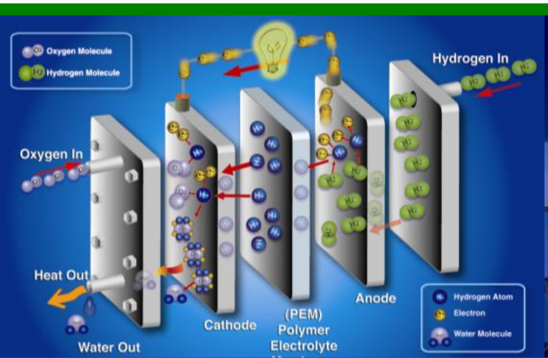
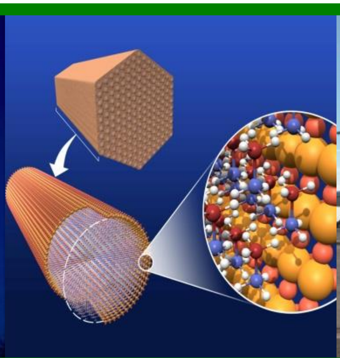



Overview of DOE Hydrogen and Fuel Cell Activities

Dr. Sunita Satyapal

United States Department of Energy

Fuel Cell Technologies Program

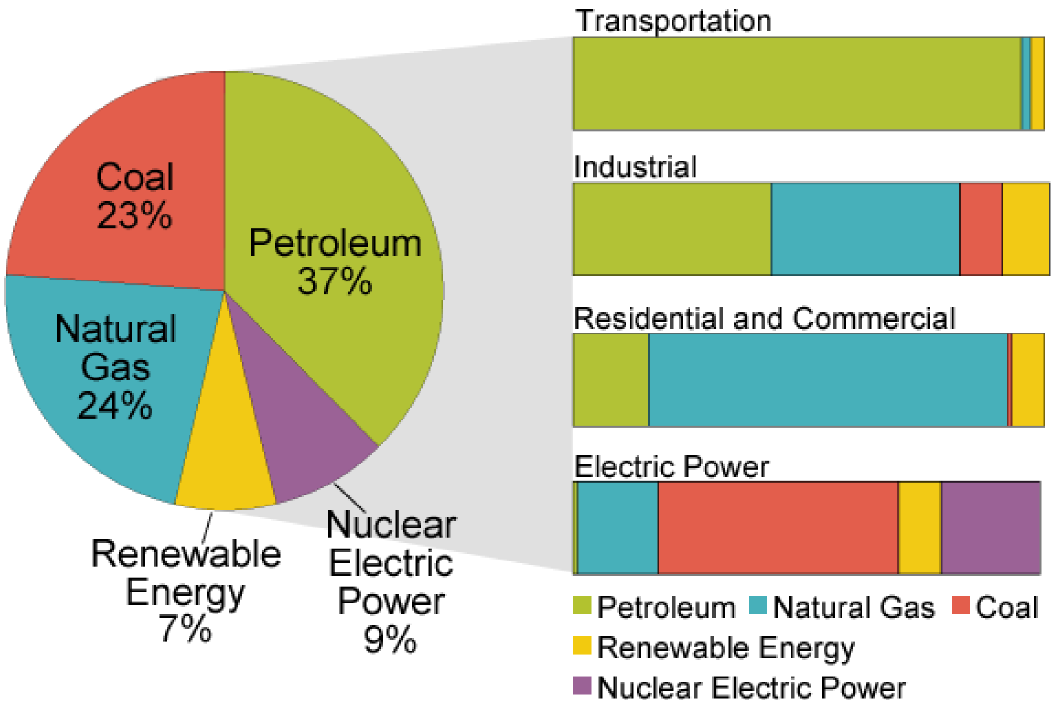
Gordon Research Conference: Fuel Cells, Rhode Island

August 1, 2010

Administration's Clean Energy Goals

- ✓ Double Renewable Energy Capacity by 2012
- ✓ Invest $150 billion over ten years in energy R&D to transition to a clean energy economy
- ✓ Reduce GHG emissions 83% by 2050

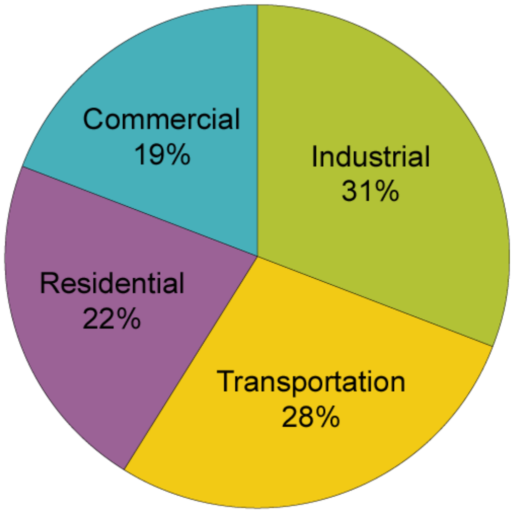
U.S. Primary Energy Consumption by Source and Sector



Total U.S. Energy = 99.3 Quadrillion Btu

Source: Energy Information Administration, *Annual Energy Review 2008*, Tables 1.3, 2.1b-2.1f.

Share of Energy Consumed by Major Sectors of the Economy, 2008



Source: Energy Information Administration, *Annual Energy Review 2008*.

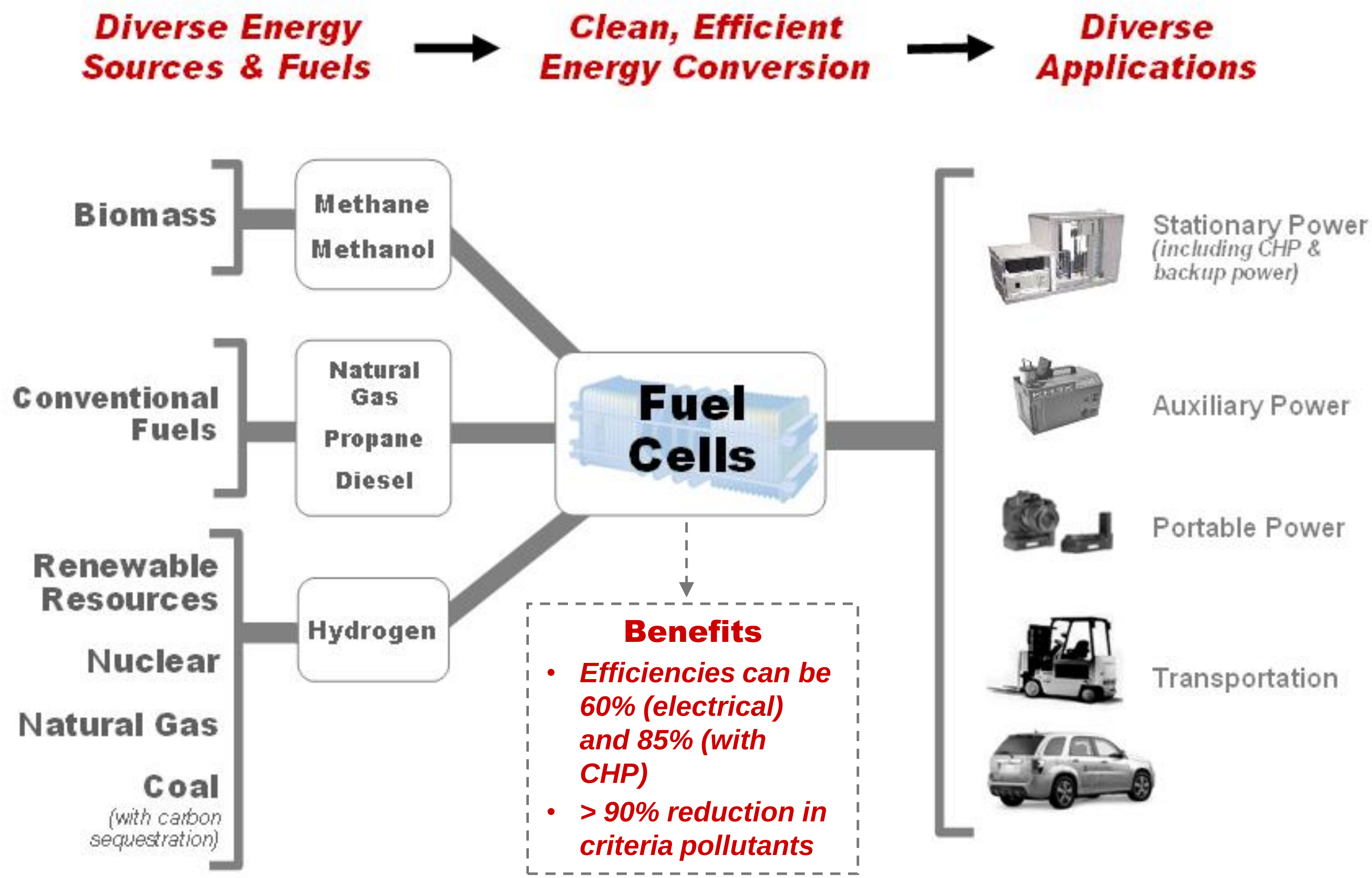
Fuel Cells: Addressing Energy Challenges

Energy Efficiency and Resource Diversity

→ *Fuel cells offer a highly efficient way to use diverse fuels and energy sources.*

Greenhouse Gas Emissions and Air Pollution:

→ *Fuel cells can be powered by emissions-free fuels that are produced from clean, domestic resources.*



Fuel Cells — *Where are we today?*

Fuel Cells for Stationary Power, Auxiliary Power, and Specialty Vehicles

The largest markets for fuel cells today are in stationary power, portable power, auxiliary power units, and forklifts.

~75,000 *fuel cells have been shipped worldwide.*

~24,000 *fuel cells were shipped in 2009 (> 40% increase over 2008).*

Fuel cells can be a cost-competitive option for critical-load facilities, backup power, and forklifts.

Fuel Cells for Transportation

In the United States:

- *> 200 fuel cell vehicles*
- *> 20 fuel cell buses*
- *~ 60 fueling stations*

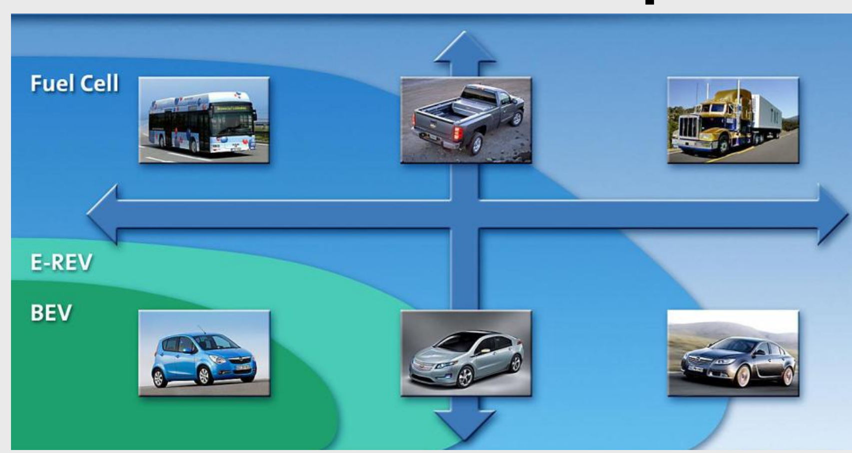
Several manufacturers—including Toyota, Honda, Hyundai, Daimler, GM, and Proterra (buses) — have announced plans to commercialize vehicles by 2015.

Production & Delivery of Hydrogen

In the U.S., there are currently:

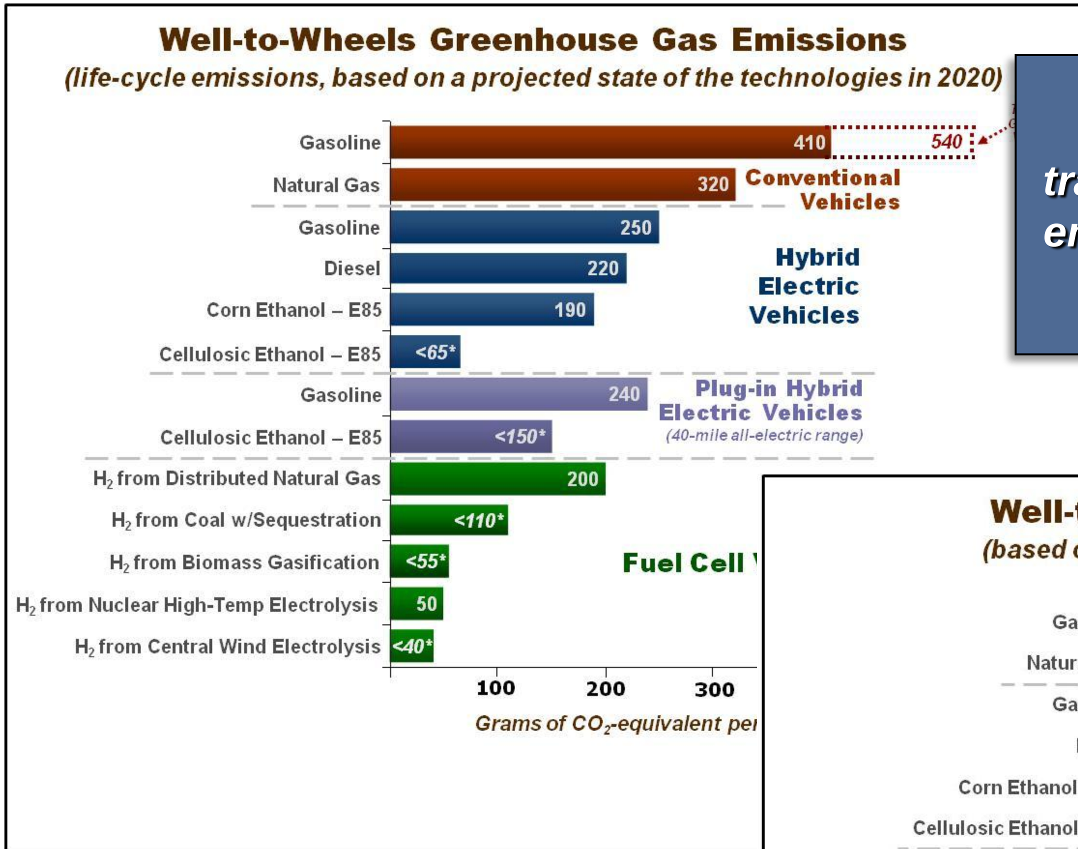
- ***~9 million metric tons*** *of H_2 produced annually*
- ***> 1200 miles*** *of H_2 pipelines*

The Role of Fuel Cells in Transportation

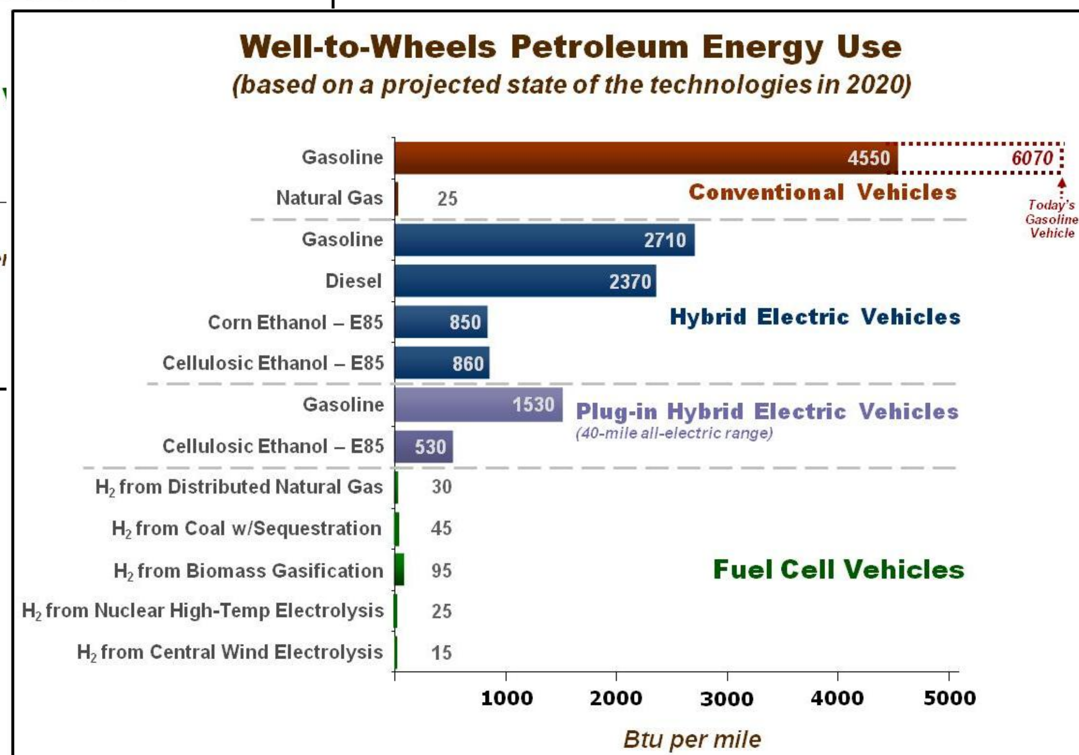


Systems Analysis — *Examples of Benefits*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Analysis shows DOE's portfolio of transportation technologies will reduce emissions of greenhouse gases and oil consumption.



DOE Program Record #9002, www.hydrogen.energy.gov/program_records.html.

Key Challenges

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The Program has been addressing the key challenges facing the widespread commercialization of fuel cells.

Technology Barriers*

Fuel Cell Cost & Durability

Targets*:

- ***Stationary Systems:*** **$750 per kW, 40,000-hr durability**
- ***Vehicles:*** **$30 per kW, 5,000-hr durability**

Hydrogen Cost

Target: $2 – 3 /gge, delivered (revision underway)

Hydrogen Storage Capacity

Target: > 300-mile range for vehicles—without compromising interior space or performance

Technology Validation:

Technologies must be demonstrated under real-world conditions.

Economic & Institutional Barriers

Safety, Codes & Standards Development

Domestic Manufacturing & Supplier Base

Public Awareness & Acceptance

Hydrogen Supply & Delivery Infrastructure

Market Transformation

Assisting the growth of early markets will help to overcome many barriers, including achieving significant cost reductions through economies of scale.

***Metrics available/under development for various applications**

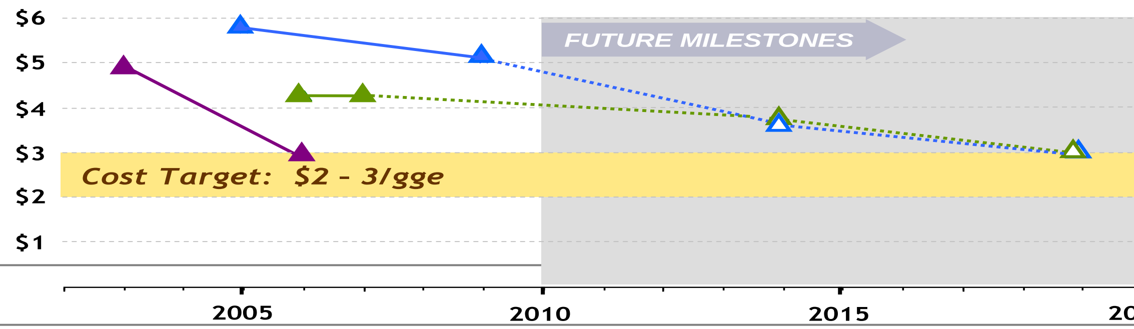
Projected* High-Volume Cost of Hydrogen (Delivered) — Status & Targets

($/gallon gasoline equivalent [gge], untaxed)

NEAR TERM:

Distributed Production

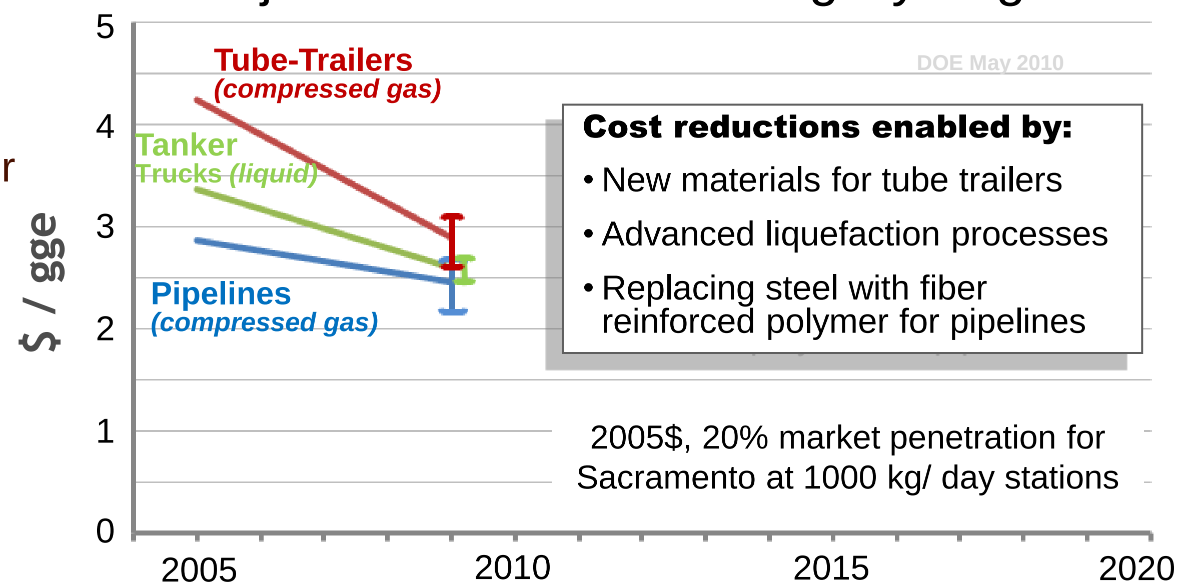
- ▲ Natural Gas Reforming
- ▲ Bio-Derived Renewable Liquids
- ▲ Electrolysis



Projected Cost of Delivering Hydrogen

We've reduced the cost of hydrogen delivery* —

- ~30% reduction in tube trailer costs
- >20% reduction in pipeline costs
- ~15% reduction liquid hydrogen delivery costs



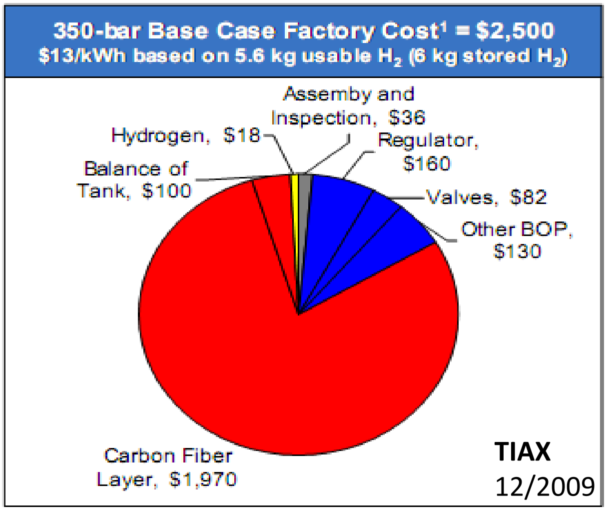
Cost targets under revision

Projected cost, based on analysis of state-of-the-art technology

Compressed gas offers a near- term option, but cost is an issue

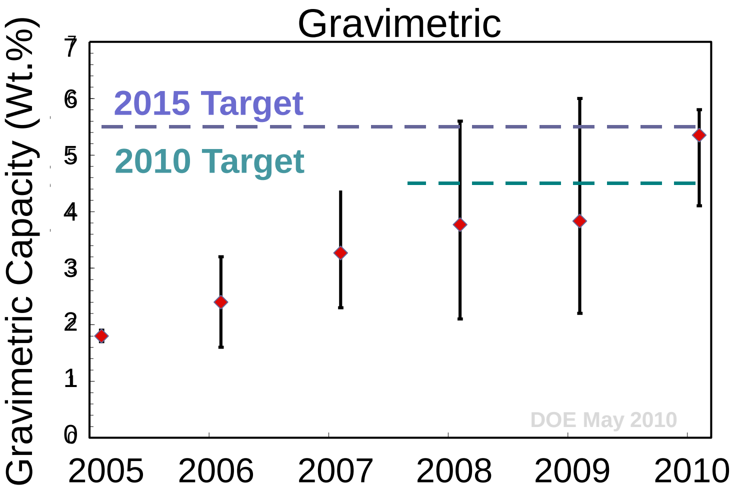
Compressed gas storage offers a near-term option for initial vehicle commercialization and early markets

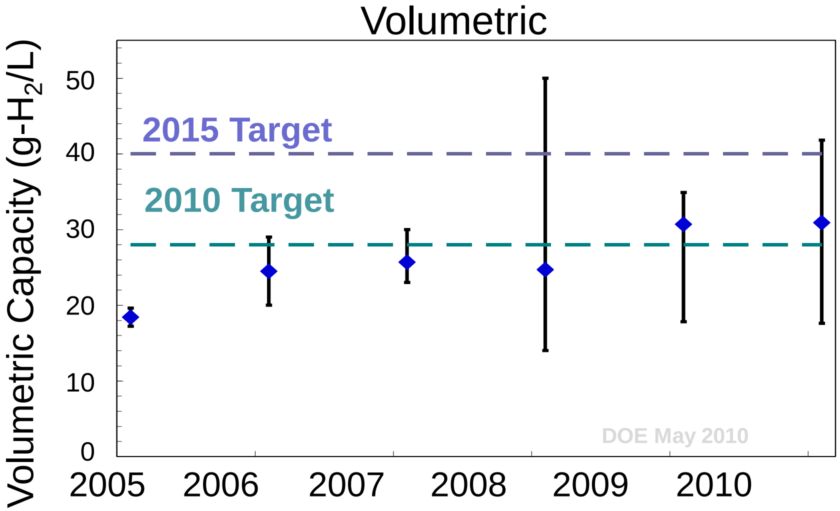
- **Validated driving range of up to ~ 430 mi**
- **Cost of composite tanks is challenging**
  - **carbon fiber layer estimated to be >75% of cost**
- **Advanced materials R&D under way for the long term**



[1] Cost estimate in 2005 USD. Includes processing costs.

Projected Capacities for Complete 5.6-kg H_2 Storage Systems



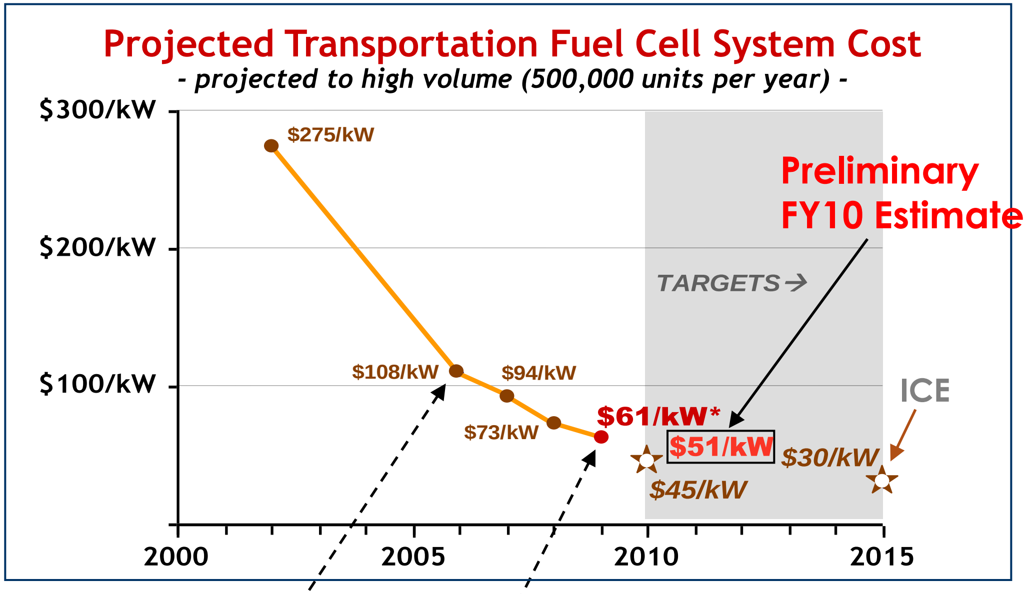


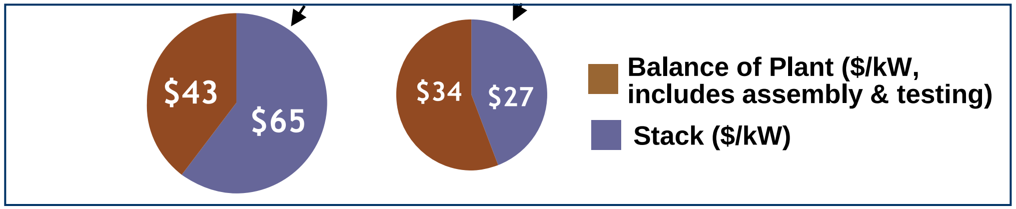
Fuel Cell R&D — *Progress: Cost*

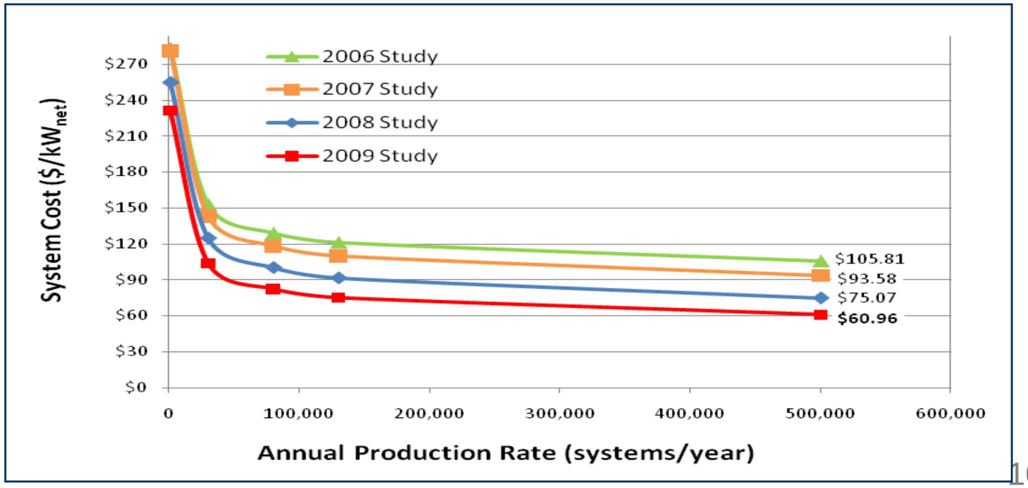
Projected high-volume cost of fuel cells has been reduced to $61/kW (2009)

- ***More than 15% reduction in the last two years***
- ***More than 75% reduction since 2002***
- ***2008 cost projection was validated by independent panel*****

As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs.







**Based on projection to high-volume manufacturing (500,000 units/year).*

***Panel found $60 – $80/kW to be a "valid estimate": http://hydrogendoedev.nrel.gov/peer_reviews.html*

The Program has reduced PGM content and increased power density, resulting in a decrease in system cost.

From 2008 to 2009, key cost reductions were made by:

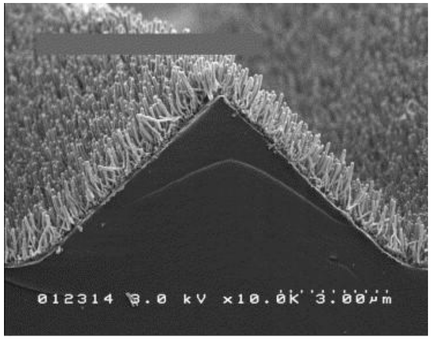
- **Reducing platinum group metal content from 0.35 to 0.18 g/kW**
- **Increasing power density from 715 to 833 mW/cm^2**

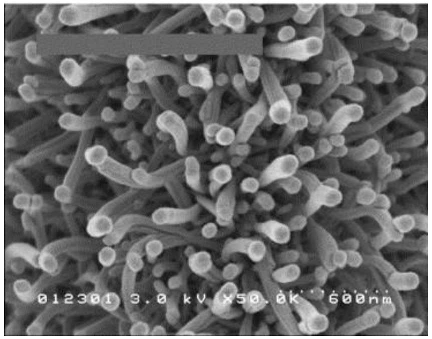
→ These advances resulted in a $10/kW cost reduction.

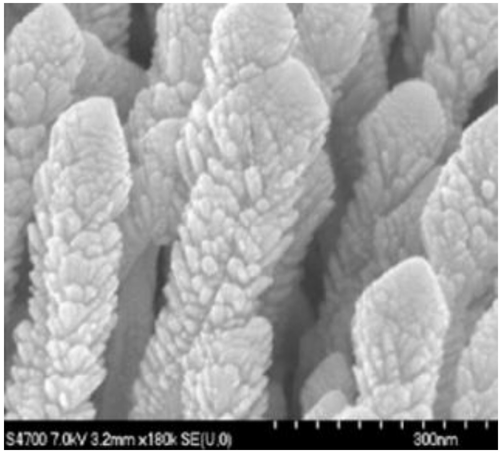
Key improvements enabled by using novel organic crystalline whisker catalyst supports and Pt-alloy whiskerettes.

There are ~ 5 billion whiskers/cm^2.

Whiskers are ~ 25 X 50 X 1000 nm.







Whiskerettes:
6 nm x 20 nm

3M

Catalysts and Supports

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

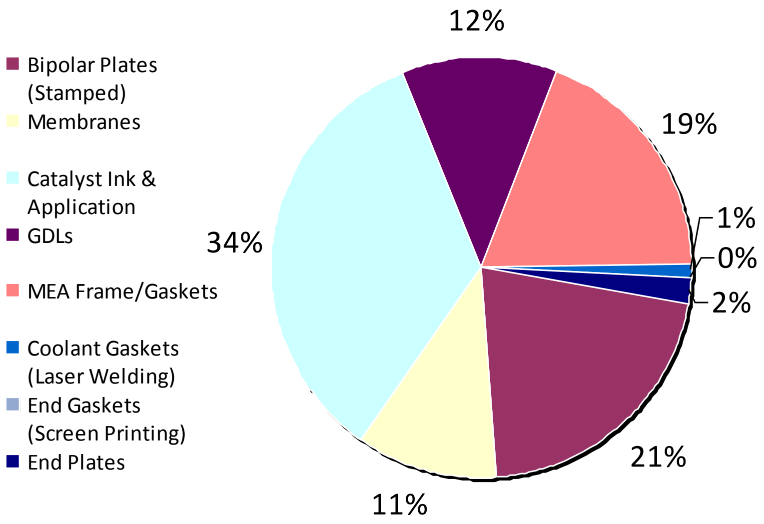
Challenges:

- **Platinum (Pt) cost is ~34% 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 with comparable performance to Pt and cost less
- Novel Support Structures
  - Non-carbon supports and alternative carbon structures
- Non-PGM catalysts
  - Non-precious metal catalysts with improved performance and durability

Stack Cost - $26/kW

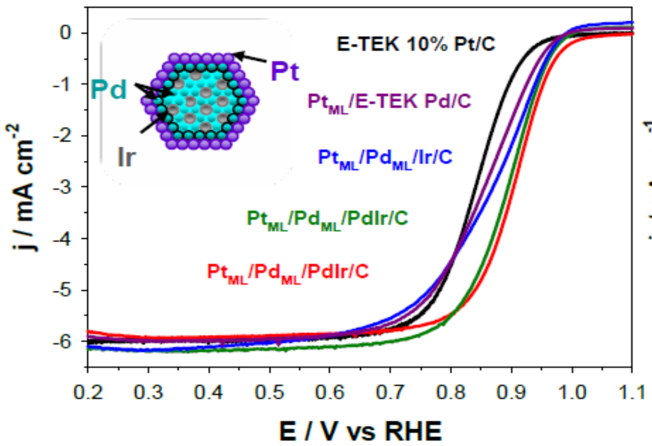


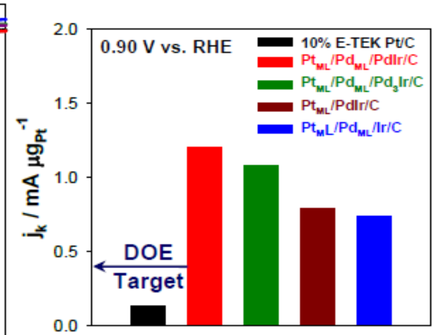
DTI, 2009 analysis, scaled to high volume production of 500,000 units/yr

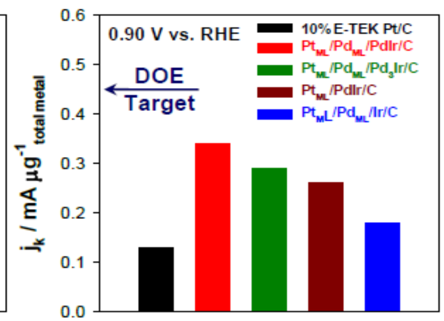
Used $1100/Troy Ounce for Pt Cost

Ultra-low Pt Content Catalysts

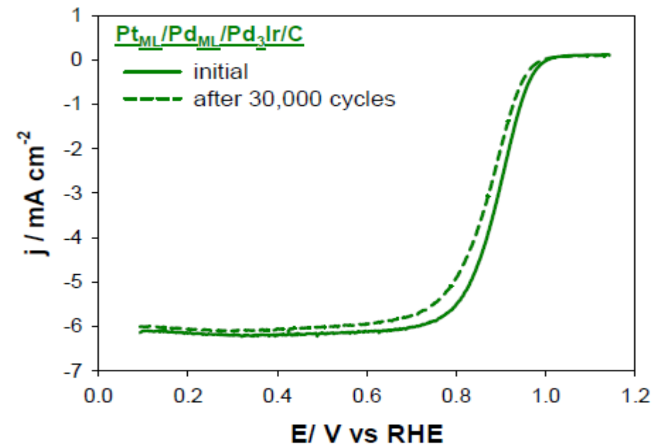
Pd Interlayer Effect on ORR Activity







- **Highlight:** 0.35 A/mg_{PGM} at 0.90 V – an improvement of 0.08 A/mg_{PGM} due to Pd interlayer (better lattice constant for Pt overlayer)
- **Highlight:** $E_{1/2}$ loss after 30,000 cycles of only 19 mV vs. 39 for Pt/C
- Pd not significantly oxidized (XAS); good substrate for Pt compared to other metals, e.g. iridium

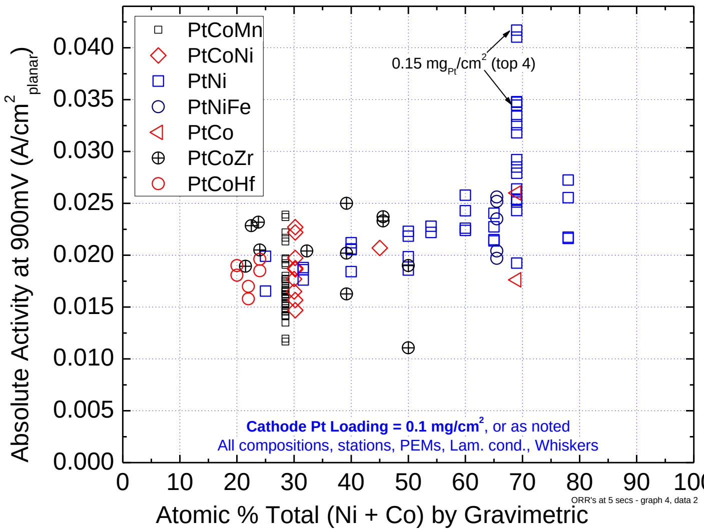


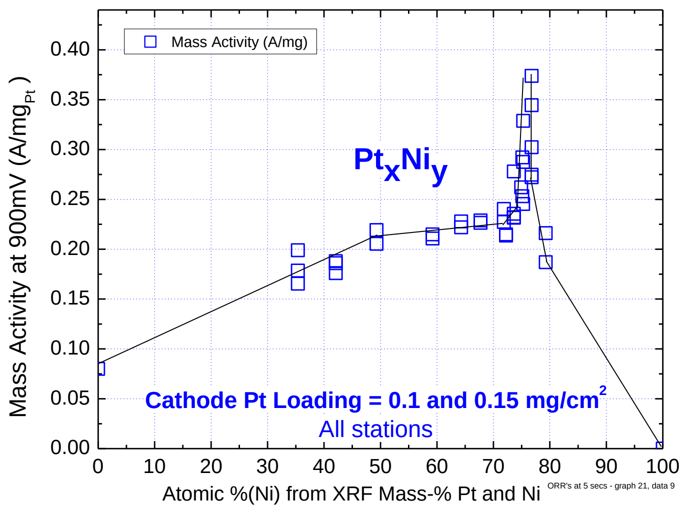
Los Alamos NATIONAL LABORATORY — BROOKHAVEN NATIONAL LABORATORY

Next Steps: Improve activity and durability. In-cell testing.

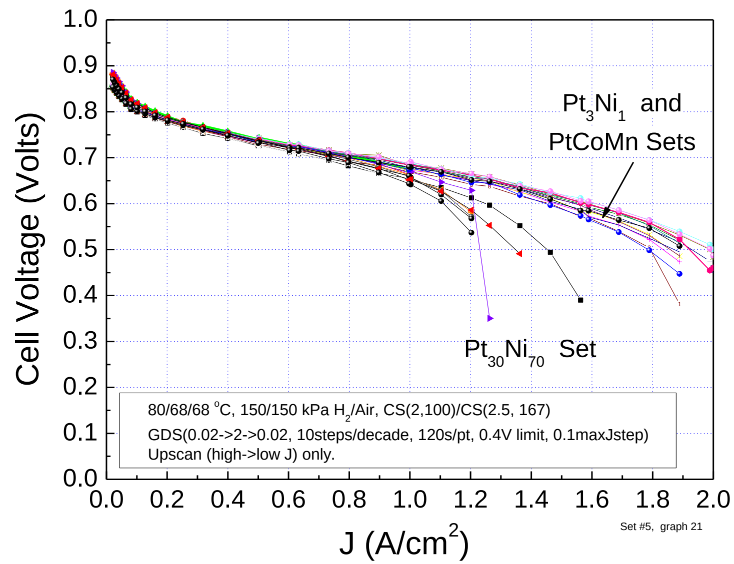
R. Adzic and P. Zelanay 2009 DOE Hydrogen Program Review

High-Activity Binary PtNi Alloy Catalyst





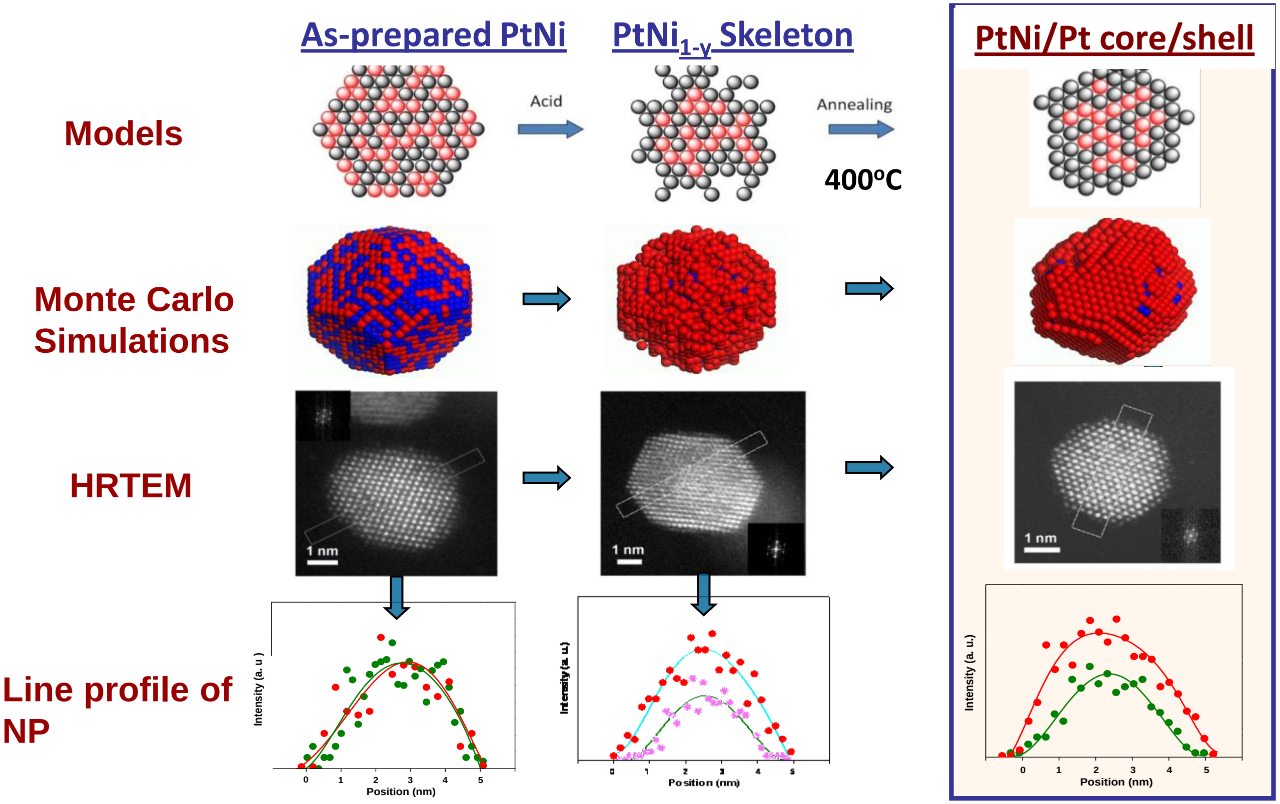
- Screening of multiple new alloys at 3M revealed anomalously high ORR activity for Pt_xNi_y at high Ni content.
- Dramatic and sharp mass activity peak at Pt_3Ni_7 (gravimetric) vs 60at% Ni and 76at% Ni by EMP and XRF respectively.
- Definite gains in kinetic performance but not a practical catalyst yet due to performance limitations above 1 A/cm^2.

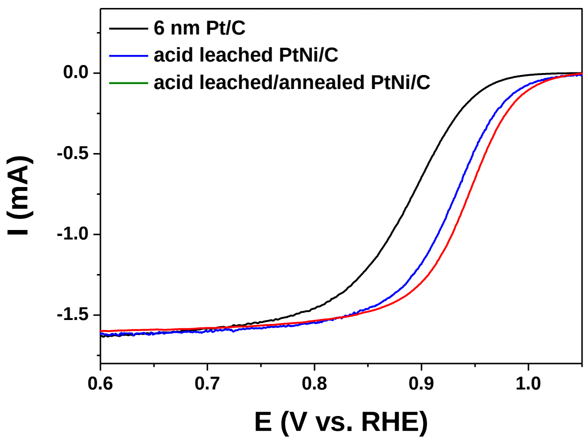


Next Steps: Improve high current density performance.

Nano-segregated Cathode Catalysts

Argonne National Laboratory approach: Materials by design to characterize, synthesize, and test nanosegregated multi-metallic nanoparticles and nanostructed thin metal films





PtNi/Pt core/shell catalyst has 7X activity over same size Pt/C.

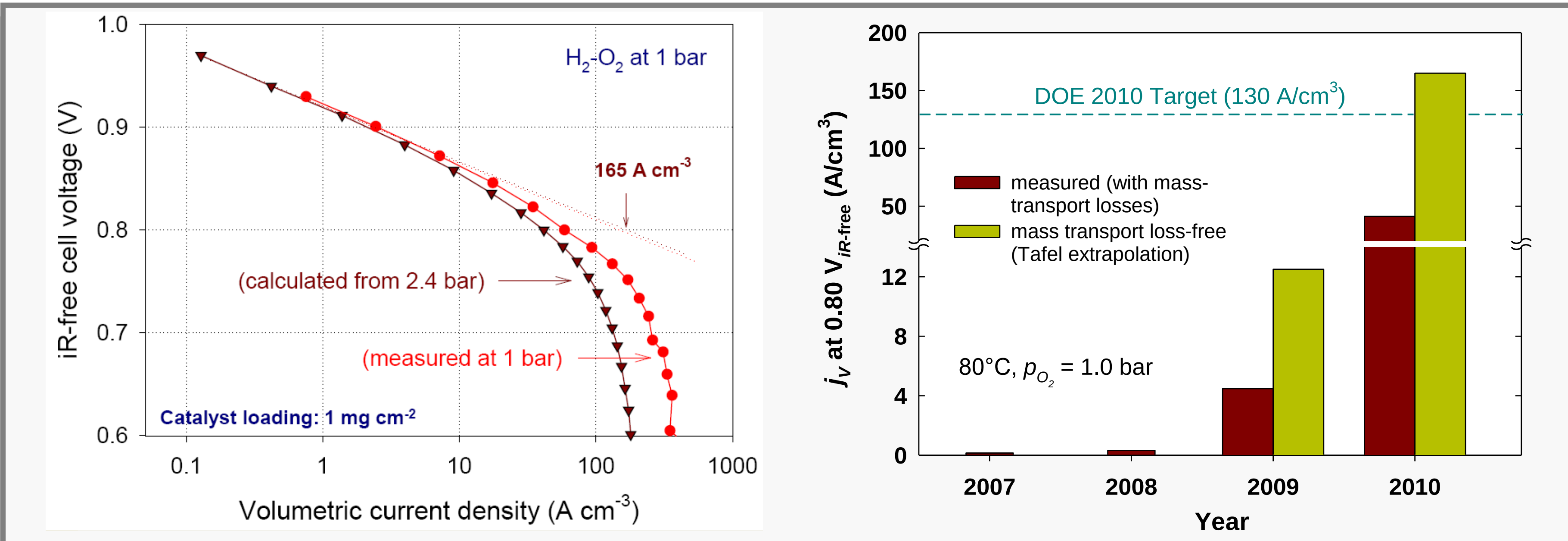
Next Steps: Evaluate in-cell durability, scale-up

N. Markovic, 2010 DOE Hydrogen Program Review

Argonne NATIONAL LABORATORY

PGM-Free Catalysts

Los Alamos National Laboratory Approach: Cyanamide –Fe-C Catalysts



- **High ORR activity reached with several non-PGM catalysts by LANL, including cyanamide-Fe-C catalyst (shown).**
- **Intrinsic catalyst activity is projected to exceed DOE 2010 activity target of 130 A/cm³ at 0.80 V.**

Next Steps: Determine active site. Improve activity to PGM catalyst level.

D. Papageorgopoulos, 2010 DOE Hydrogen Program Review

Los Alamos NATIONAL LABORATORY

Fuel Cell Technologies — Catalysts
Technical Targets vs. Status

Electrocatalysts for Transportation Applications	Status[a]	Targets[b]	
	2009	**2010**	**2015**
Platinum group metal (PGM) total content (both electrodes)	**0.2 g/kW**	**0.15 g/kW**	**0.125 g/kW**
PGM Total Loading	**0.15 mg/cm^2**	**0.15 mg/cm^2**	**0.125 mg/cm^2**
Loss in catalytic (mass) activity[c]	**TBD**	**<40% loss of initial**	**<40% loss of initial**
Catalyst support loss[d]	**TBD**	**< 10% mass loss**	**< 10% mass loss**
Mass activity[e]	**0.16 A/mg Pt in MEA >0.44 A/mg Pt new alloy in RDE**	**0.44 A/mg PGM**	**0.44 A/mg PGM**
Activity per volume of supported catalyst (non-PGM)[f]	**155 A/cm^3**	**>130 A/cm^3**	**>300 A/cm^3**

[a] single cell status – will require scale-up
[b] preliminary targets – approval pending
[c] after 30,000 cycles from 0.6 – 1.0 V; after 400 hours at 1.2 V
[d] after 400 hours at 1.2 V
[e] baseline @ 900mV$_{IR\text{-}free}$
[f] baseline @ 800mV$_{IR\text{-}free}$

H	= High (significant challenge)	**M**	= Medium
M/H	= Medium/High	**L**	= Low (minimal challenge)

Update of Multiyear RD&D Plan in process

Membranes

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Challenges:

- Membranes account for 48% of stack cost at low volume
- Limits on operating range
- Chemical and mechanical durability

Membrane R&D:

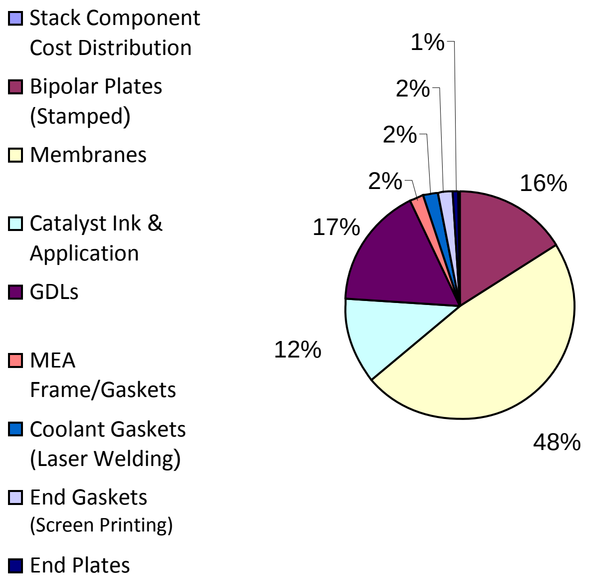
High-Temperature, Low Humidity Conductivity

- Phase segregation (polymer & membrane)
- Non-aqueous proton conductors
- Hydrophilic additives

High Conductivity and Durability Across Operating Range with Cycling

- Mechanical support or membrane reinforcement
- Chemical stabilization (additives, end-group capping)
- Polymer structure (side chain length, grafting, cross-linking, backbone properties, blends, EW)
- Processing parameters (temperature, solvents)
- New materials

Stack Cost - $137/kW



DTI, 2009 analysis, production of 1,000 units/yr

Used $453/m^2 for membrane Cost

Strategies for Hi-T Membrane R&D

High conductivity at 120 C 50% RH achieved with a variety of approaches

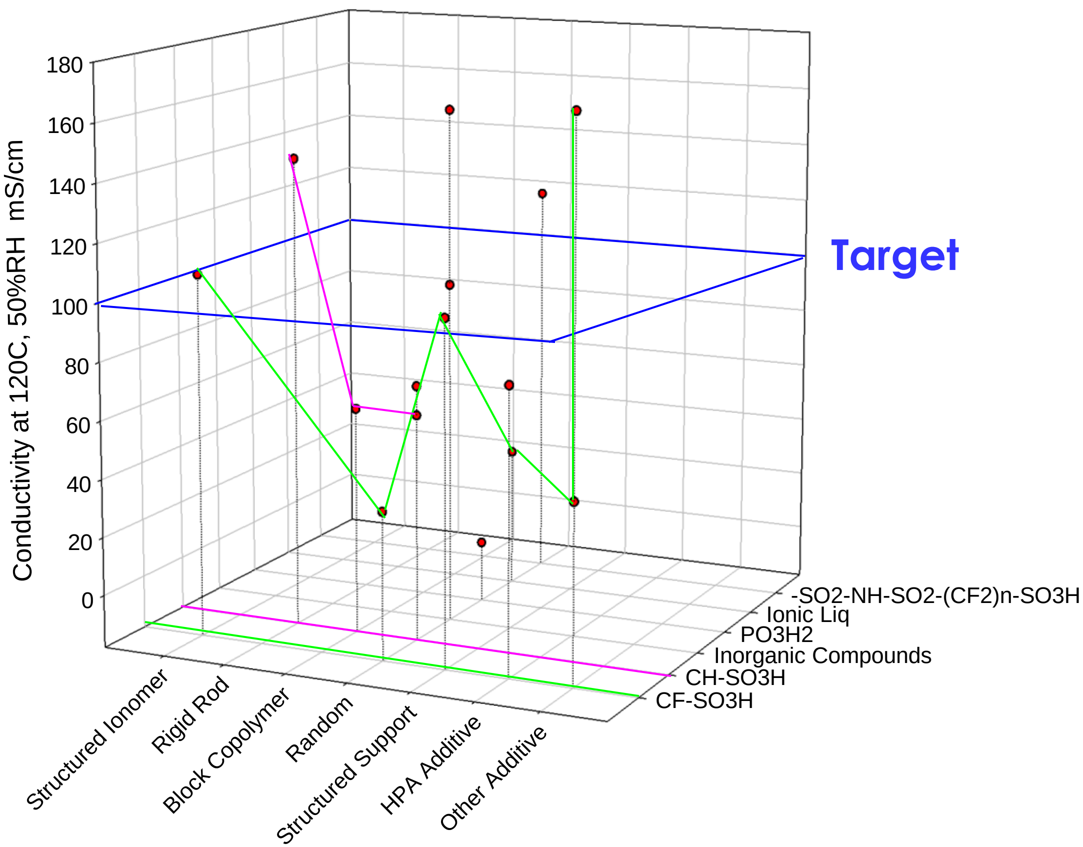
	Morphology	Molecular Approach			Additive Approach				Micro/nano engineering approach	
Conduction Mechanism		Other Polymer	Block Copolymer	Rigid Rods	ZrPhosphate	HPA	Zeolite	Other	Structured Support	Structured Ionomer
Aqueous										
	FC-SO3H	(yellow)			(orange)	(yellow)		(green)	(green)	(green)
	HC-SO3H	(yellow)	(yellow)	(green)	(orange)	(orange)				
	Hydrous Metal Oxides									
	Perfluoro imide acid	(green)								
Potential Non Aqueous										
	polyPOMs	* (green)								
	Phosphates	** (green)								
	Phosphonic acids	(orange)								
	Phosphoric acid		(yellow)							
	Heterocyclic bases									
	Ionic liquids	(orange)								

(green)	≥ 0.1 S/cm at 120C and 50%RH
(yellow)	> 50% of target
(orange)	Less than 50% of target — NRE 212 < 50% of target
*	Measured in-house and by a second party
**	Measured in-house

Conductivity Results (120 C, 50% RH)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Need to go to even lower humidity to simplify fuel cell system designs: Need high conductivity at low RH

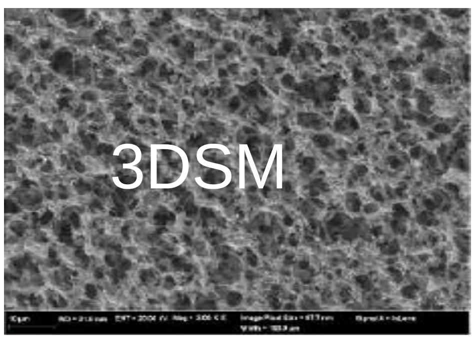


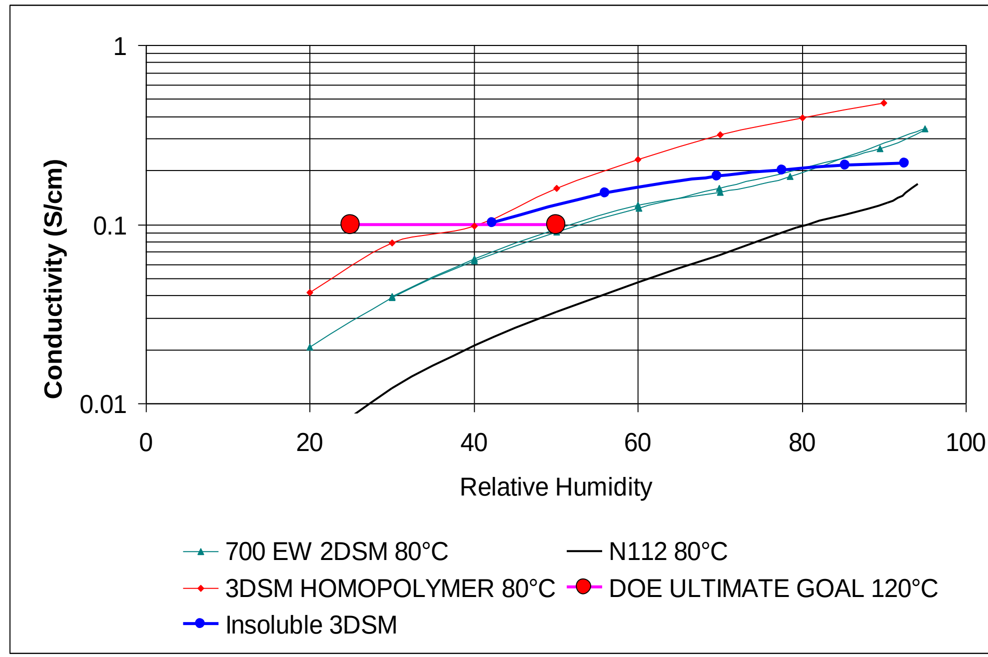
Exceeded 0.1 S/cm at 120 C and 50% RH using several conducting groups.

For a given conducting group, morphology can have a large effect on conductivity.

Additives can also have a large effect.

Giner Electrochemical Systems approach: Engineering polymer matrix provides mechanical properties. Low-EW ionomer provides conductivity





Next Steps: Impregnation of thin porous mats with low-EW ionomer. Fabricate large-area films. Improve fuel cell performance.

C. Mittelsteadt, 2010 DOE Hydrogen Program Review

GES

Nanocapillary Network Membranes

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Vanderbilt University approach: Simultaneously electrospin dual nanofiber mat, one fiber is ionomer, the other is an inert polymer. Melt one fiber around other.

Generation 2: Co-spin PFSA and polysulfone nanofibers then process into membrane

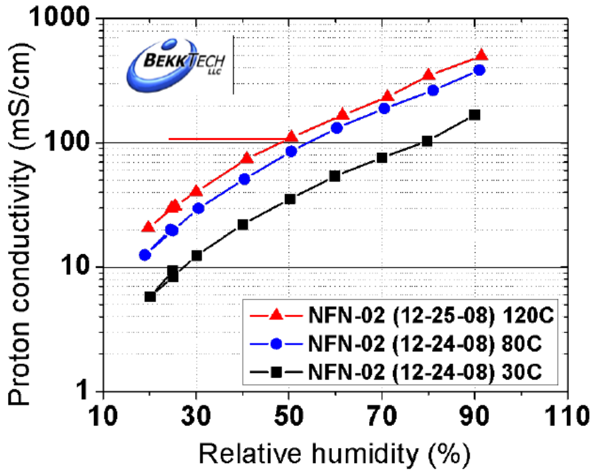
Nafion® matrix (~70 vol%), polyphenylsulfone nanofibers

Simultaneous electro-spinning of PFSA and polyphenylsulfone (inert matrix) – eliminates need for impregnation step; also can create PFSA nanofibers with polysulfone matrix from the same dual fiber mat.

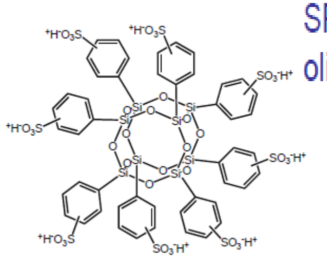
Next Steps: Establish water retention at low RH, improve performance.

P. Pintauro, 2009, 2010 DOE Hydrogen Program Review

Generation 1: PFSA/SPOSS nanofiber mat that is impregnated with inert polymer



Membrane: 60 wt% 3M PFSA (825EW) + 35 wt% SPOSS + 5 wt% poly(acrylic acid) with NAO63 (inert matrix)

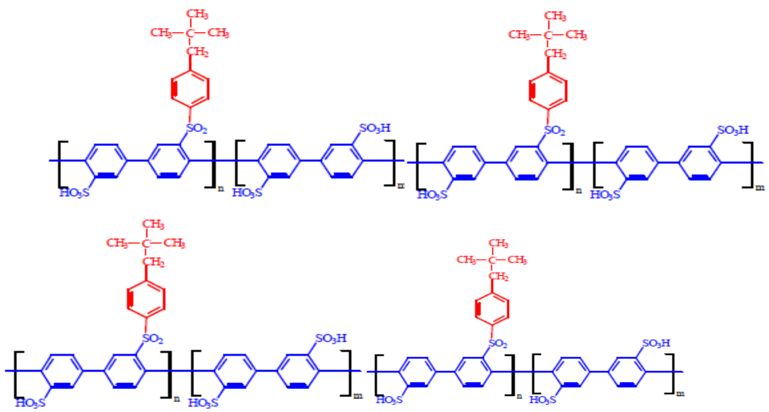


SPOSS = sulfonated polyhedral oligomeric silsesquioxanes

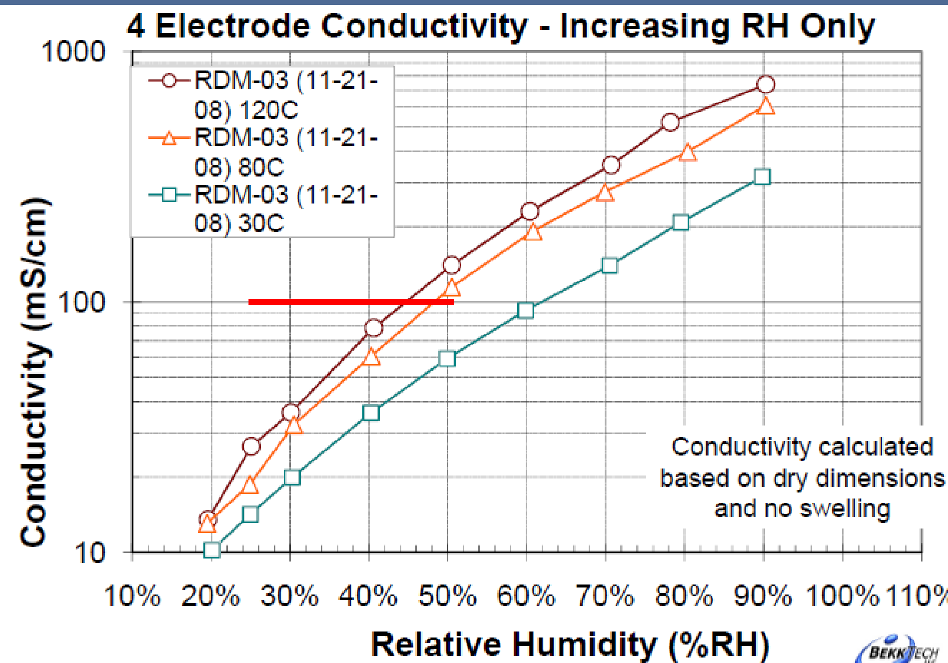
Vanderbilt University

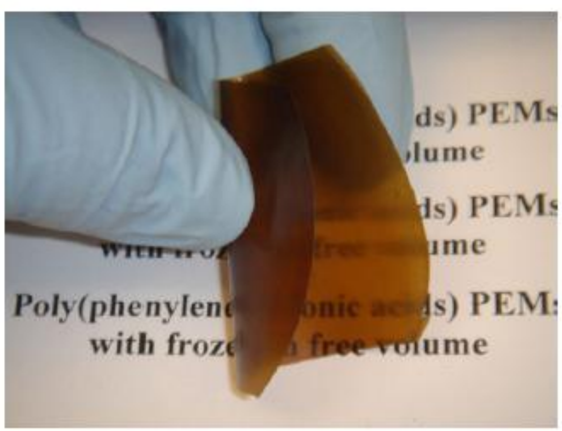
Rigid-rod Structure

Case Western Reserve University approach: Molecular design with frozen-in free volume retains H_2O at low RH



Neopentyl benzene graft (4%) provides water insoluble film with decent mechanical properties





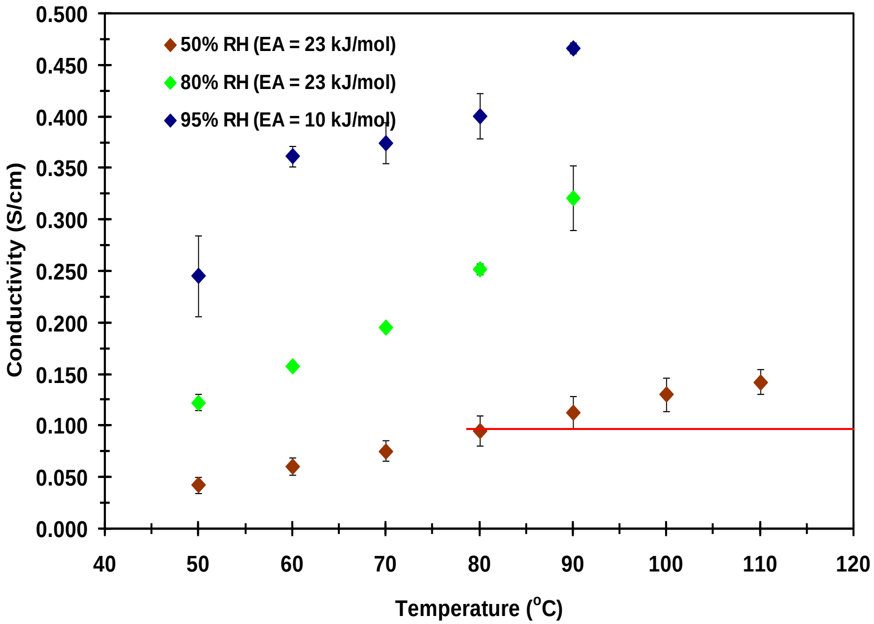
Demonstrates good conductivity at low RH

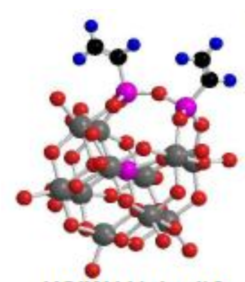
Next Steps: Improve mechanical properties. Homopolymers are water soluble. Grafting with non-polar moieties yields insoluble polymers with high conductivity at low RH. Grafting not easily scaled-up.

M. Litt, 2010 DOE Hydrogen Program Review

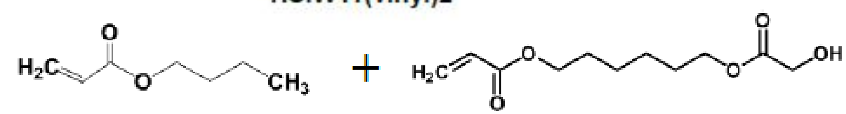
Case Western Reserve University

Colorado School of Mines approach: Tethered hetero-poly acids for high conductivity in dry conditions





HSiW11(vinyl)2



BA

HDDA

HSiW11(vinyl)2/BA/HDDA co-polymer

(PolyPOM85V/BA)

Demonstrated concept of HPA-based polymeric ionomers for high conductivity at low RH.

Next Steps: Improve mechanical properties and oxidative stability. Currently developing chemistry to attach POM to more robust polymers.

A. Herring, 2010 DOE Hydrogen Program Review

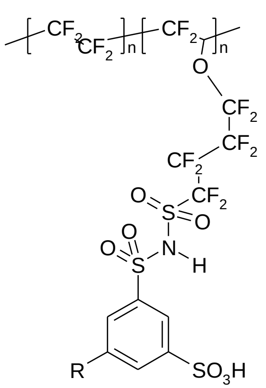
Colorado School of Mines

Multi-acid Side Chain Polymers

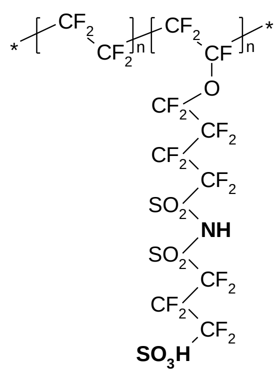
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

3M Approach: Per Fluoro Imide Acid (PFIA) and Sulfonic Acid

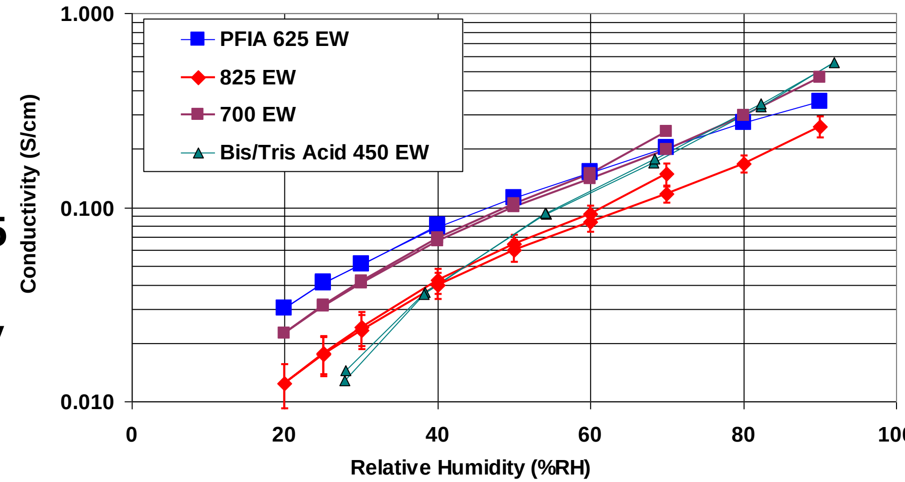
- **Multi Acid Side-chains (MASC) allow Lower EW while maintaining higher crystallinity**
- **Starting with an 835 EW polymer, prepared a MASC PFIA ionomer with 625 EW**
- **Membrane has >100 mS/cm conductivity at 120ºC, 50% RH – similar to about 700 EW PFSA**

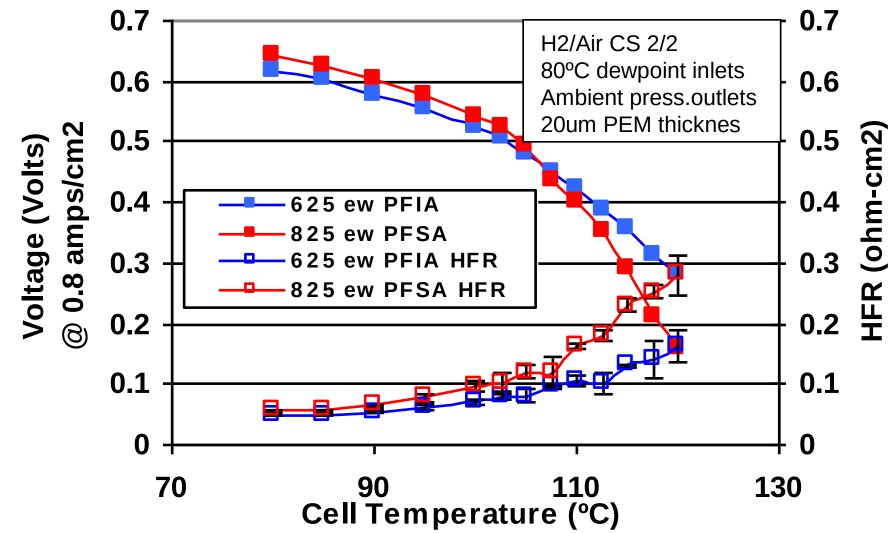


Bis/Tri Acid
R = 1:1 SO3H/X



PFIA





Next Steps: Evaluate durability of PFIA.

S. Hamrock, 2010 DOE Hydrogen Program Review

3M

DOE membrane targets

Characteristic	Units	2010 target	2015 target	Nafion® NRE211
Maximum operating temperature	C	120	120	120
Area specific resistance at:				
Maximum operating temp and water partial pressures from 40 to 80 kPa	ohm cm^2	0.02	0.02	0.186
80 C and water partial pressures from 25 - 45 kPa	ohm cm^2	0.02	0.02	0.03-0.12
30 C and water partial pressures up to 4 kPa	ohm cm^2	0.03	0.03	0.049
-20 C	ohm cm^2	0.2	0.2	0.179
Oxygen crossover	mA/cm^2	2	2	2.7
Hydrogen crossover	mA/cm^2	2	2	2.2
Cost	$\$/m^2$	20	20	
Durability				
Mechanical	Cycles w/<10 sccm crossover	20,000	20,000	5000
Chemical	H_2 crossover mA/cm^2	20	20	6

Summary of Key Issues

- Catalysts
  - Durability of low-PGM and non-PGM catalysts
  - Effects of impurities on low-PGM and non-PGM catalysts
  - Durability of catalyst supports
  - Water management with high-activity catalysts
  - Cost of PGM catalysts
- Membranes
  - Low RH performance
  - Durability of new membranes
  - Cost at low volumes
- MEAs
  - Low-temperature performance
  - Water management
  - High-current operation

DOE R&D Topics not Discussed

This talk covered only some of the technical challenges and aspects of the DOE portfolio. Other areas being addressed by DOE are:

Water management – freeze issues, materials properties

Modeling – durability, transport

Impurity effects – fuel, air, system-generated

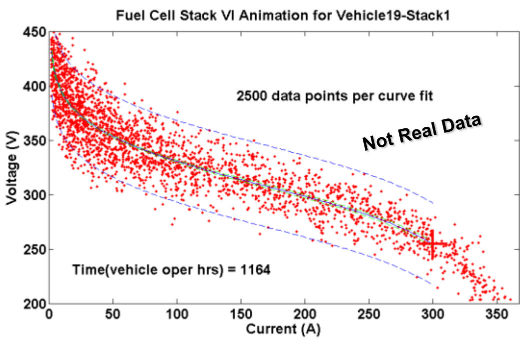
Cell hardware – plates, seals

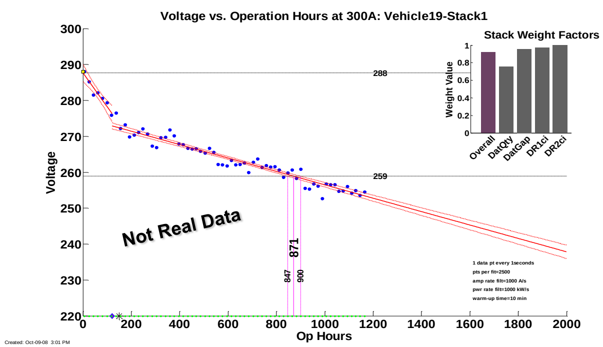
Stationary fuel cells – APUs, CHP

NREL Durability Analysis

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

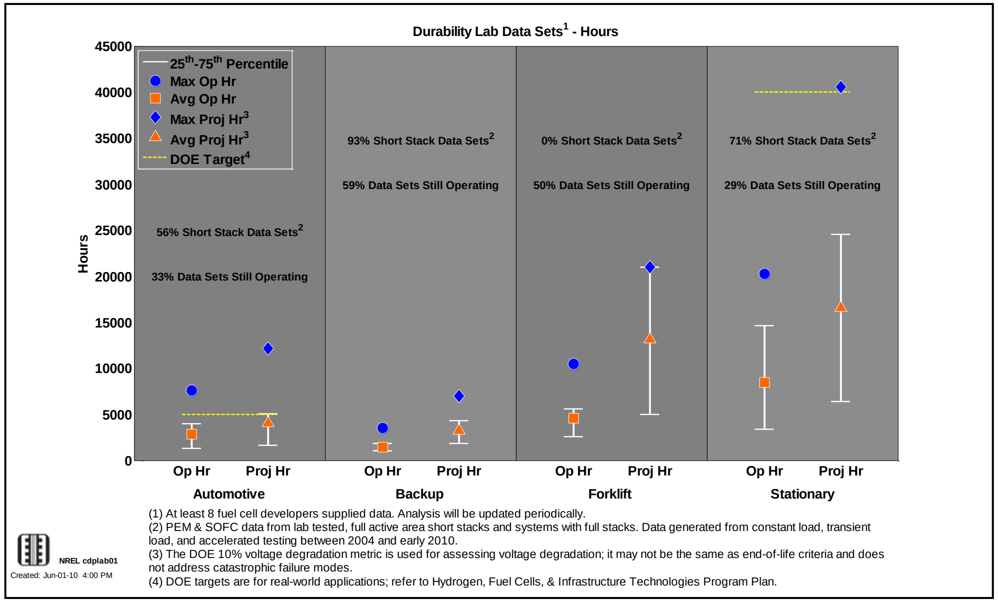
Process and analyze fuel cell stack data





Report to data provider and publish Composite Data Products

http://www.nrel.gov/hydrogen/proj_tech_validation.html



Contact Info

Jennifer Kurtz

jennifer.kurtz@nrel.gov

303-275-4061

Example: CDP Lab#01 - Operation data from lab testing for automotive, backup, material handling, and stationary power applications

Demonstrations are essential for validating the performance of technologies in integrated systems, under real-world conditions.

RECENT ACCOMPLISHMENTS

Vehicles & Infrastructure

- 144 fuel cell vehicles and 23 hydrogen fueling stations have reported data to the project
- Over 2.5 million miles traveled
- Over 150,000 kg- H_2 produced or dispensed*
- Fuel cell durability- 2,500 hours (nearly 75K miles)
- Fuel cell efficiency 53-59%
- Vehicle Range: ~196 – 254 miles

Buses

- DOE is evaluating real-world bus fleet data (DOT collaboration)
  - H_2 fuel cell buses have 39% to 141% better fuel economy when compared to diesel & CNG buses

Forklifts

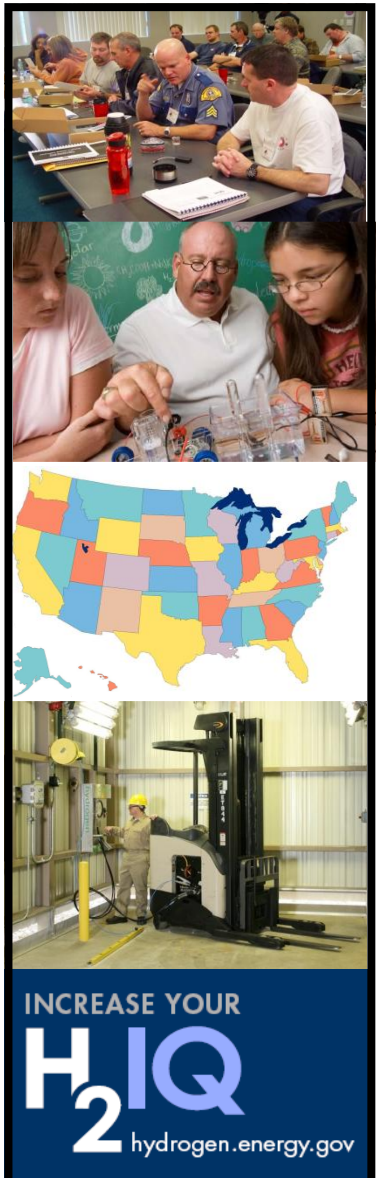
- Forklifts at Defense Logistics Agency site have completed more than 10,000 refuelings

Recovery Act

- NREL is collecting data (backup power, forklifts, etc.)

* Not all hydrogen produced is used in vehicles

Education, Safety, Codes, & Standards



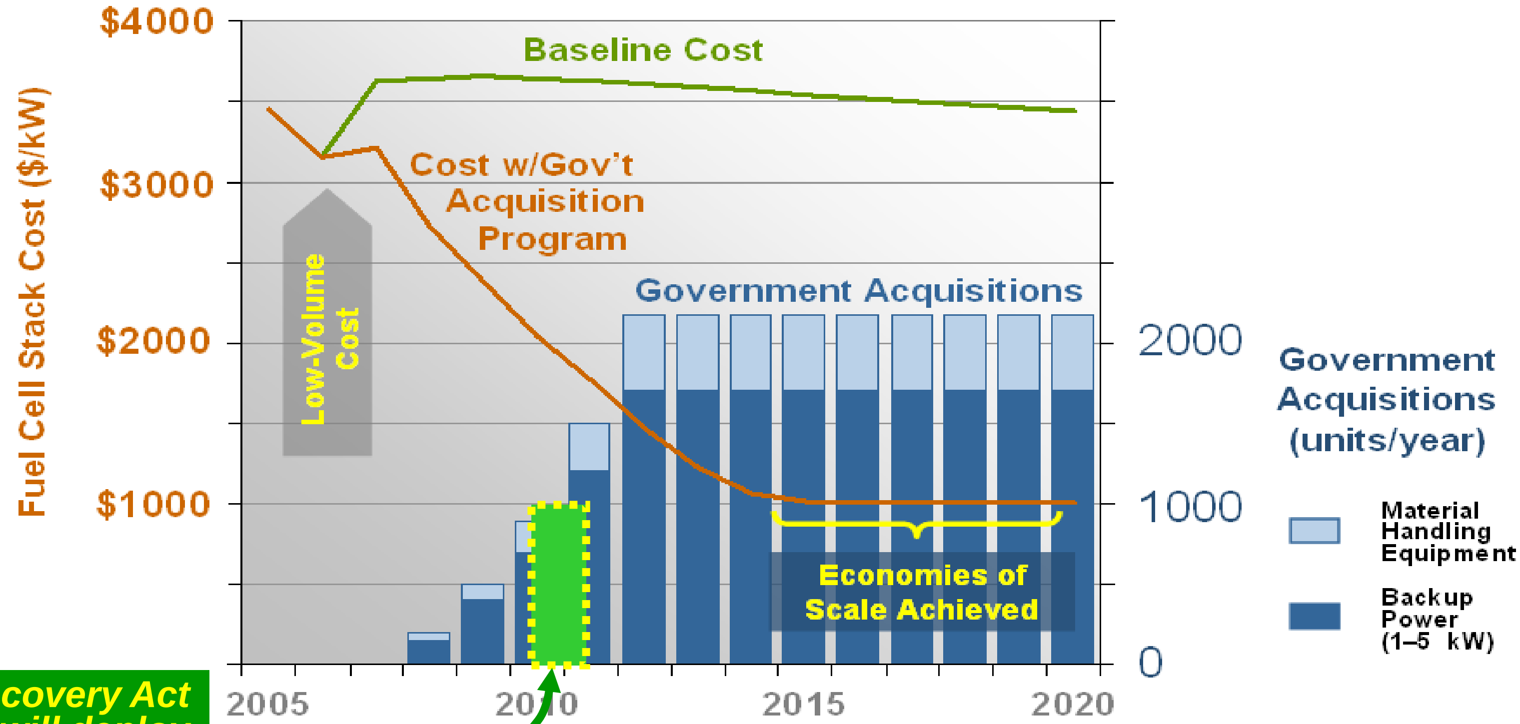
- **Safety & Code Officials**
  - Trained >90 first responders in 3 advanced-level first responder training courses in 18 states and deployed an Intro to Hydrogen web course for code officials
- **Schools & Universities**
  - Working with 5 universities to finalize & teach >25 university courses & curriculum modules specializing in H_2 and fuel cells
- **End Users**
  - Provided day-long educational seminars to lift truck users, including hands-on forklift demos and real-world deployment data
- **State & Local Governments**
  - Conducted >19 workshops and seminars across the country to educate decision-makers on fuel cell deployments

- **CNG H_2 Fuels Workshop**
  - Brazil, Canada, China, India and U.S. identified critical gaps and lessons learned from CNG vehicles
- **H_2 Fuel Quality Specification**
  - Technical Specification published and harmonized with SAE J2719
- **Separation Distances**
  - Incorporated Quantitative Risk Assessment for separation distances into codes (NFPA2)
- **Materials & Components Compatibility**
  - Completed testing to enable deployment of 100 MPa stationary storage tanks
  - Forklift tank lifecycle testing program underway to support the development of CSA HPIT1

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Example: Government acquisitions could significantly reduce the cost of fuel cells through economies of scale, and help to support a growing supplier base.

Impact of Government Acquisitions on Fuel Cell Stack Costs (for non-automotive fuel cells)



Recovery Act funding will deploy up to 1000 fuel cells, in the private sector, by 2012.

Source: ORNL

We are facilitating the adoption of fuel cells across government and industry:

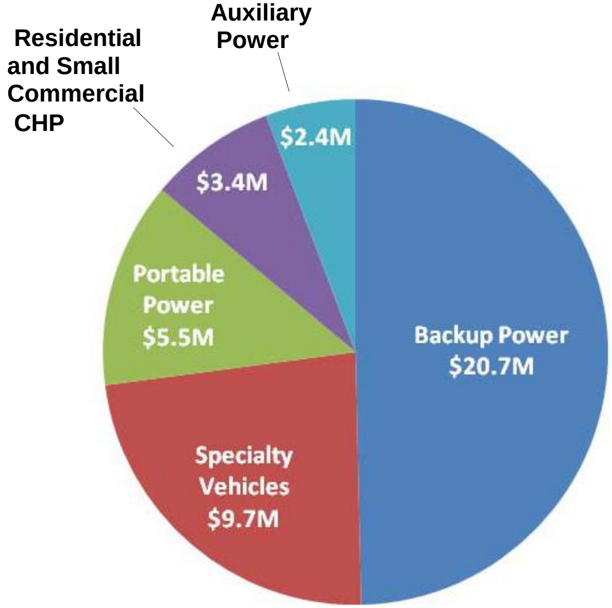
- **>100 fuel cells are being deployed, through interagency agreements.**
- **More interagency agreements under development.**

Recovery Act Deployments

DOE announced ~$42 million from the American Recovery and Reinvestment Act to fund 12 projects to deploy more than 1,000 fuel cells — to help achieve near term impact and create jobs in fuel cell manufacturing, installation, maintenance & support service sectors.

FROM the LABORATORY to DEPLOYMENT:

DOE funding has supported R&D by all of the fuel cell suppliers involved in these projects.

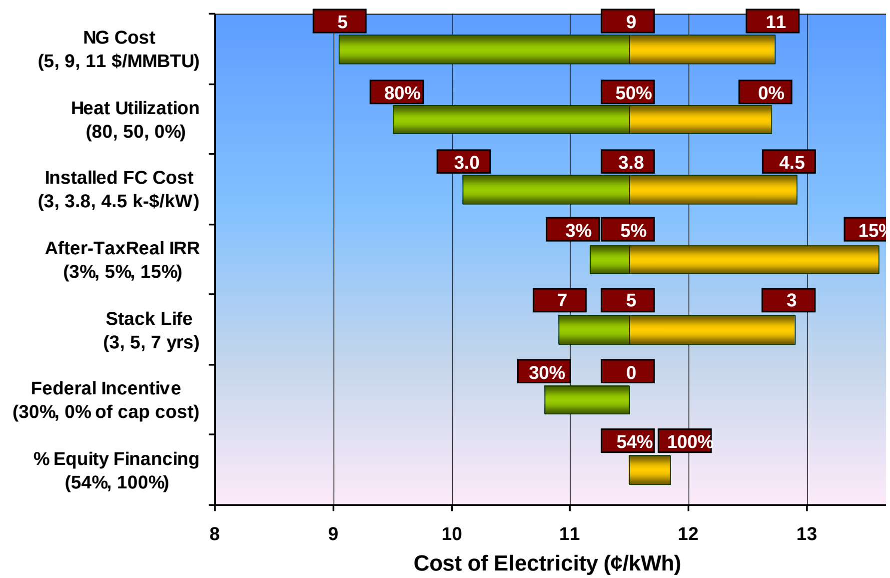


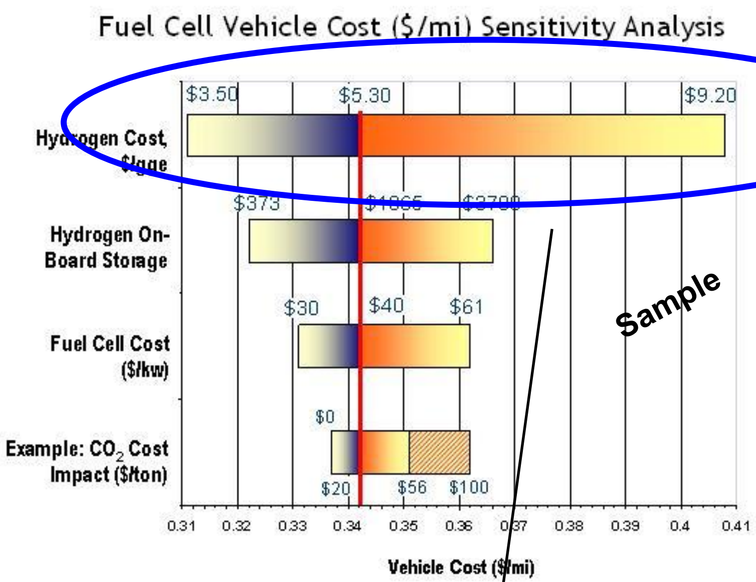
Approximately $51 million in cost-share proposed by industry participants—for a total of nearly $93 million.

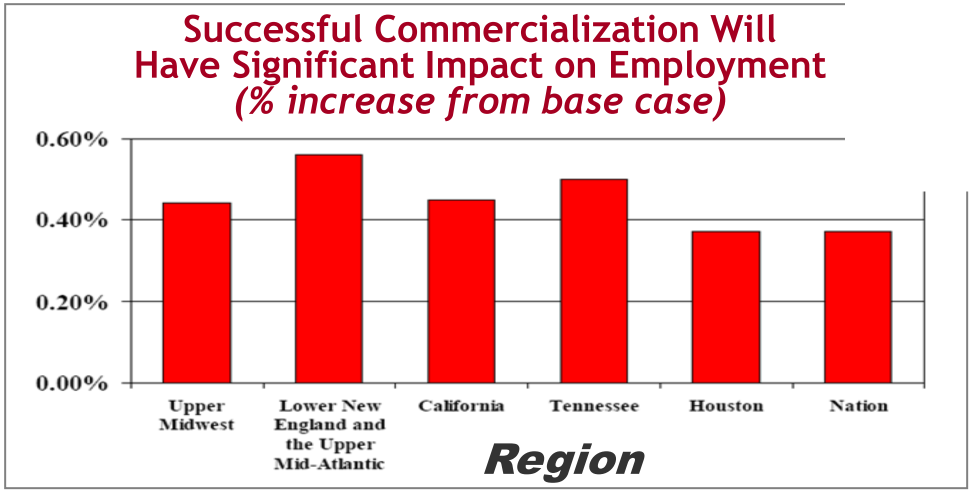
COMPANY	AWARD	APPLICATION
Delphi Automotive	$2.4 M	Auxiliary Power
FedEx Freight East	$1.3 M	Specialty Vehicle
GENCO	$6.1 M	Specialty Vehicle
Jadoo Power	$2.2 M	Backup Power
MTI MicroFuel Cells	$3.0 M	Portable
Nuvera Fuel Cells	$1.1 M	Specialty Vehicle
Plug Power, Inc. (1)	$3.4 M	CHP
Plug Power, Inc. (2)	$2.7 M	Backup Power
University of North Florida	$2.5 M	Portable
ReliOn Inc.	$8.5 M	Backup Power
Sprint Comm.	$7.3 M	Backup Power
Sysco of Houston	$1.2 M	Specialty Vehicle

Systems Analysis: *Examples*

We are assessing the costs and benefits of various technology pathways and conducting a range of analyses including sensitivity analysis, life cycle analysis and job creation analysis.





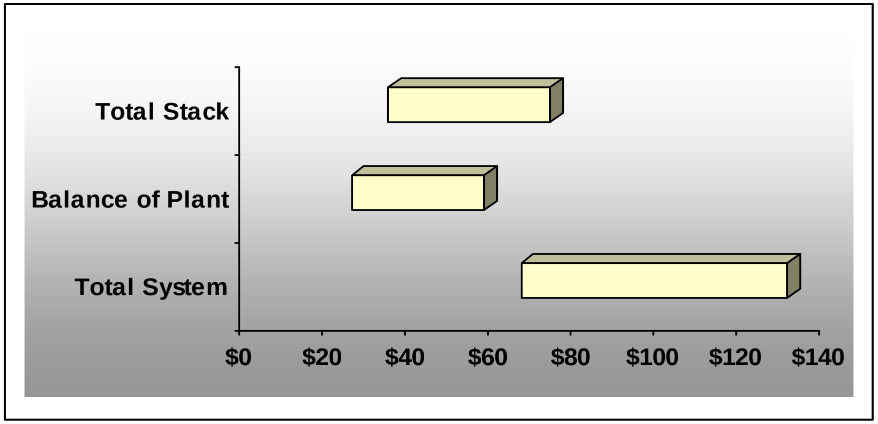


Example:
Need to reduce H_2 cost (production, delivery & storage)

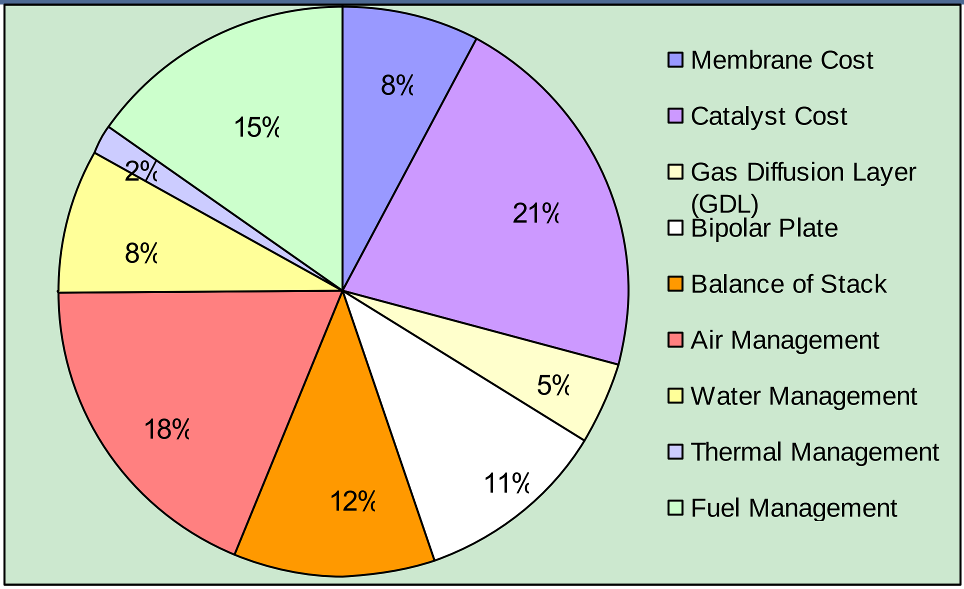
Stakeholder Cost Analyses

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

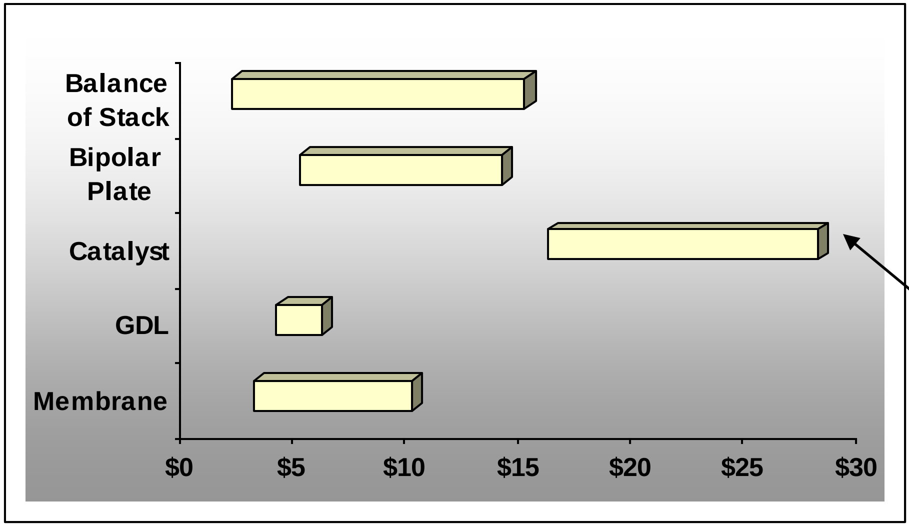
Representatives from the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) compiled fuel cell cost estimates for automotive applications to identify potential R&D focus areas



Cost range for 500,000 – 1M units/year: system status



Example of cost breakdown from China IPHE reference (500,000 units)



Cost range for 500,000 units/year: stack status

- **Range of cost estimates varies widely for some components**
- **Catalyst cost reduction is clearly required**

Ref: www.iphe.net/docs/Resources/IPHE%20Fuel%20Cell%20Cost%20Comparison%20Report.pdf

Workshops & WG Activities

Working Group (WG)	DOE Representative	Leads
High Temp Membrane	Nancy Garland	Jim Fenton (UCF/FSEC) John Kopasz (ANL)
Durability	Donna Ho	Debbie Myers (ANL) Rod Borup (LANL)
Transport Modeling	Dimitrios Papageorgopoulos	Adam Weber (LBNL) R. Mukundan (LANL)
Stationary	Jason Marcinkoski	TBD

<u>Examples of Workshops</u>

Analysis, Tank Safety- China, 9/10
Reversible Fuel Cells- TBD
Product/Component Validation- TBD
Energy Storage-TBD
Other Ideas?

What more can DOE be doing to help accelerate progress and maximize value?

Collaborations

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Federal Agencies

- DOC
- DOD
- DOEd
- DOT
- EPA
- GSA
- DOI
- DHS
- NASA
- NSF
- USDA
- USPS

– *Interagency coordination through staff-level Interagency Working Group (meets monthly)*
– *Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.*

Universities

~ 50 projects with 40 universities

International

- IEA Implementing agreements – 25 countries
- International Partnership for the Hydrogen Economy – 16 countries, 30 projects

DOE Fuel Cell Technologies Program*

– *Applied RD&D*
– *Efforts to Overcome Non-Technical Barriers*
– *Internal Collaboration with Fossil Energy, Nuclear Energy and Basic Energy Sciences*

Industry Partnerships & Stakeholder Assn's.

- FreedomCAR and Fuel Partnership
- National Hydrogen Association
- U. S. Fuel Cell Council
- Hydrogen Utility Group
- ~ 65 projects with 50 companies

State & Regional Partnerships

- California Fuel Cell Partnership
- California Stationary Fuel Cell Collaborative
- SC H_2 & Fuel Cell Alliance
- Upper Midwest Hydrogen Initiative
- Ohio Fuel Coalition
- Connecticut Center for Advanced Technology

National Laboratories

National Renewable Energy Laboratory P&D, S, FC, A, SC&S, TV
Argonne A, FC, P&D
Los Alamos S, FC, SC&S
Sandia P&D, S, SC&S
Pacific Northwest SC&S,P&D, S, FC, A
Oak Ridge P&D, S, FC, A
Lawrence Berkeley FC, A
Lawrence Livermore P&D, S
Savannah River S, P&D
Brookhaven S, FC
Idaho P

Other Federal Labs: **Jet Propulsion Lab, National Institute of Standards & Technology, National Energy Technology Lab**

P&D *= Production & Delivery;* ***S*** *= Storage;* ***FC*** *= Fuel Cells;* ***A*** *= Analysis;* ***SC&S*** *= Safety, Codes & Standards;* ***TV*** *= Technology Validation*

* Office of Energy Efficiency and Renewable Energy

FY 10 DOE Program Partners — *Fuel Cells*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Analysis & Testing
- ANL
- DTI
- TIAX
- LANL
- NIST
- ORNL
- Battelle

Catalysts & Supports
- 3M
- General Motors
- ANL
- BNL
- LANL
- LBNL
- NREL
- PNNL
- UTC Power
- Illinois Institute of Technology
- University of South Carolina
- Northeastern University

Cross-cutting
- Case Western Reserve University
- Kettering University
- Stark State
- University of Connecticut

Distributed Energy Systems
- Acumentrics
- Intelligent Energy
- Plug Power
- IdaTech
- Versa Power Systems

Durability
- UTC Power
- LANL
- Ballard Power Systems
- ANL
- Nuvera Fuel Cells
- DuPont

Hardware
- ANL
- Treadstone
- ORNL
- UTC Power

Impurities
- Clemson University
- LANL
- NREL
- University of Hawaii
- University of Connecticut

Membranes
- 3M
- Arizona State University
- Arkema
- Case Western Reserve University
- Colorado School of Mines
- FuelCell Energy
- Giner Electrochemical Systems
- LBNL
- University of Central Florida
- Vanderbilt University
- LANL
- Ion Power

Portable Power
- LANL
- NREL
- Arkema
- University of North Florida

Transportation Systems
- ANL
- Cummins
- Delphi
- Honeywell
- W.L. Gore

Water Transport and Freeze
- CFD Research Corp.
- LANL
- Nuvera Fuel Cells
- Rochester Institute of Technology
- SNL
- LBNL
- Giner Electrochemical Systems
- Plug Power
- General Motors

Key Program Documents

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Fuel Cell Program Plan

Outlines a plan for fuel cell activities in the Department of Energy

→ ***Replacement for current* Hydrogen Posture Plan**

→ ***To be released in 2010***

Annual Merit Review Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

→ ***Latest edition released June 2010***

www.hydrogen.energy.gov/annual_review10_proceedings.html

Annual Merit Review & Peer Evaluation Report

Summarizes the comments of the Peer Review Panel at the Annual Merit Review and Peer Evaluation Meeting

→ ***Latest edition released October 2009***

www.hydrogen.energy.gov/annual_review08_report.html

Annual Progress Report

Summarizes activities and accomplishments within the Program over the preceding year, with reports on individual projects

→ ***Latest edition published November 2009***

www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: May 9 – 13, 2011

Washington, D.C.

http://annualmeritreview.energy.gov/

Thank you

http://www.eere.energy.gov/hydrogenandfuelcells

Sunita.Satyapal@ee.doe.gov