U.S. DEPARTMENT OF
ENERGY

Systems Analysis

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2009 DOE Hydrogen Program & Vehicle Technologies Program

Merit Review and Peer Evaluation Meeting

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Goal and Objectives

GOAL: ***Provide system-level analysis to support infrastructure development and technology readiness by evaluating technologies and pathways, guiding the selection of RD&D technology approaches/options, and estimating the potential value of RD&D efforts.***

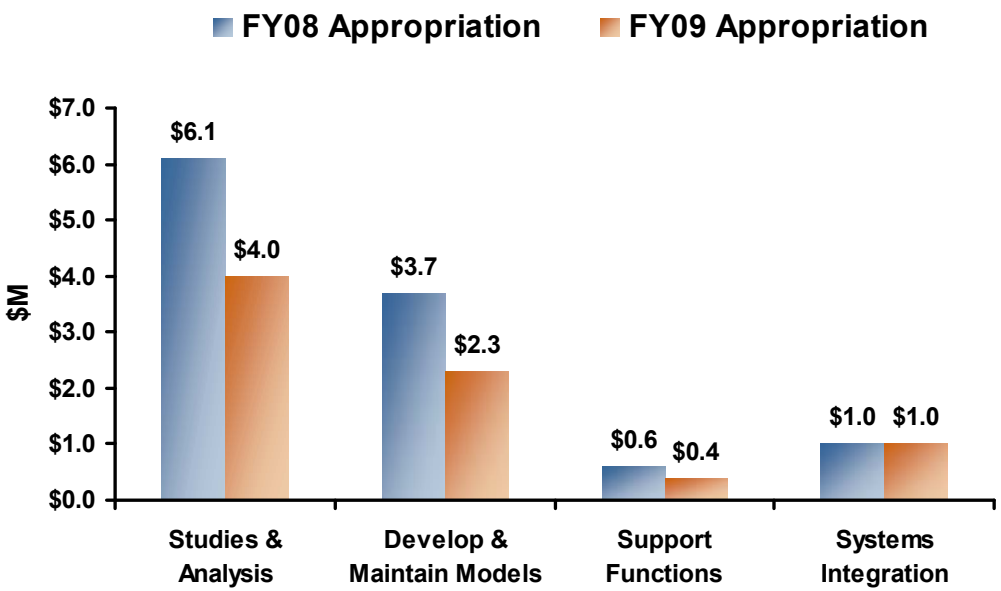
OBJECTIVES

- By 2011, enhance the Macro System Model (MSM) to include stationary electrical generation and infrastructure.
- By 2014, complete environmental studies for technology readiness.
- By 2015, analyze resource requirements, fuel production and infrastructure for penetration of fuel cell vehicles.
- Provide milestone-based analysis, including risk analysis, independent reviews, financial evaluations and environmental analysis, to support Program's needs prior to technology readiness.
- Update the Well-to-Wheels analysis for technologies and pathways for the Program to include technological advances or changes.

Studies and analyses remain high priority.

FY 2009 Appropriation = $7.7M

FY 2008 Appropriation = $11.5M



EMPHASIS

- Conduct early market analysis.
- Assess synergies of integrating transportation and stationary power fuel cells.
- Evaluate barriers to and solutions for hydrogen infrastructure development.

Challenges

Data inconsistency, market complexities and unplanned analysis needs present challenges.

Future Market Behavior

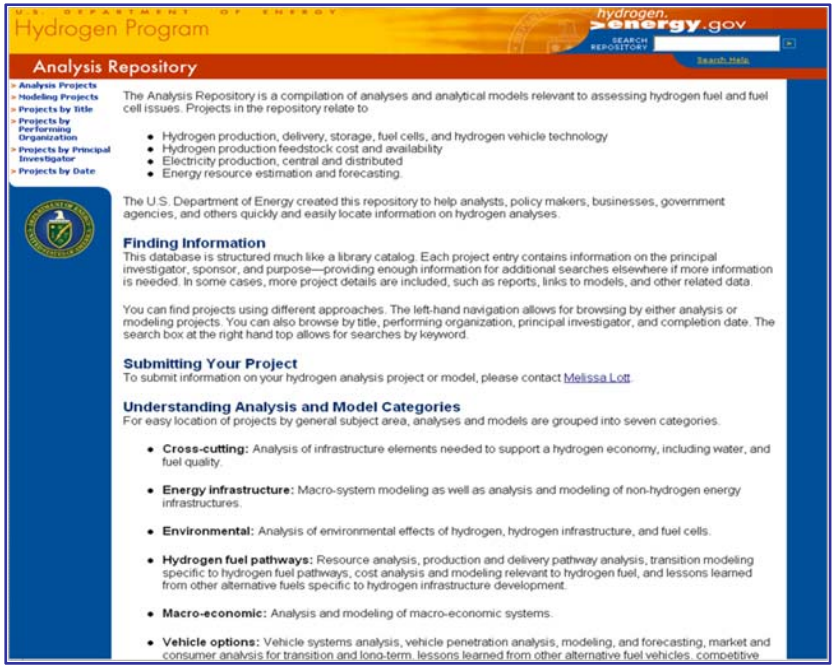
- Understanding of drivers of fuel and vehicle markets needed for long-term projections.
- Models need to adequately address interactions - hydrogen/vehicle supply and demand.

Inconsistent Data, Assumptions & Guidelines

- Analysis results depend on data sets and assumptions used.
- Large number of stakeholders and breadth of technologies - difficult to establish consistency.

Coordination of Analytical Capability

- Analytical capabilities segmented by Program element, organizationally by DOE office, and by performers/analysts.



For details, see --
http://www.hydrogen.energy.gov/systems_analysis.html

Analysis Strategy and Domains

Technology Analysis

- Pathway & Component Costs
- Hydrogen Quality Impact
- WTW Energy & GHG Emissions
- Vehicle Technology

- H2A Production
- H2A Delivery
- PSAT
- GREET
- MSM

SYSTEMS ANALYSIS

- PROGRAMMATIC ANALYSIS
  - Risk analysis of H_2 Program targets and goals
  - Petroleum and CO_2 reduction benefits
  - Integrating stationary and transportation fuel cells
  - Program benefits for program-related product commercialization
- PROGRAM ELEMENT ANALYSIS
  - H_2 production and delivery pathway analysis
  - Platinum recycling impact on fuel cell cost
- ENVIRONMENTAL ANALYSIS
  - Atmospheric impacts of H_2
  - WTW analysis of GHG emissions
  - Policy analysis
- CO_2 ANALYSIS
  - Fuel, infrastructure and vehicle subsidy evaluation
- EARLY MARKETS ANALYSIS
  - Cost and GHG benefit analysis of early market applications

Implementation & Impact Analysis

- Infrastructure & Resource Analysis
- Consumer Choice
- Vehicle Penetration

- DTI HyPRO
- EEA
- HyDS
- NREL Infrastructure
- HyDRA
- RCF Agent-based
- TIAX Hydrogen Logistics Model

Market/Benefits & Policy Analysis

- National Economic Impacts
- Policy Options
- System Dynamics

- HyTrans
- NEMS
- MARKAL
- HyDive

Systems Analysis Progress

Model & Tool Development Focused → **Analysis and Results Focused**

2004
- ✓ Systems analysis function established

2005
- ✓ Established process for developing hydrogen cost target
- ✓ Revised hydrogen cost target to $2.00- 3.00/gge
- ✓ Identified analytical gaps and "missing pieces"

2006
- ✓ Hydrogen Analysis Resource Center issued
- ✓ WTW analysis process established
- ✓ H2A Production Model issued
- ✓ Systems Analysis Plan issued
- ✓ HyDS model completed

2007
- ✓ WTW analysis completed
- ✓ Macro-System Model test version completed and validated
- ✓ Cross-cut team established
- ✓ Scenario Analysis for Transition completed
- ✓ Resource and infrastructure analysis started

2008
- ✓ Preliminary water analysis completed
- ✓ Macro-System Model completed and issued
- ✓ H2A Production Model revised and issued
- ✓ CO_2 policy analysis completed
- ✓ Early market analysis
- ✓ Hydrogen quality analysis of impact on production and fuel cell completed
- ✓ Pt recycling cost analysis completed

2009
- ➢ Stationary FC analysis
- ➢ PHEV analysis
- ➢ Early markets analysis initiated
- ➢ Environmental impact analysis
- ➢ H_2 quality analysis
- ➢ WTW on stationary FCs
- ➢ Impact of Hydrogen Program targets on CO_2
- ➢ "Lessons learned" study on infrastructure

2004 2005 2006 2007 2008 2009

What's New?

- Early market analysis
- H2A stationary model
- Integration of transportation and stationary applications
- Sensitivity analysis of CO_2 emission reduction to Program targets
- Effects of transition to hydrogen on employment
- Infrastructure Development Analysis

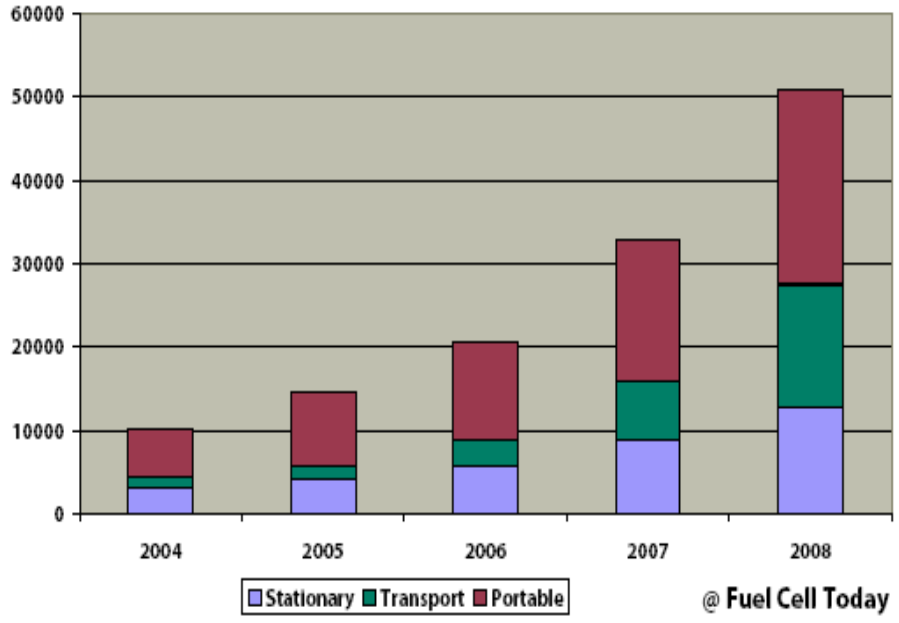
Early Markets

- *Technology development is a continuous path with different entry points.*
- *Analysis effort on early market hydrogen/fuel cell applications helps understand related issues and ways to support early market entry.*

Fuel Cell Industry

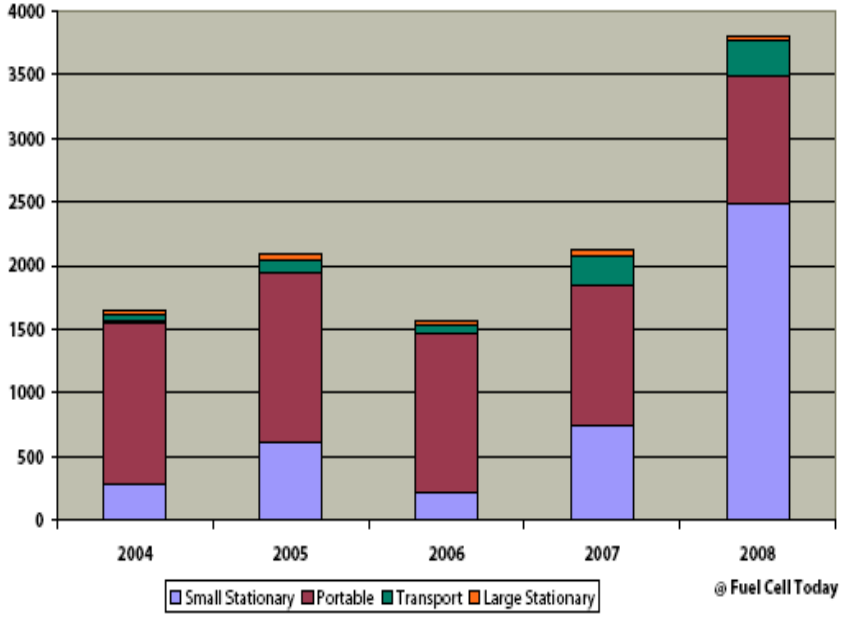
The fuel cell industry has seen an average annual growth of 100% over the past four years worldwide. More than 12,000 new units were shipped in 2007.

Cumulative Shipments Worldwide



Approximately ~2,400 jobs created through units developed worldwide from 2007 to 2008.*

Development in North America



Approximately 200 jobs created through units developed in North America from 2007 to 2008.*

*** Assuming $20,000/unit and 6 jobs/$1M.**

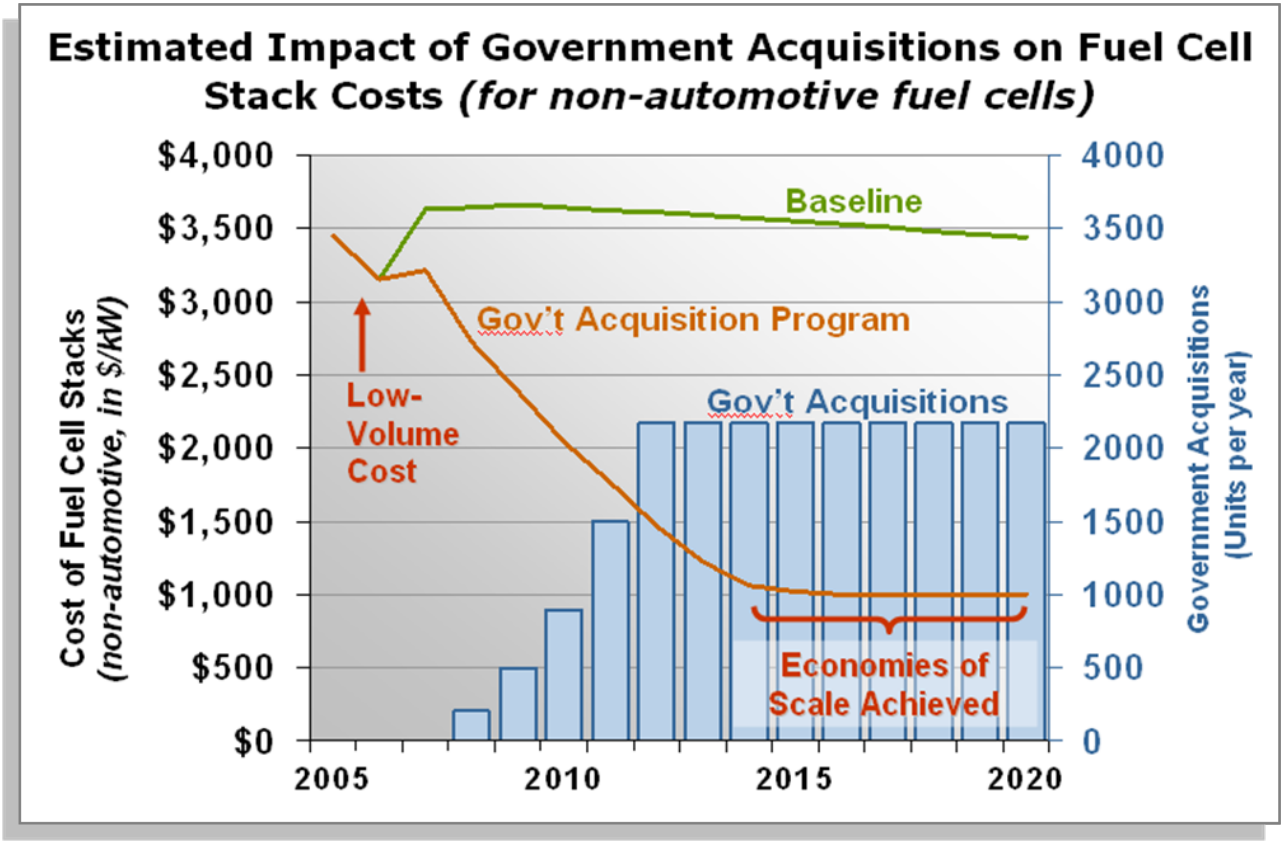
Source: Fuel Cell Today 2008.

2009 Progress & Accomplishments
Government Acquisition Analysis

A government acquisition program could significantly reduce the cost of fuel cells through economies of scale, and help to support a growing supplier base.

OBJECTIVES

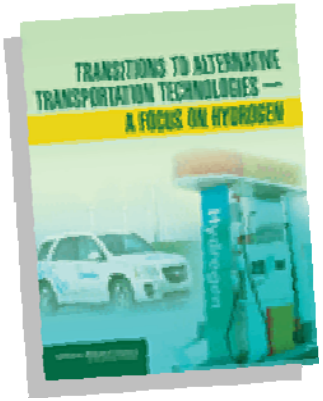
- Enable federal agencies to implement fuel cell technologies.
- Increase sales & manufacturing volumes of fuel cells to achieve economies of scale.
- Support development of national infrastructure and domestic supplier base.
- Improve user confidence in fuel cell reliability.



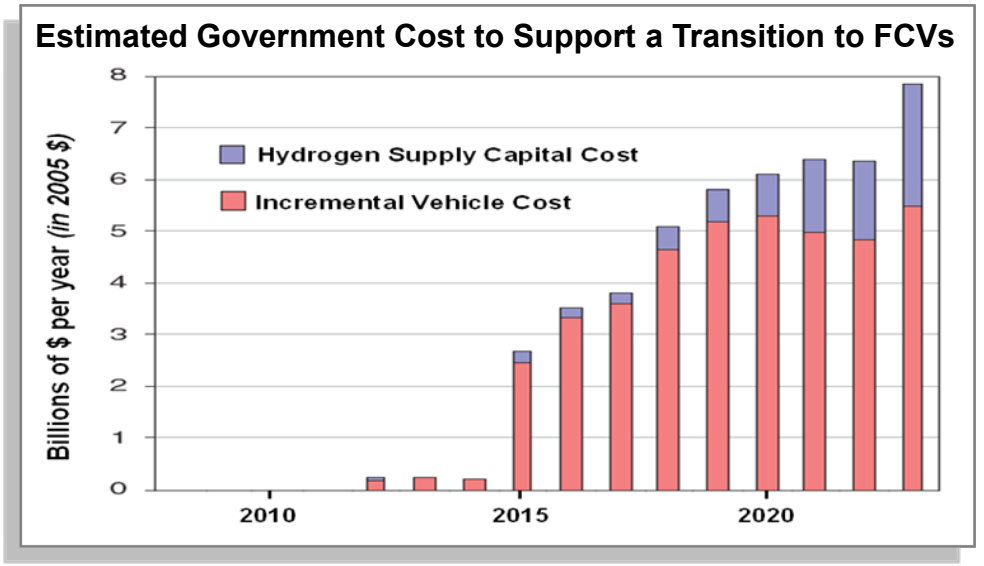
Recent increase in fuel cell investment tax credit (to $3,000/kW) will help accelerate progress.

For details, see -- http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_183.pdf

NAS study, "Transitions to Alternative Transportation Technologies: A Focus on Hydrogen," shows positive outlook for hydrogen & fuel cell technologies—results are similar to ORNL's "Transition Scenario Analysis."



The study was required by EPACT section 1825 and the report was released in 2008, by the Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies.



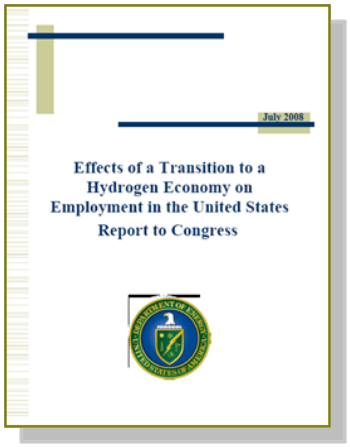
Key Findings

- Possibly **2 million FCVs on the road** by 2020. Number could grow rapidly to ~60 million by 2035 and ~200 million by 2050.
- Government cost to support transition to FCVs (for 2008 – 2023) estimated to be $55 billion—about **$3.5 billion/year**.
- BY 2050, potential exists ***to eliminate petroleum use*** in LDV sector and to reduce GHG emissions from LDVs to 20% of current levels—by 2050.

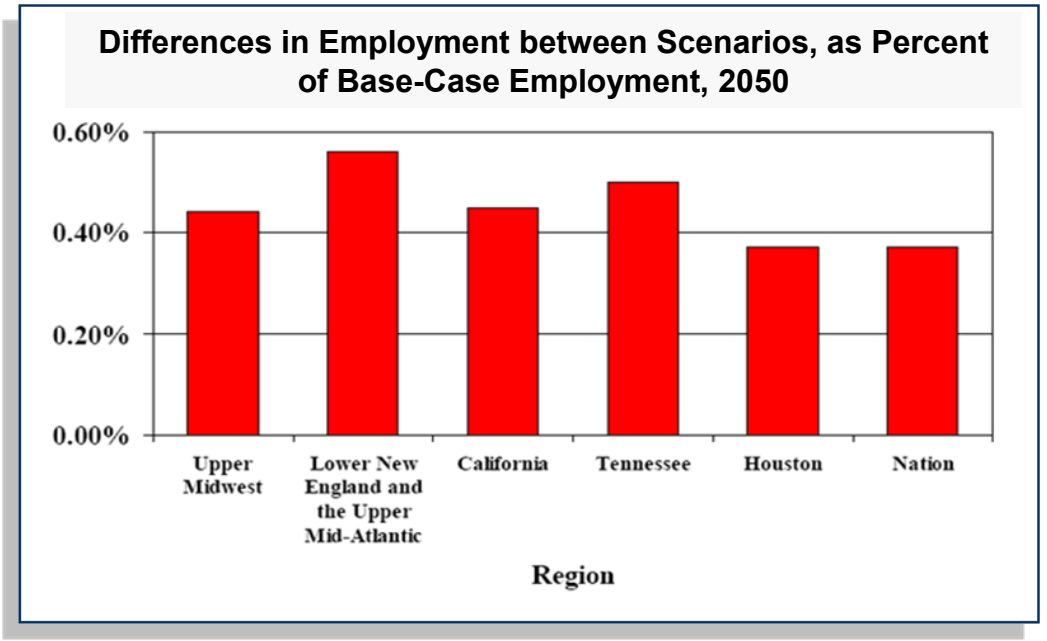
For details, see -- http://www.nap.edu/catalog.php?record_id=12222

2009 Progress & Accomplishments
Socio-Economic Benefits – Employment Growth

Commercialization of hydrogen and fuel cell technologies could lead to significant job growth.



- Projected increase in U.S. employment of 360,000 – 675,000 jobs
- Job gains would be distributed across up to 41 industries
- Workforce skills would be mainly in the vehicle manufacturing and service sectors
- U.S. competitive leadership in a critical technology sector would be strengthened



Study required by EPACT Section 1820(b)

http://www.hydrogen.energy.gov/pdfs/epact1820_employment_study.pdf

SCENARIO ASSUMPTIONS

Fuel cell vehicles ramp up to:

a) 100% of LDV sales (96% of stock) in 2050

b) 63% of LDV sales (38% of stock) in 2050

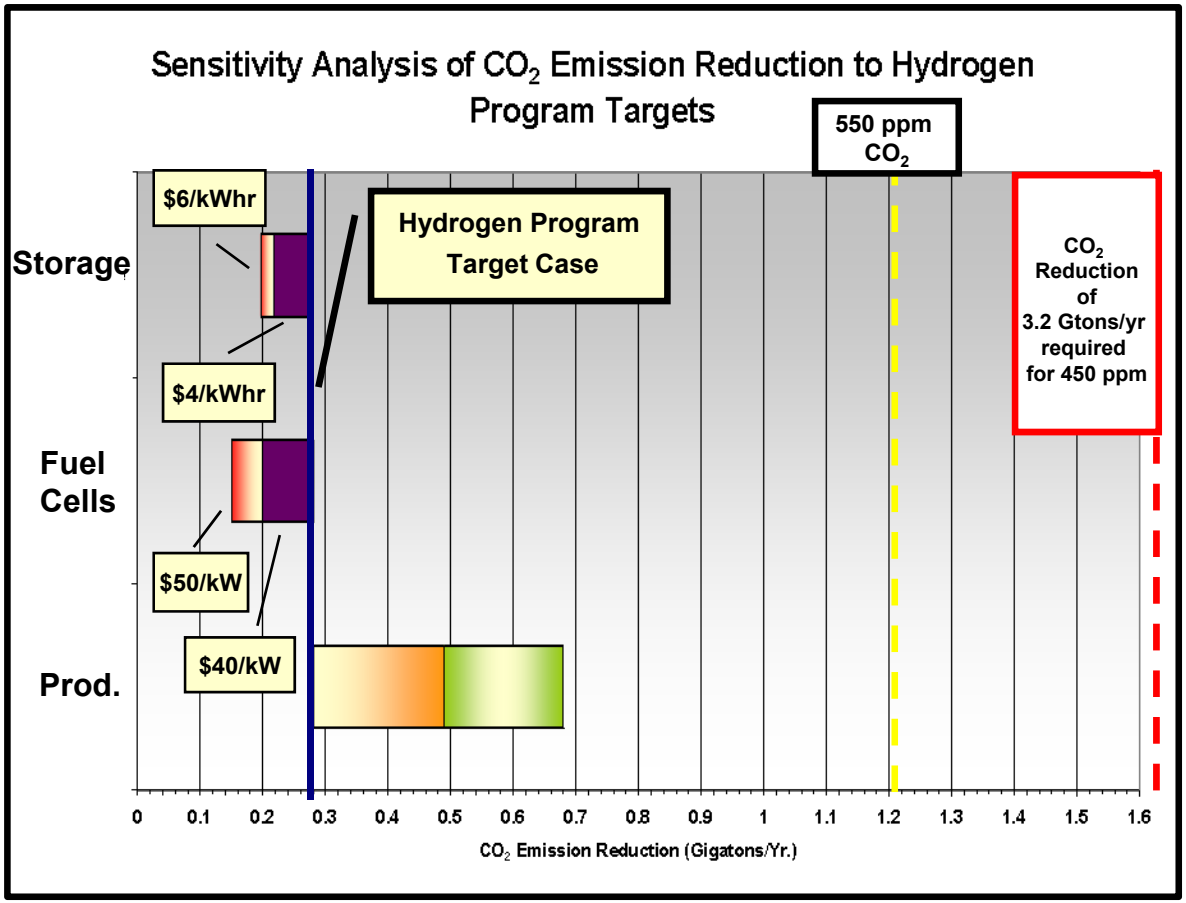
Stationary fuel cells ramp up to:

a) 10% of incremental electricity demand beyond 2015

b) 5% of incremental electricity demand beyond 2015

2009 Progress & Accomplishments
CO_2 Reduction and Hydrogen Program Targets

Renewable H_2 production pathways realizing cost goal of $2 - $3/gge and achieve largest CO_2 reduction benefit of Hydrogen program targets.



PRELIMINARY

Legend:

- Renewable and coal gasification with CO_2 sequestration
- Biomass gasification with CO_2 sequestration

Assumptions for Hydrogen Program at Target

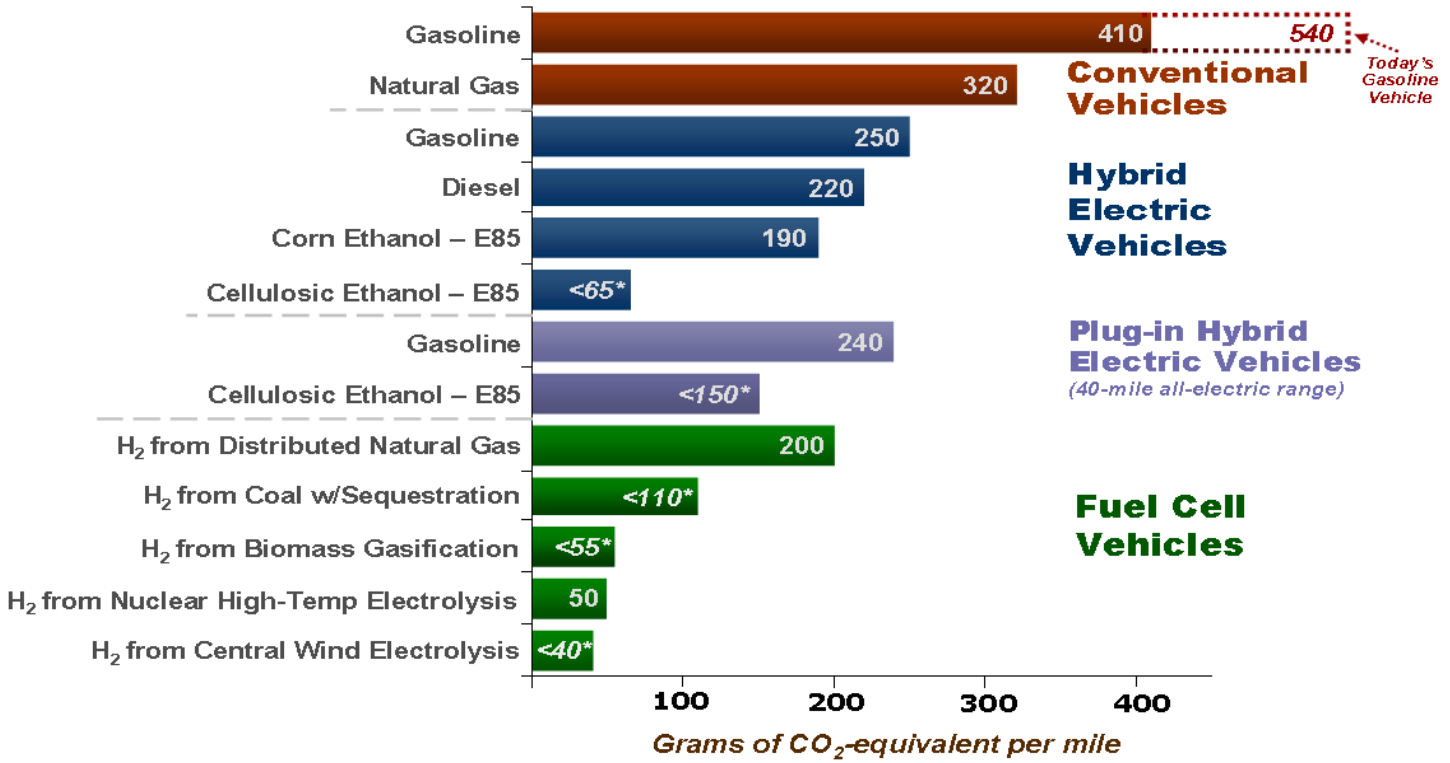
- Storage meets $2/kW hr target
- Fuel cells meets $30/kW target
- Distributed natural gas at $3/gge*
- Hydrogen from coal gasification and biomass gasification based on H2A model
- Only pipeline distribution from existing pipelines in LA, Houston, Chicago and Gulf Coast up to 2020.
- After 2020, pipeline distribution is available at $1/gge.
- FCV fuel economy is 60 mi/gge

* Assuming installation rate of 500 new forecourt units per year and capacity of 1,500 kg/day.

DOE is pursuing a portfolio of technologies with the potential to significantly reduce emissions of greenhouse gases from light-duty vehicles.

Well-to-Wheels Greenhouse Gas Emissions

(direct emissions, based on a projected state of the technologies in 2020)

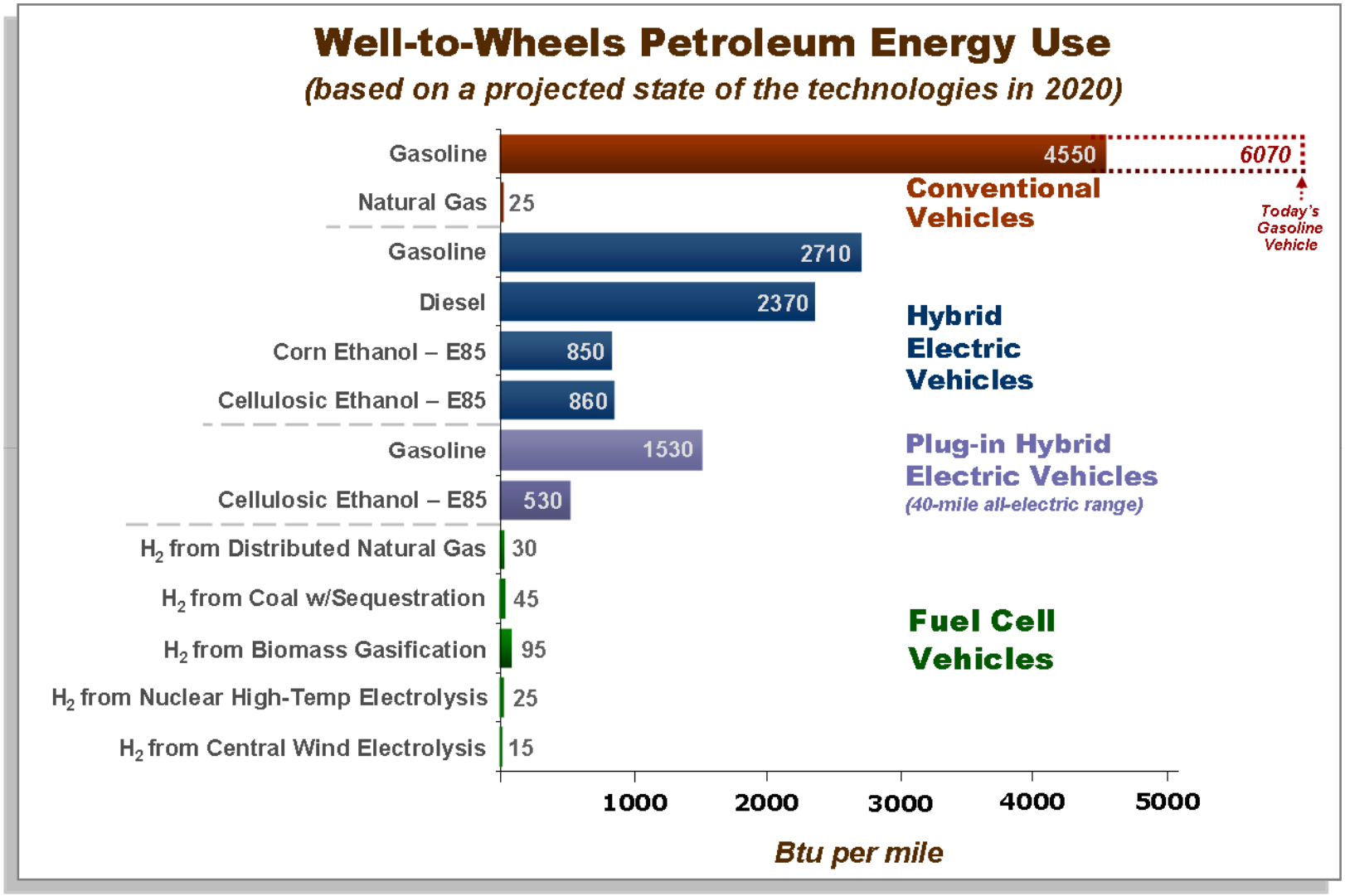


***Net emissions from these pathways will be lower if these figures are adjusted to include:**

- The displacement of emissions from grid power–generation that *will* occur when surplus electricity is co-produced with cellulosic ethanol
- The displacement of emissions from grid power–generation that *may* occur if electricity is co-produced with hydrogen in the biomass and coal pathways, and if surplus wind power is generated in the wind-to-hydrogen pathway
- Carbon dioxide sequestration in the biomass-to-hydrogen process

For details, see -- http://www.hydrogen.energy.gov/pdfs/9002_well-to-wheels_greenhouse_gas_emissions_petroleum_use.pdf

DOE is pursuing a portfolio of technologies with the potential to significantly reduce the consumption of petroleum by light-duty vehicles.



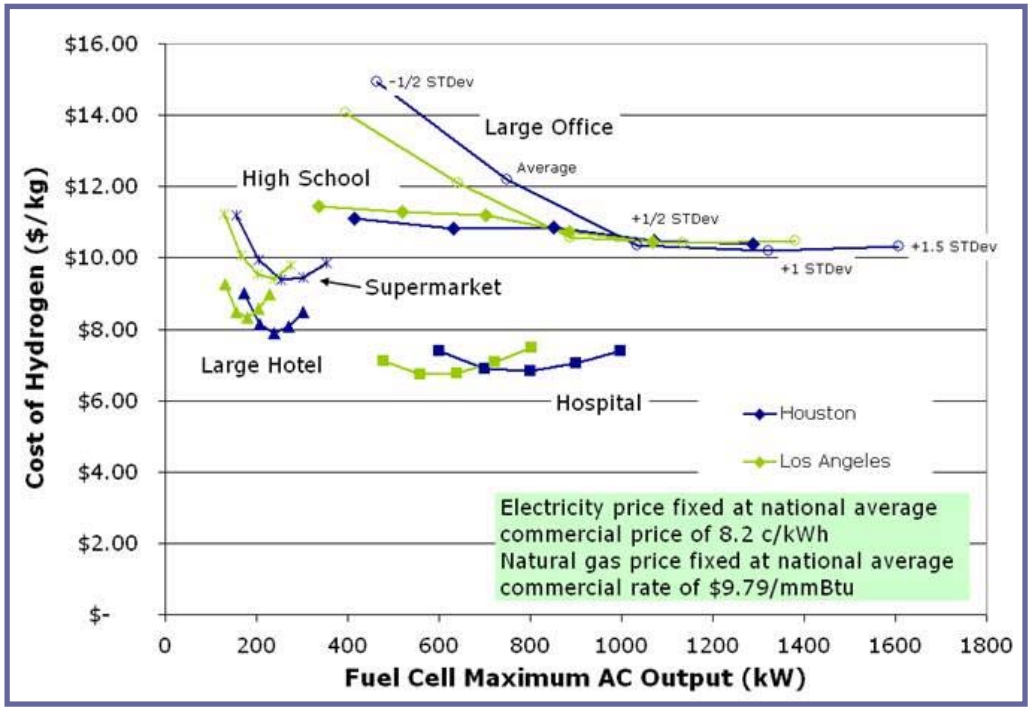
For details, see -- http://www.hydrogen.energy.gov/pdfs/9002_well-to-wheels_greenhouse_gas_emissions_petroleum_use.pdf

2009 Progress & Accomplishments
Transportation & Stationary Power Integration

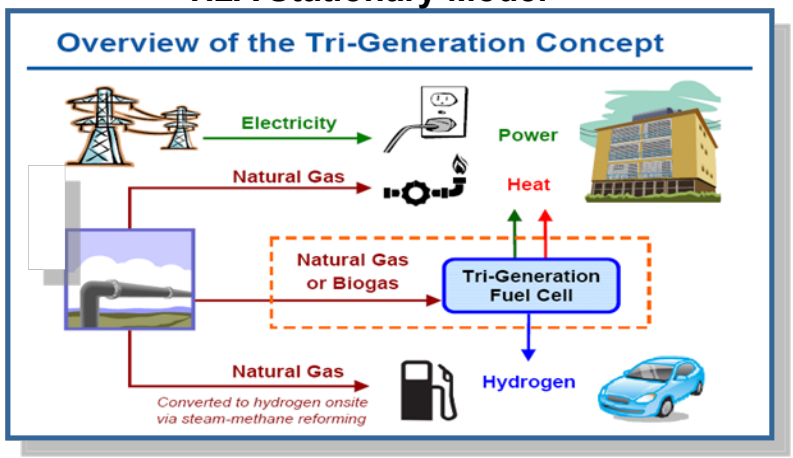
Integrating transportation and stationary power applications of fuel cells to start developing economies of scale and to jump start transition.

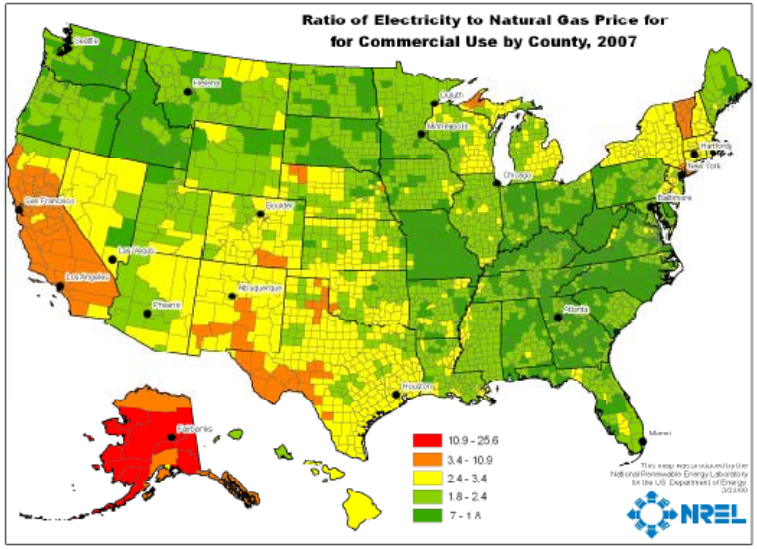
Tri-generation of electricity, heat and hydrogen can achieve market penetration in areas of high electric prices, moderate natural gas prices and emerging demand for hydrogen for transportation fuel.

Optimal Size of Fuel Cell System as Function of Building Location - Cost of Electricity/Heat/Hydrogen



H2A Stationary Model





Opportunities for Tri-generation in California, New Mexico, New England and Alaska due to electricity and natural gas prices.

Summary

- Systems Analysis sub-program includes diverse portfolio of models.
- Models well-developed as comprehensive tools – current focus on using these capabilities to address analysis gaps.
- Emphasis on *early market analysis*:
  - Means to developing economies of scale and jump starting transition and infrastructure development.
  - Economic, environmental and social benefits.
- Plans to enhance existing models and expand analyses.
- Identify metrics for other applications, key challenges and prioritizing R&D.

FUTURE PLANS

Complete Agent Based Model for infrastructure analysis of fuel and vehicles

Complete resource and infrastructure analysis

Analysis of technology environmental impacts

2009 2010 2011 2012 2013 2014 2015

Complete 2nd version of Macro-System Model with electrical infrastructure

Assess technology gaps and progress towards metrics for multiple applications

For More Information

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BACK-UP

Models and Analyses

Analysis Category	Technology Analysis				Implementation & Impact Analysis			Policy Analysis		
Analysis Type / Models	Pathway & Components Cost	H2 Quality Impact	WTW Energy & GHG Emissions	Vehicle Technology	Infrastructure & Resource Anal.	Consumer Choice	Vehicle Penetration	National Econ. Impacts	Policy Options	System Dynamics
H_2A Production Cost Model[1]	✓									
H_2A Delivery Cost Model[1]	✓									
DTI HyPRO[1]					✓					
EEA[1]					✓					
HyDS[1]					✓					
NREL Infrastructure[1]					✓					
HyDRA[1]					P					
PSAT				✓						
HyTrans[1]						✓	✓		✓	
GREET[1]			✓							
Macro-System Model (MSM)[1]	✓	P								
RCF Agent Based Model[1]					✓					
NEMS								✓	✓	
MARKAL								✓	✓	
HyDive[1]										P
Hydrogen Logistics Model (TIAX)					✓					

NOTES

- Projects funded by Systems Analysis are denoted with a "1."
- Risk analysis being incorporated into models. GREET model has risk analysis capabilities.
- Primary analysis focus of models are illustrated in matrix. However, models are multi-functional and can be applied for other analyses in the matrix.

LEGEND

✓ **Completed Models**

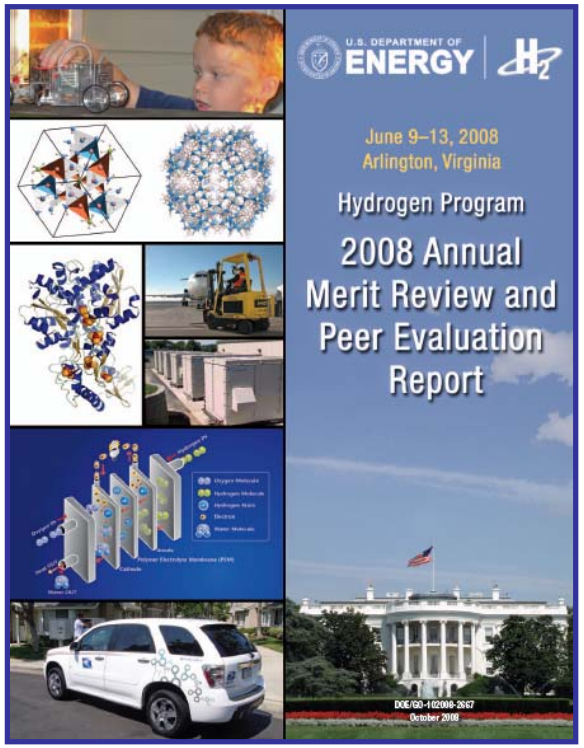
P **Planned Models**

Feedback from 2008 AMR

Positive feedback received with suggestions for further improvements and emphasis areas.

OBSERVATIONS

- LLNL Water Analysis important - should be extended to include renewable hydrogen production pathways.
- HyDRA tool well received and encouraged.
- Environmental projects with University of Illinois and Tetra Tech important in understanding effects on upper atmosphere and the environment.
- Importance of TIAX platinum availability/leasing strategy and ANL hydrogen quality recognized in addressing fuel cell cost and performance.
- Understanding lessons from previous efforts to introduce alternative fuels and power important for developing successful strategy to introduce hydrogen.



RECOMMENDATIONS

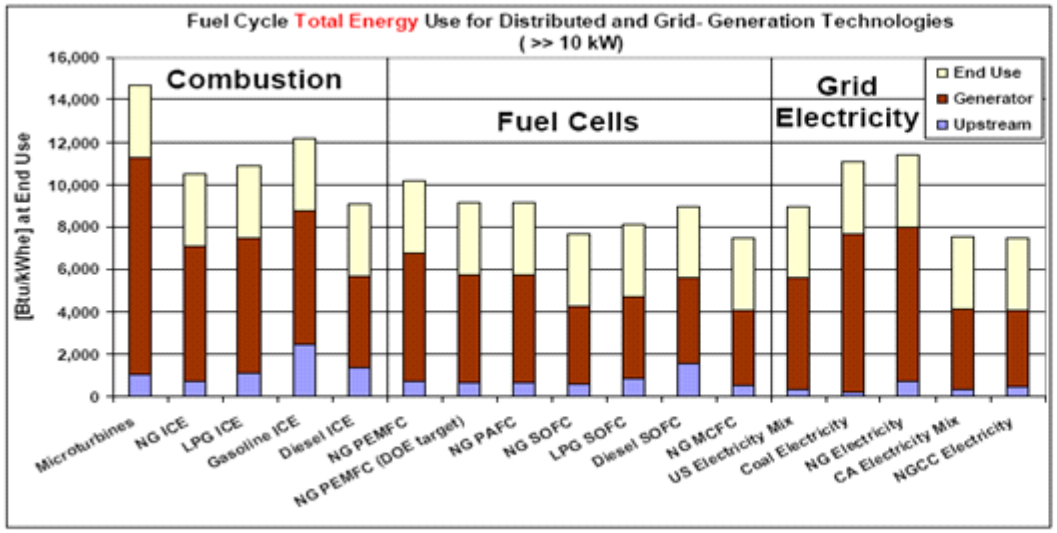
- Summary of assumptions should continue to be provided at beginning of analysis session.
- Model discussion and demonstration found useful.
- Fuel purity and impact on performance and cost tradeoff analysis should continue.
- Model validation and peer review is critical for sound and credible analysis.
- Consistent set of inputs and assumptions should be used.

IN SHORT…

- Systems Analysis subprogram an essential component to Hydrogen Program mission.
- Projects appropriately diverse and focused on addressing technical barriers and meeting targets.
- Analysis and model portfolio complete and making good progress.

2009 Progress & Accomplishments
Distributed Power Generation

Fuel cell technologies can readily penetrate distributed electricity markets on basis of energy efficiencies and/or GHG emissions advantages.



Fuel cell technologies can readily penetrate distributed electricity markets on basis of energy efficiencies and/or GHG emissions advantages.

For details, see --
http://www.transportation.anl.gov/pdfs/TA/554.pdf