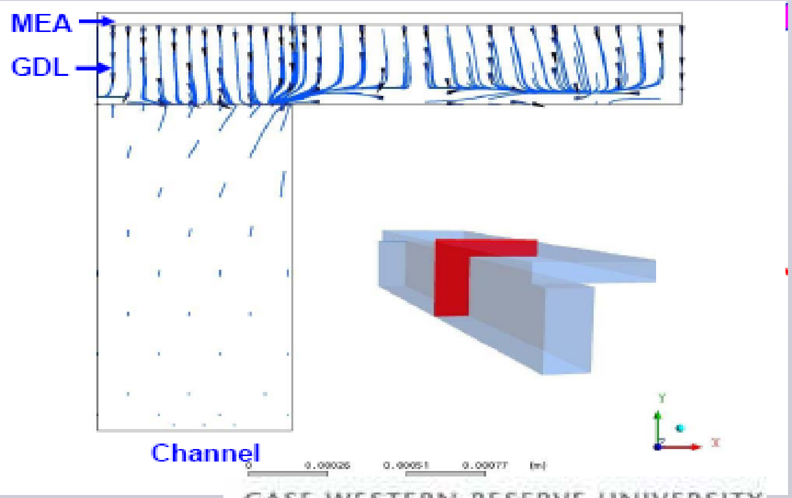
Neutron Images validate Water Transport Models





- 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

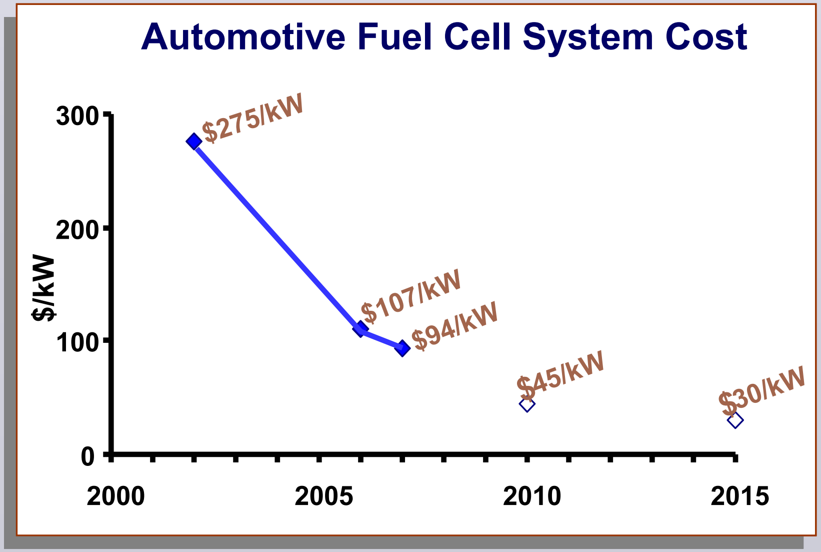


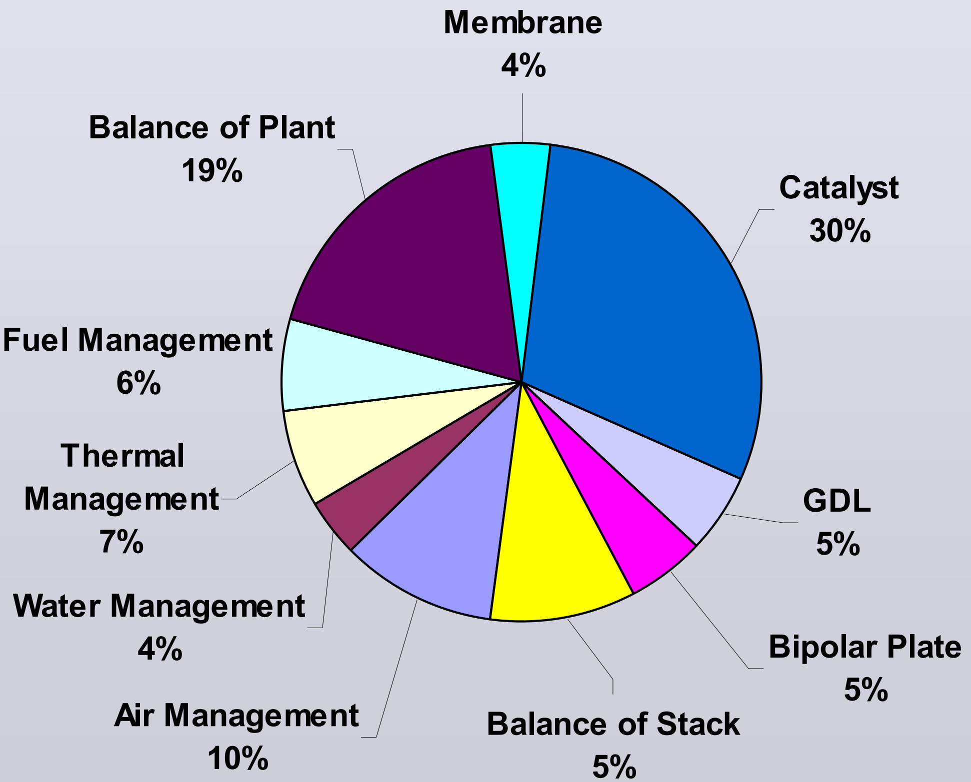


Automotive Fuel Cell System Cost reduced to $94/kW

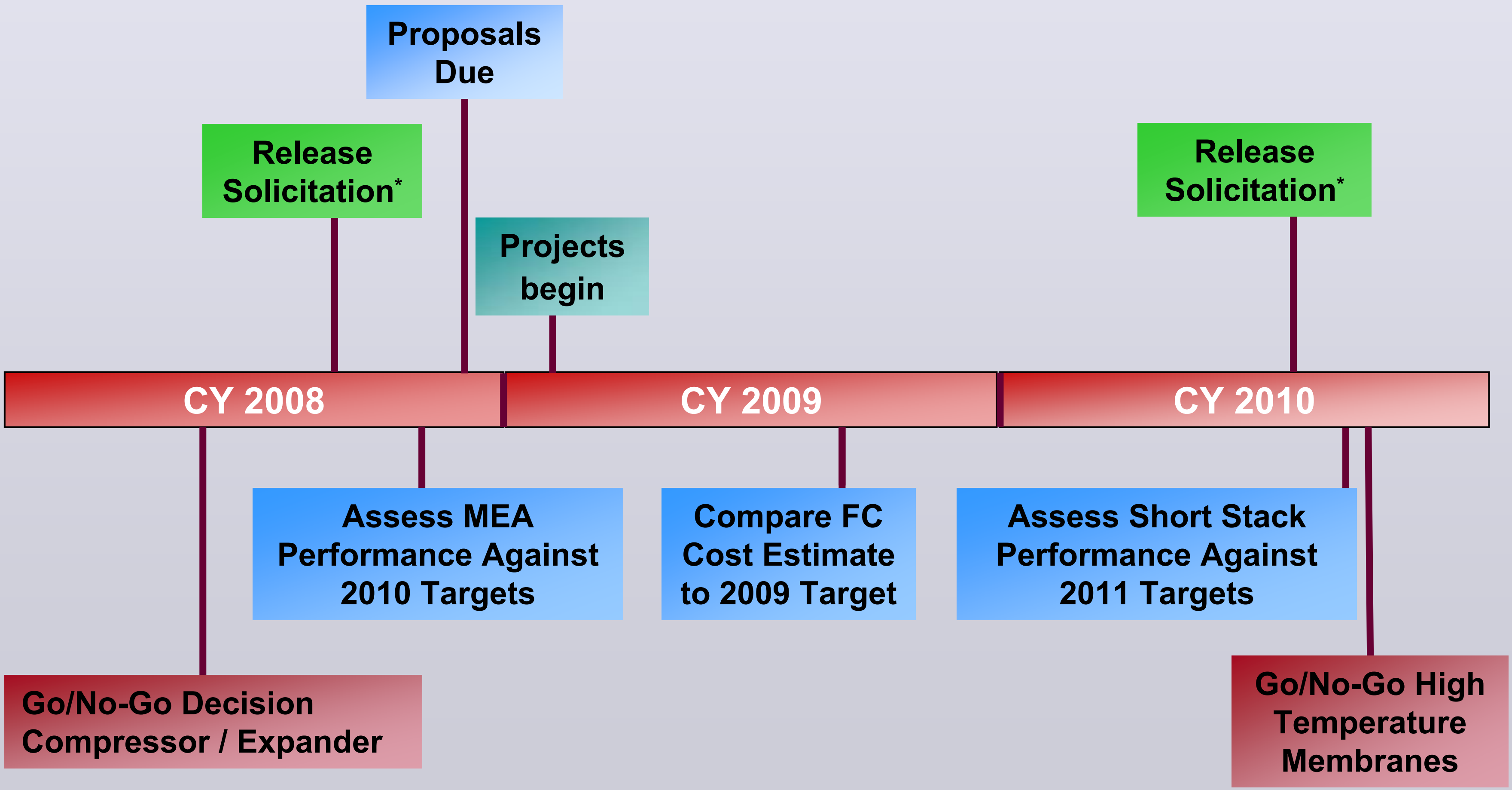
- Based on DTI DFMA 2007 cost analysis
- Projected to manufacturing volume of 500,000 units per year.

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

MEAs

- Develop characterization tools, understanding of material behavior

SOFCs

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

For More Information

Fuel Cell Team

Nancy Garland, Acting Team Leader
Overall Fuel Cells/International
202-586-5673
nancy.garland@ee.doe.gov

Jason Marcinkoski
Cost Analyses, BOP, Systems Analysis
202-586-7466
jason.marcinkoski@ee.doe.gov

Kathi Epping Martin
Stationary, Stack Components
202-586-7425
kathi.epping@ee.doe.gov

Terry Payne
On Assignment to DOE
Oak Ridge Nat'l Lab
202-586-9585
terry.payne@ee.doe.gov

Field Office Project Officers:
Jesse Adams
Jill Gruber
Dave Peterson
Reg Tyler
Lea Yancey

Support:
Kevin McMurphy (Sentech)