U.S. DEPARTMENT OF ENERGY

Fuel Cell R&D

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2006 DOE Hydrogen Program
Merit Review and Peer Evaluation Meeting

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Challenges

- Durability
- Cost
- Electrode Performance
- Water Transport Within the Stack
- Thermal, Air and Water Management
- Start-up Time and Energy

Cost and durability present two of the more significant technical barriers to the achievement of clean, reliable, cost-effective systems.

Key Targets

Integrated Transportation Fuel Cell Power System (80 kW_e) Operating on Direct Hydrogen
• $45/kW by 2010
• $30/kW by 2015
• 5,000 hours durability by 2010 (80^{O}C)

Other Key Targets

Distributed Energy (PEMFC)

- $750/kW by 2011
- 40,000 hours durability by 2011
- 40% electrical efficiency

Auxiliary Power Units (SOFC)

- Specific power of 100 W/kg by 2010
- Power density of 100 W/L by 2010

Consumer Electronics (DMFC)

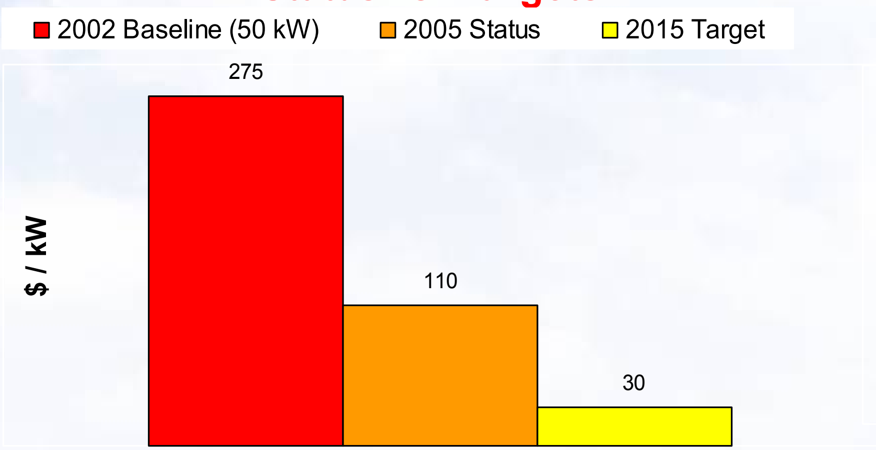
- Energy density of 1,000 W-h/L by 2010

Transportation Fuel Cell System Targets & Progress

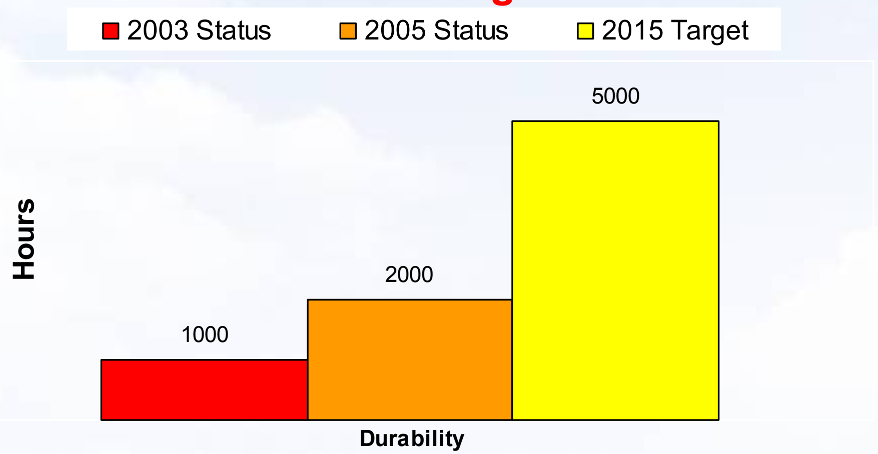
Characteristic		2003 Status	2005 Status	2015 Target
Cost	$/kW	200	110	30
Precious metal loading	g/kW (rated)	<2.0	1.1	0.2
Power density	W/L	440	525	650
Lifetime (durability w/ cycling)	hr	N/A	~1,000	5,000
Start-up time to 50% of rated power at: -20°C ambient temp	sec	120	20	30
+20°C ambient temp	sec	60	<10	5
Start-up and shut down energy at: -20°C ambient temp	MJ	na	7.5	5
+20°C ambient temp	MJ	na	na	1

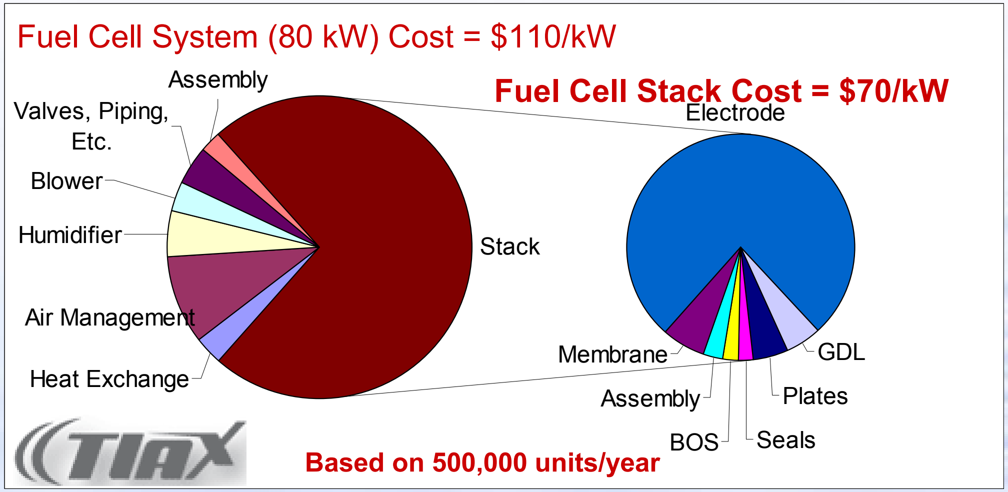
Targets & Progress: Reduced Cost and Increased Durability

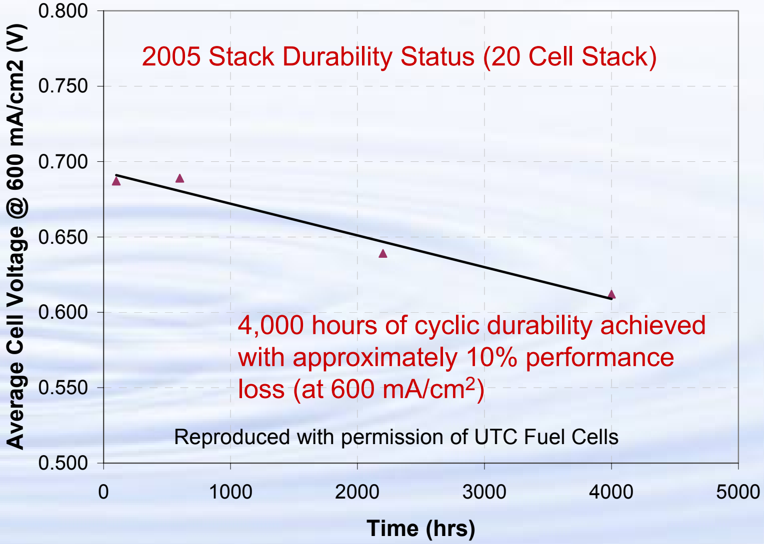
Fuel Cell System (80 kW) Costs Status vs. Targets



Fuel Cell Stack (only) Durability Status vs. Targets





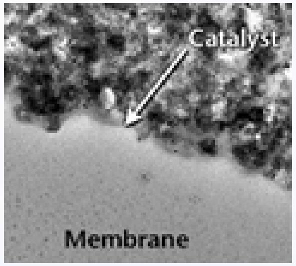


Strategy

- Primary focus is on fuel cells for transportation applications
- R&D is focused on components rather than systems

Membranes	**Bipolar Plates**
Electrodes	**Seals**
Membrane Electrode Assemblies	**Balance-of-plant Components**
Gas Diffusion Layers	**Innovative Concepts**

Analysis, Characterization and Benchmarking



Solicitation and Lab Call for $100 million over 2-4 years: closed April 7; selections expected in the fall

Strategy

- Secondary focus is on stationary and other early market fuel cells to establish the manufacturing base

<u>Distributed Power</u>

- Improve system durability
- Improve stack performance w/ reformate
- Improve fuel processor performance
- Increase system electrical efficiency

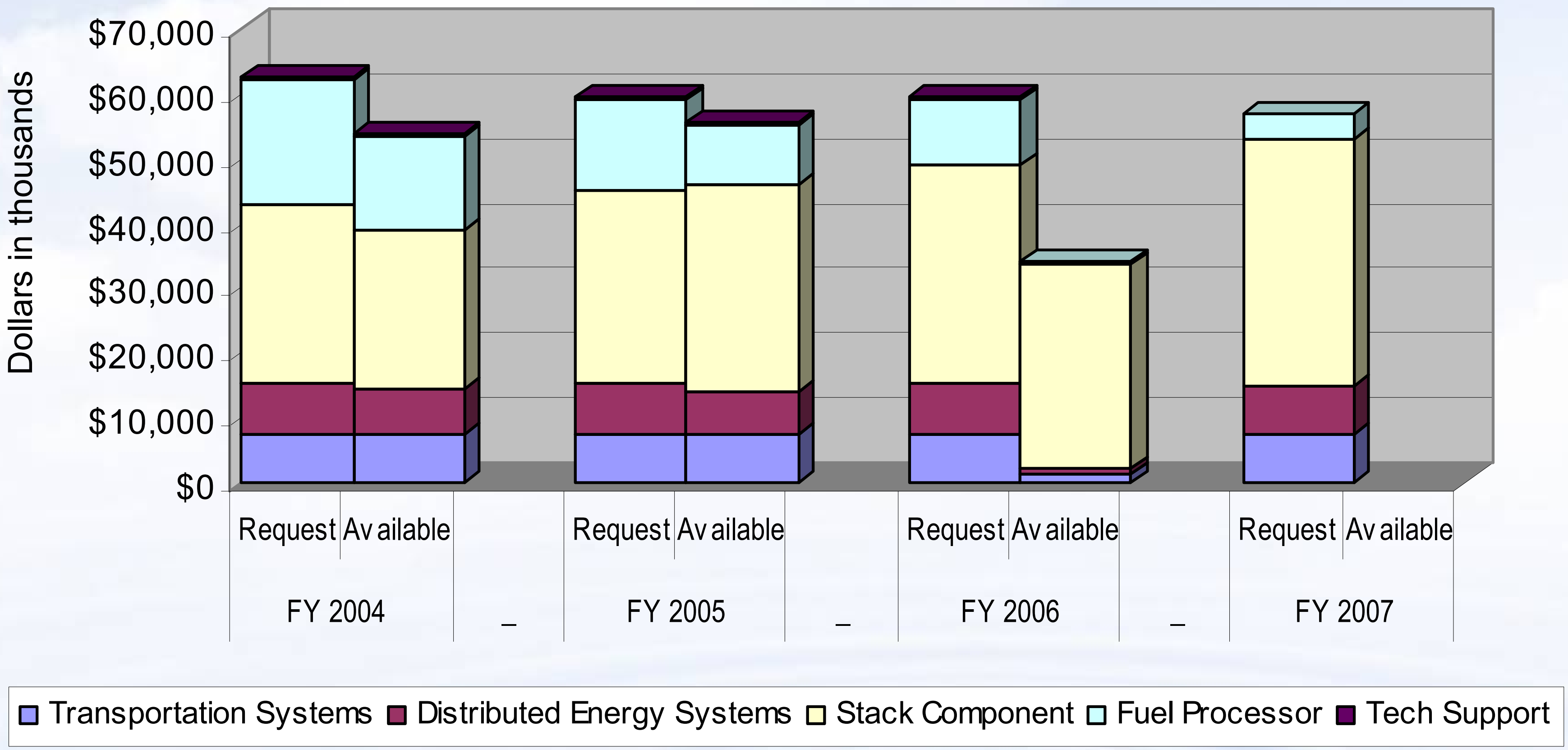
<u>APUs</u>

- Develop diesel fuel processor
- Develop FC that operates on reformate
- Design, build, & test under real-world conditions

<u>Portable Power</u>

- Develop membranes to reduce methanol crossover
- Design, build, & test under real-world conditions

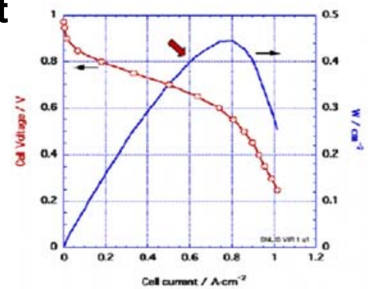
Fuel Cell Budget



Results: R&D Highlights

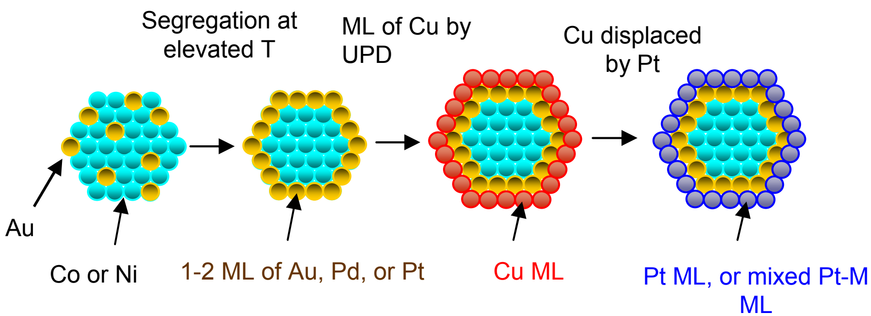
Catalysts (Pt Alloy)

- **Achieved state-of-the-art Pt-alloy mass activities (0.26A/mg_{Pt}) in durable whisker electrode structure (3M)**
- **Improved MEA lifetime under harsh FC conditions *(3M)***
- **Achieved mass activity 4x that of Pt *(BNL)***



BNL,

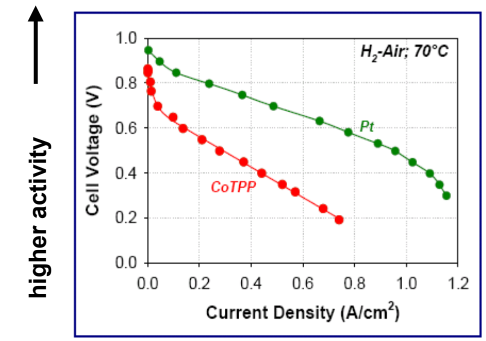
MEA testing at LANL

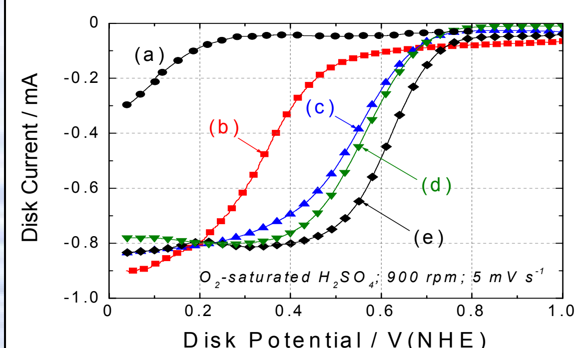


Catalysts (Non-Pt)

- **10X increase in catalyst layer while maintaining mass transport *(LANL)***
- **Metal-free carbon based catalyst with activity approaching other non-pt metal catalysts (USC)**
- **Reduced H_2O_2 generation by more than 70% *(USC)***

Air-electrode behavior of equal loadings of Pt & non-Pt (cobalt-based) catalysts, **LANL**





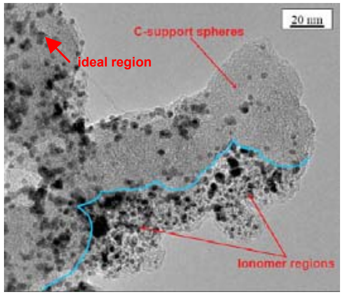
(a) as-received carbon
(e) 2CN/2CN-X
University of South Carolina

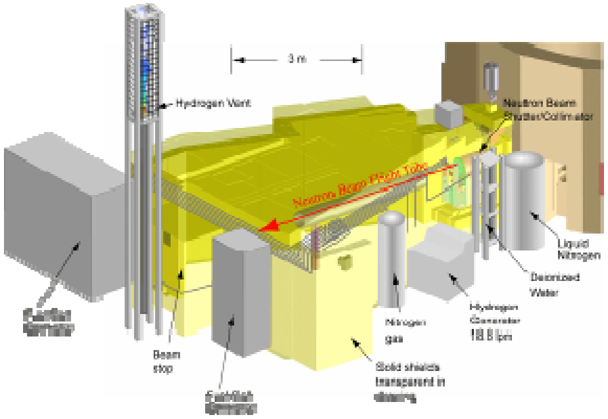
Results: R&D Highlights

Characterization

- **Achieved real-time imaging of water in FC components during transients *(NIST)***
- **Developed microstructural characterization of PEM FC MEAs *(ORNL)***

TEM image showing the distribution of Pt catalyst **(ORNL)**



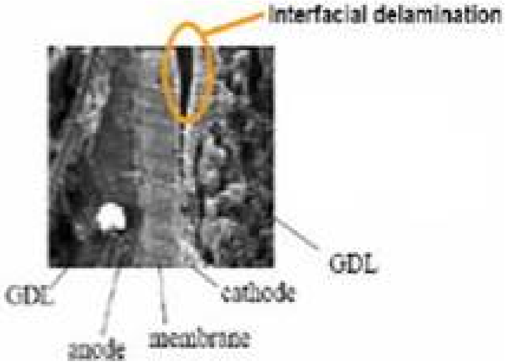


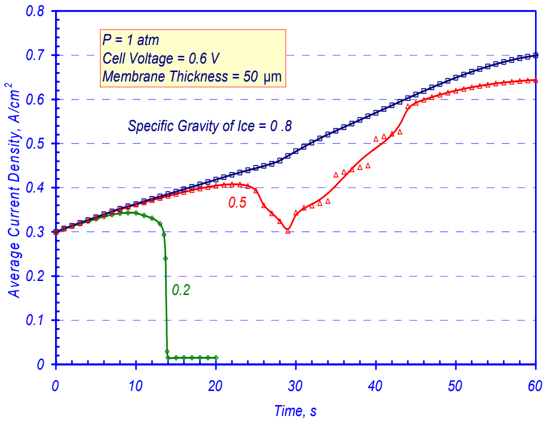
NIST's New BT-2 Neutron Imaging Facility

Water Management Freeze (sub-freeze)

- **Accomplished dynamic model of freeze start showing self start possible when specific gravity of ice formation is >0.5 *(ANL)***
- **Identified delamination of cathode catalyst, but only at <-40°C *(LANL)***

SEM micrograph after 10 cycles from -80 to 80°C, **LANL**





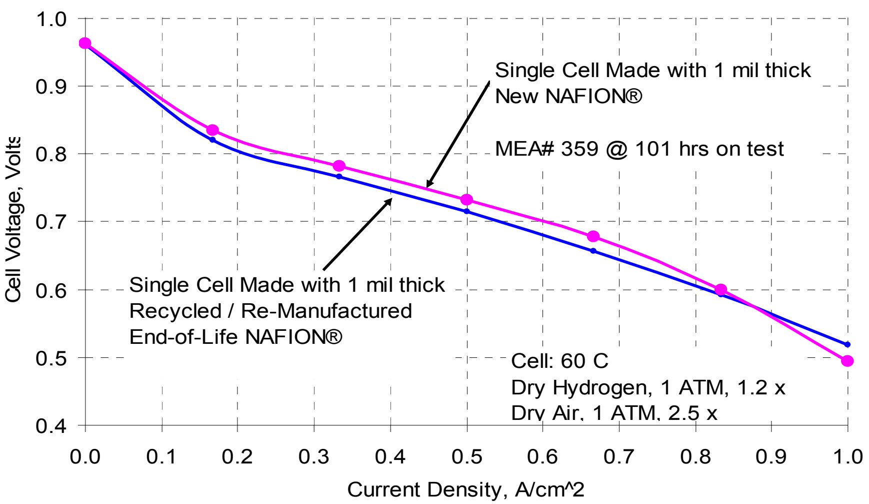
Modeled startup from subfreezing conditions (<30 s), **ANL**

Results: R&D Highlights

Recycling

- **Developed first operating FC with remanufactured membrane/down-select of Pt separation procedures *(Ion Power, Engelhard)***
- **Developed testing procedures determining catalyst separation of used MEAs from polymers for use in new MEAs *(Ion Power)***
- **Developed more conventional Pt-recycling approach *(Engelhard)***

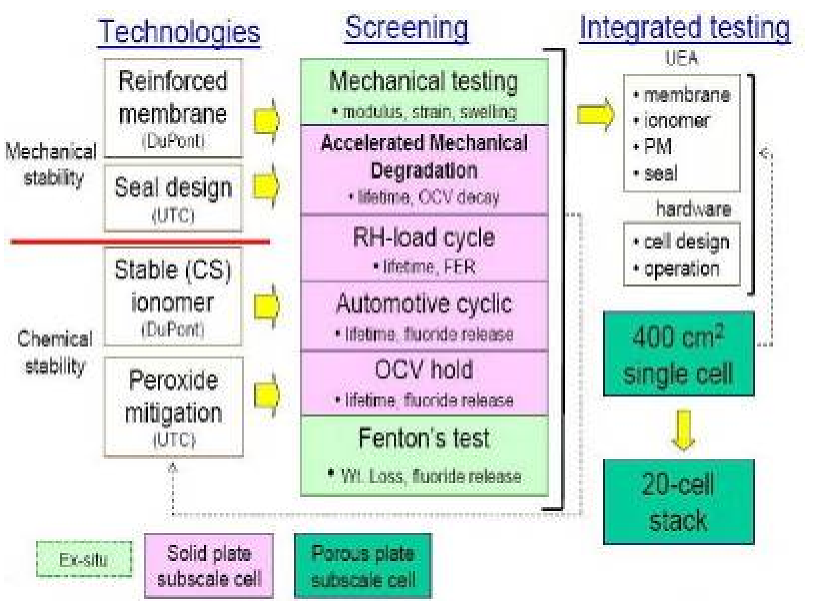
Recycled NAFION® from End-of-life Fuel Cell System has Performance Close to Virgin NAFION®



Ion Power, Engelhard

Membrane Durability

- **Identified chemical and mechanical modes of degradation and demonstrated a coupling between the two modes *(DuPont/UTC)***



Lifetime Improvements Achieved through Coordinated work from Fundamentals to Stack, **DuPont**

For More Information

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