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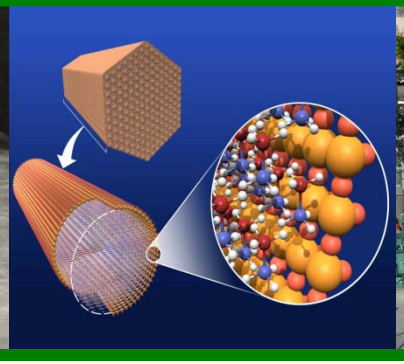

Systems Analysis

Fred Joseck

2011 Annual Merit Review and Peer Evaluation Meeting

May 9, 2011

Goal & Objective

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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

- Assess the Life Cycle Analysis benefits of hydrogen and fuel cells for diverse applications
- Quantify the benefits of integrating hydrogen fuel production with stationary fuel cell power generation
  - Evaluate the potential for biogas, landfill gas, and stranded hydrogen streams
- Evaluate fueling station costs for early vehicle penetration
- Evaluate the use of hydrogen for energy storage and as an energy carrier
- Evaluate socio-economic benefits of the Program such as job creation

Challenges

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Market complexities and data inconsistency present challenges

Future Market Behavior

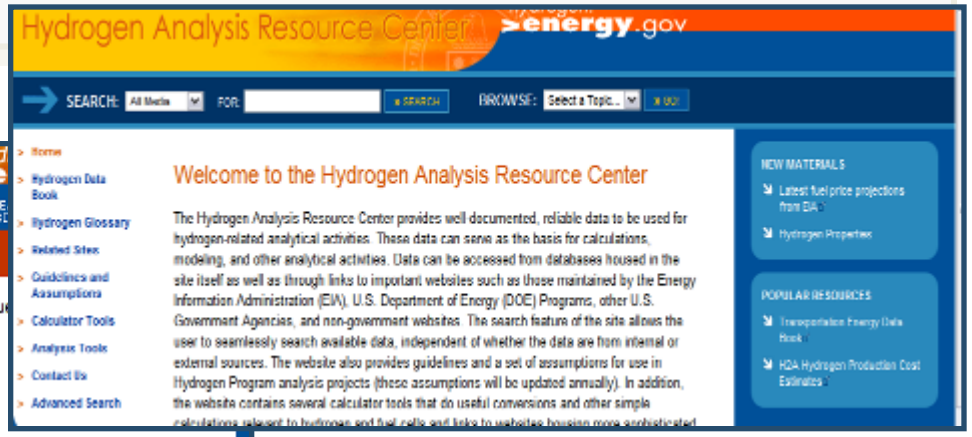
- Understanding of drivers of fuel and vehicle markets needed for long-term projections.
- Models need to adequately address interactions - hydrogen/vehicle supply and demand.

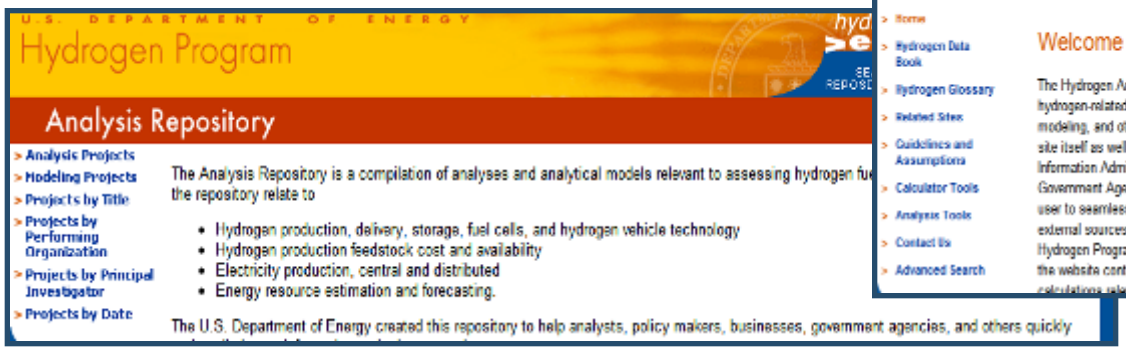
Inconsistent Data, Assumptions & Guidelines

- 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.





Analysis Portfolio

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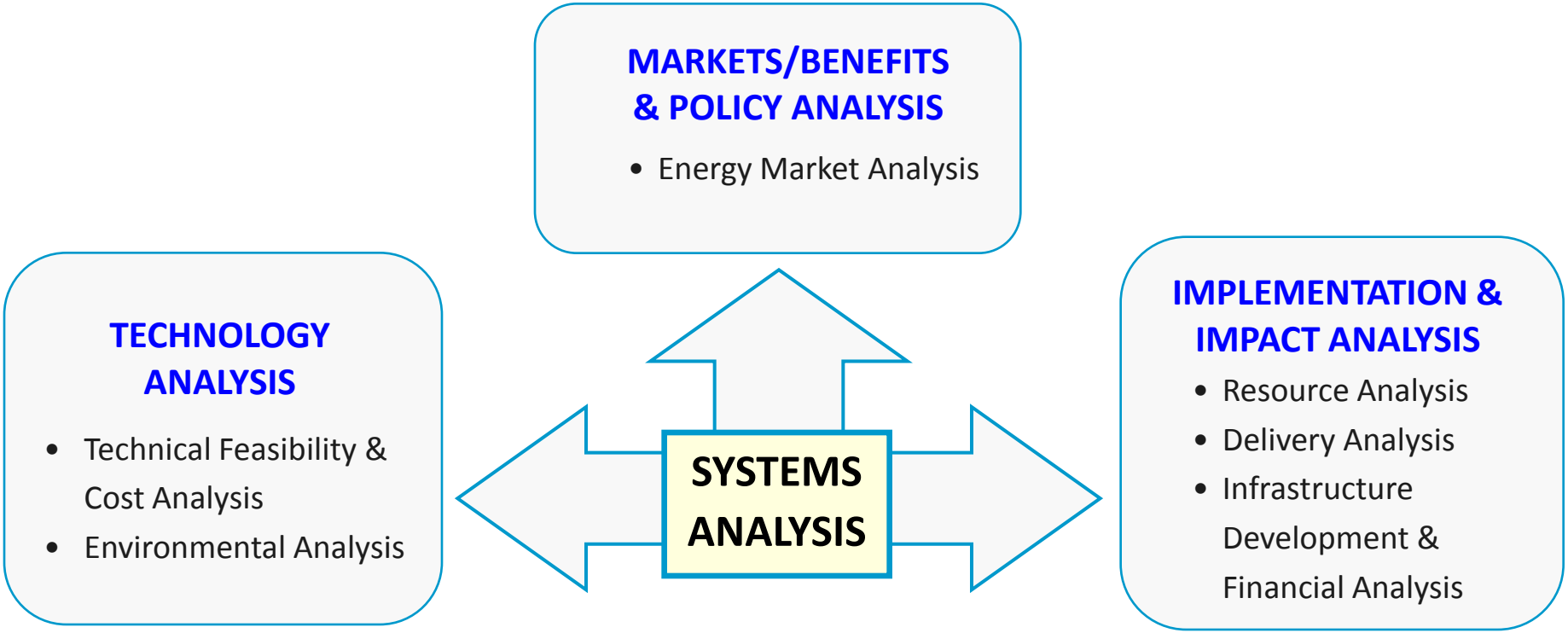
A variety of analysis methodologies are used in combination to provide a sound understanding of hydrogen and fuel cell systems and developing markets, as well as quantifying benefits, impacts, and risks of different hydrogen and fuel cell systems.



Systems Analysis Budget

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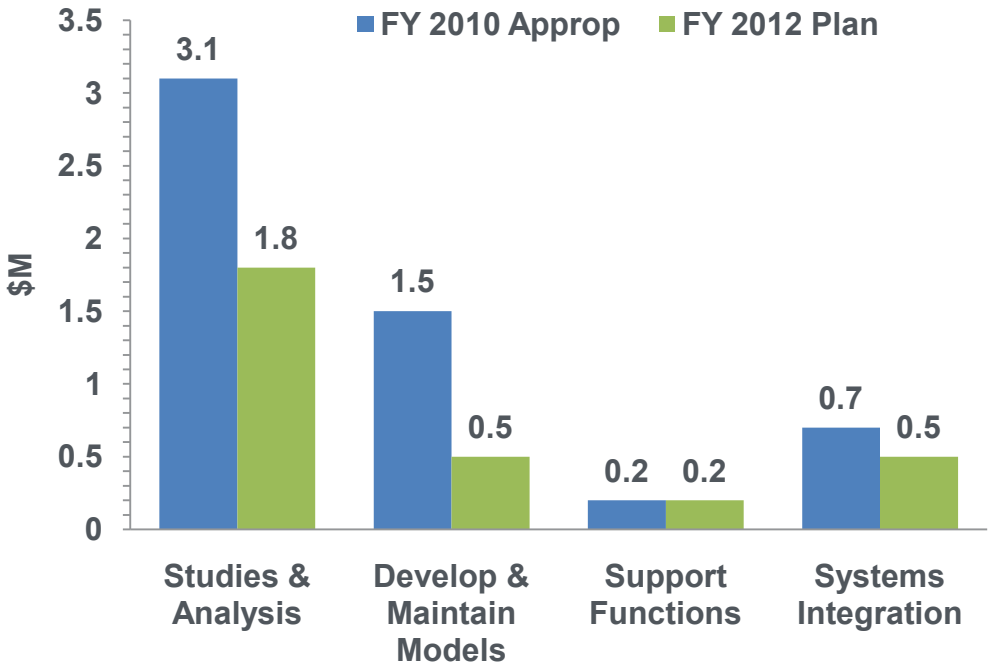
Determine technology gaps, economic/jobs potential, and quantify 2012 technology advancement

FY 2012 Request = $3.00 M

FY 2010 Appropriation = $5.41 M



* Subject to FY11 budget

EMPHASIS

- Update models for program analysis, using cost performance and environmental information.
- Assess market penetration, job creation, and opportunities for fuel cell applications in the near term.
- Assess gaps and drivers for early market infrastructure cost for transportation and power generation applications
- Assess business cases of biogas applications, infrastructure applications and integration in a domestic fueling network, and fuel cell Combined Heat and Power (CHP) applications for Federal facilities.

Programmatic Analysis: Hydrogen Threshold Cost

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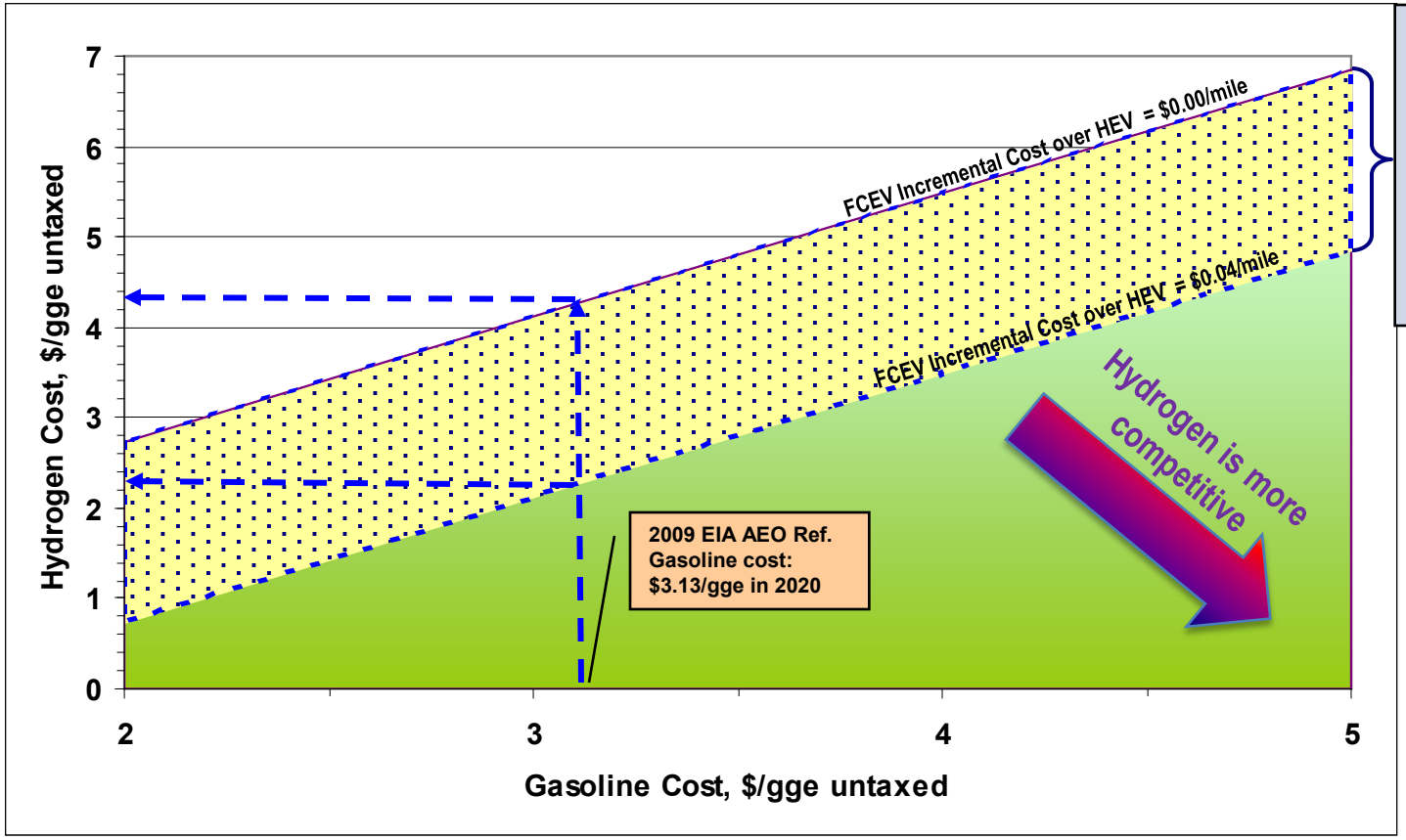
Competitive cost of hydrogen compared to gasoline HEV is ~$2.00–$4.00/gge



Range includes diverse technologies, fuel economies and incremental vehicle cost assumptions.

- **H_2 Threshold Cost includes vehicle incremental cost**
- **H_2 Threshold Cost will be applied across the Program**
  - **Target setting**
  - **Subprogram R&D progress gauge**

- The fuel cost per mile for a hydrogen fuel cell vehicle is set equivalent to the price of the competing vehicle on a "per mile" basis.

$$\$/\text{gge H2} = \left[\left(\frac{\text{Gasoline HEV cost, \$/gge}}{\text{HEV fuel economy, miles/gge}}\right) - \text{FCEV incremental vehicle cost, \$/mile}\right] \times \text{FCEV fuel economy, miles/gge}$$

See DOE Record 11001

Expert review included National Laboratories, Hydrogen Technical Advisory Committee and FreedomCAR Partnership

Programmatic Analysis: Well-to-Wheels Analysis Updates

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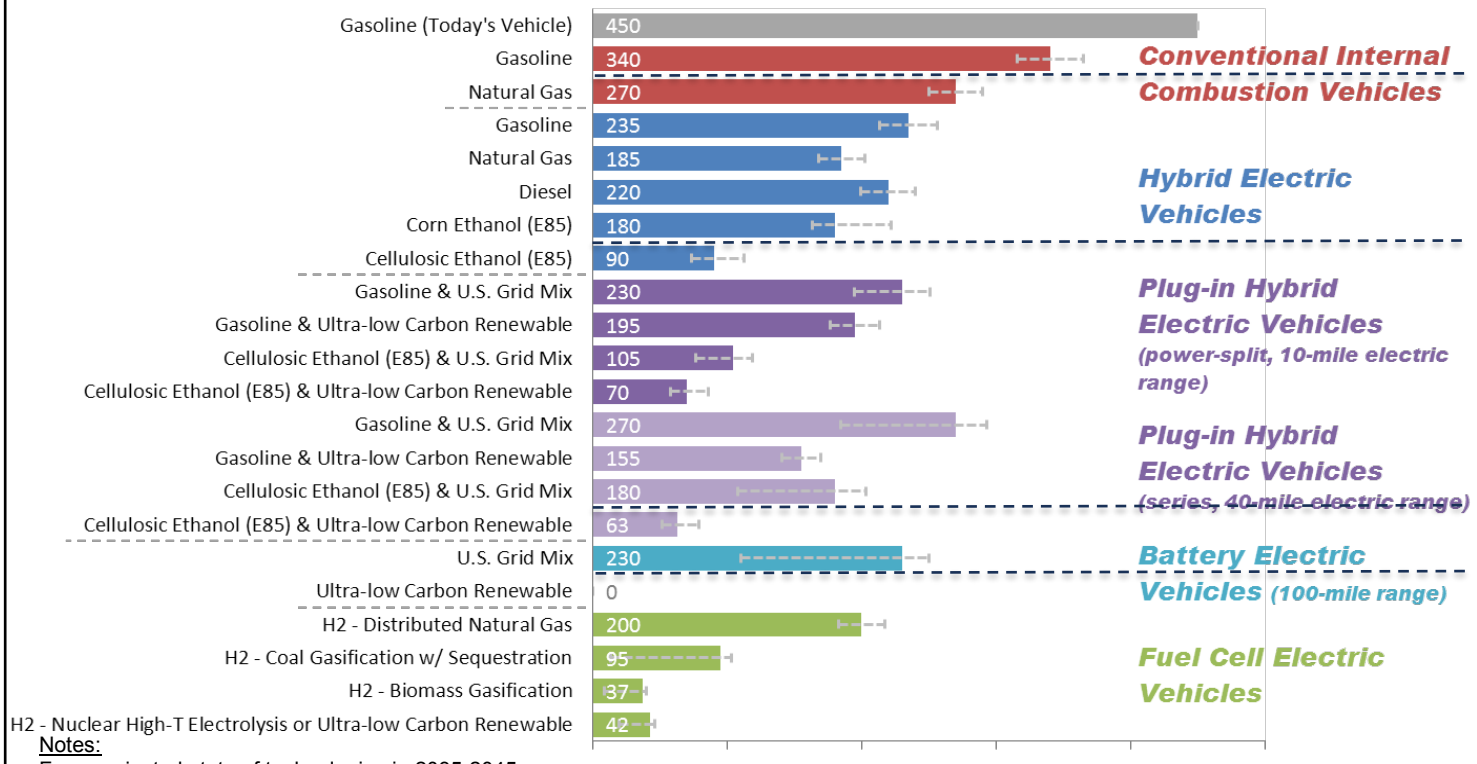
DOE is pursuing a portfolio of technologies with the potential to significantly reduce emissions of greenhouse gases from light-duty vehicles.

Well-to-Wheels Greenhouse Gases Emissions Future Mid-Size Car (Grams of CO2-equivalent per mile)



Notes:
For a projected state of technologies in 2035-2045.
Ultra-low carbon renewable electricity includes wind, solar, etc.
Does not include the life-cycle effects of vehicle manufacturing and infrastructure construction/decommissioning.

- **Multi- Program analysis with consistent assumptions and transparent approach**
- **Analysis included Vehicles Technologies and Biomass Programs, and ANL and NREL**
- **Analysis illustrates need for portfolio approach to reduce greenhouse gas emissions from conventional vehicle fleet**

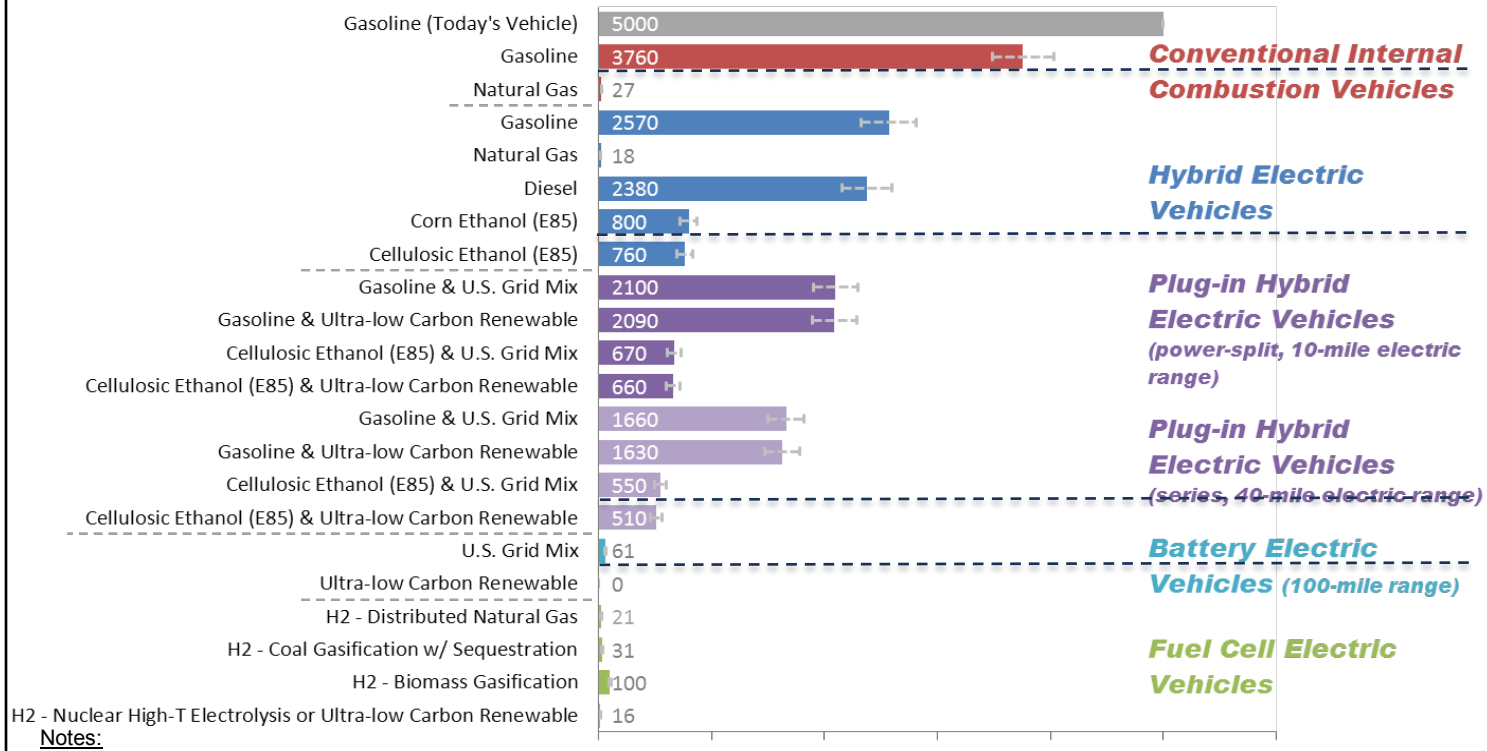
Analysis & Assumptions at: ***http://hydrogen.energy.gov/pdfs/10001_well_to_wheels_gge_petroleum_use.pdf***

Programmatic Analysis: Well-to-Wheels Analysis Updates

U.S. DEPARTMENT OF ENERGY

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

Well-to-Wheels Petroleum Energy Use for Future Mid-Size Car (*BTUs per mile*)



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Policy Analysis: Benefits of Policy and Incentives

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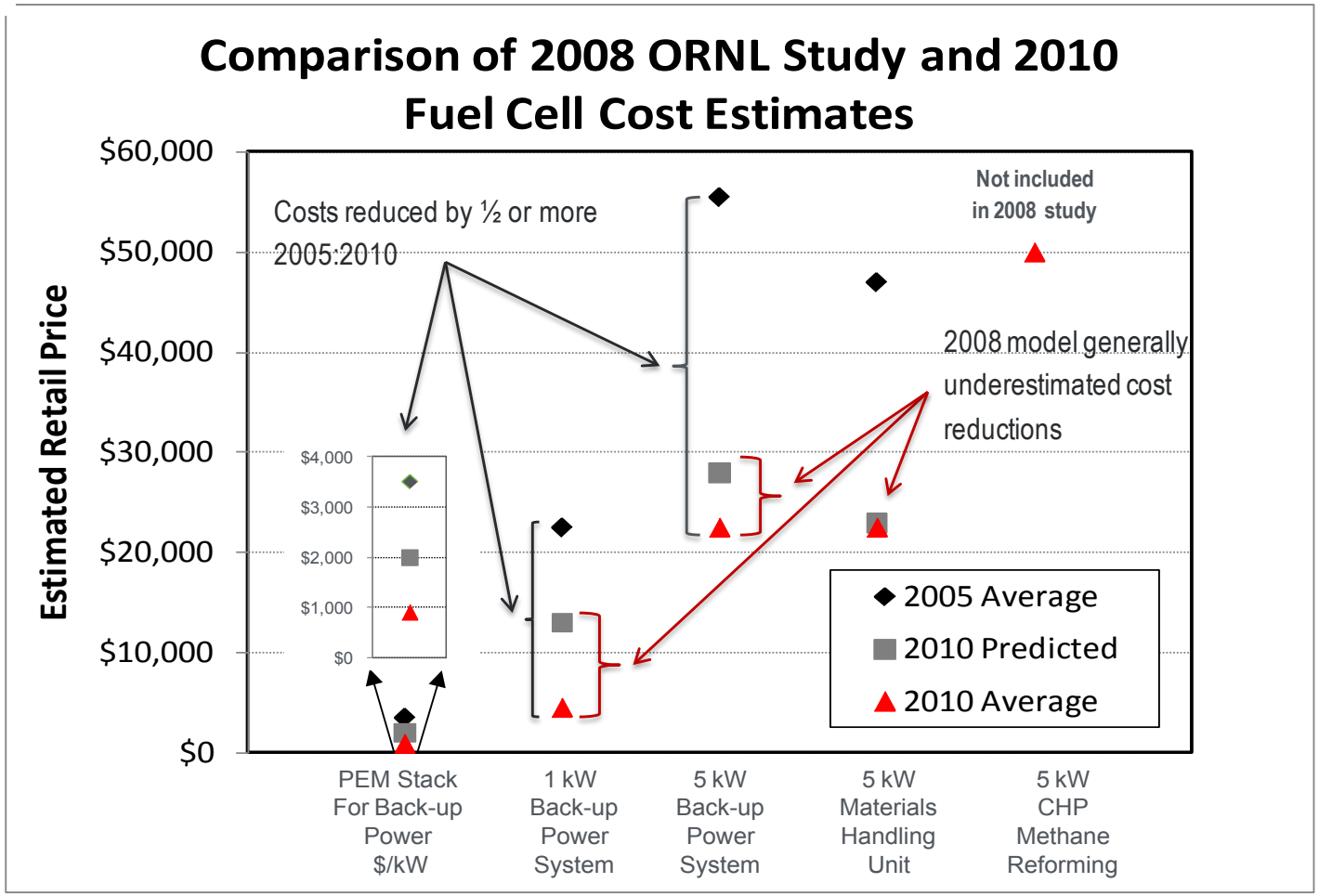
Oak Ridge National Laboratory model provided projections of the benefits from purchases to help reduce the fuel cell costs.



- **Fuel cell cost for multiple applications have decreased from 2005 to 2010 as a result of purchases and programs such as ARRA and investment tax credits.**
- **ORNL model provides a method to estimate the impact of purchases.**

2005 and 2010 averages based on estimates supplied by OEMs. 2010 predicted assumed government procurements of 2,175 units per year, total for all market segments. Predictions assumed a progress ratio of 0.9 and scale elasticity of -0.2.

Technical Analysis: Vehicle Lifecycle Cost Breakdown Analysis

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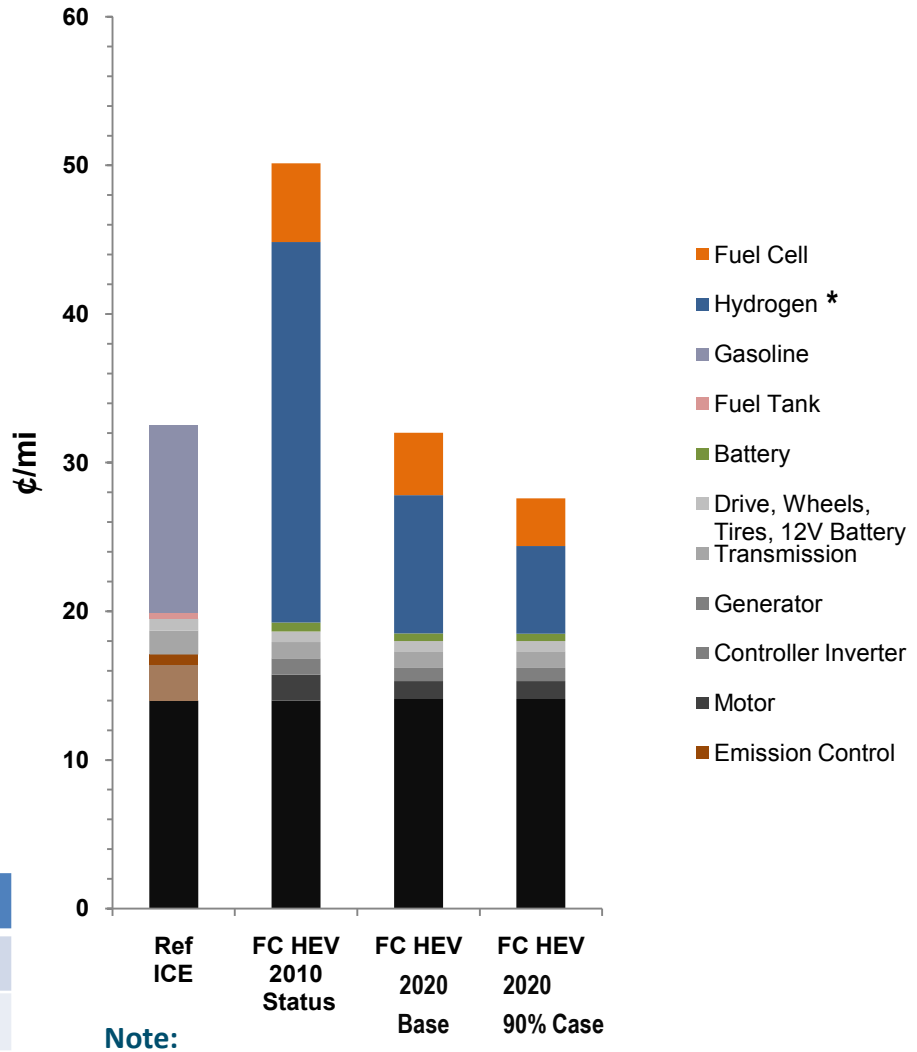
Reducing the cost of hydrogen fuel is a key requirement for fuel cell electric vehicles to compete with conventional ICEs on a lifecycle cost basis.

Preliminary Analysis - Vehicle Cost, ¢/mi

¢/mi	2010 Ref ICE	2010 FC HEV 2010 Status	2020 FC HEV 2020 Base	2020 FC HEV 2020 90% Case
Fuel Cell		5	4	3
Hydrogen		26	9	6
Other Vehicle	33	19	19	19
Gasoline ($3.08/gal.)	13	N/A	N/A	N/A
Fuel Tank	0	N/A	N/A	N/A
Battery	0	1	1	1
Drive, Wheels, Tires, 12V Battery	1	1	1	1
Transmission	2	1	1	1
Generator	0	0	0	0
Controller Inverter	0	1	1	1
Motor	0	2	1	1
Emission Control	1	0	0	0
ICE	2	0	0	0
Glider	14	14	14	14
Carbon Cost	0	0	0	0
Total	33	50	32	28

Assumptions	Ref ICE	2010	2020	2020
H_2 cost	NA	$9.50	$3.50	$3.00
H_2 Storage cost	NA	$5,050	$2,100	$1,050
Fuel Cell cost (80 kW)	NA	$4,000	$3,200	$2,400
Vehicle Fuel Economy	25	50	54	67



Note:
***Hydrogen:** *Includes production, delivery, and on-board storage*

Technical Analysis: Lifecycle Costs for Light Duty Vehicles

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Conclusion: Meeting subprogram targets is key to enabling fuel cell vehicles to compete with other vehicle platforms.

Preliminary Analysis

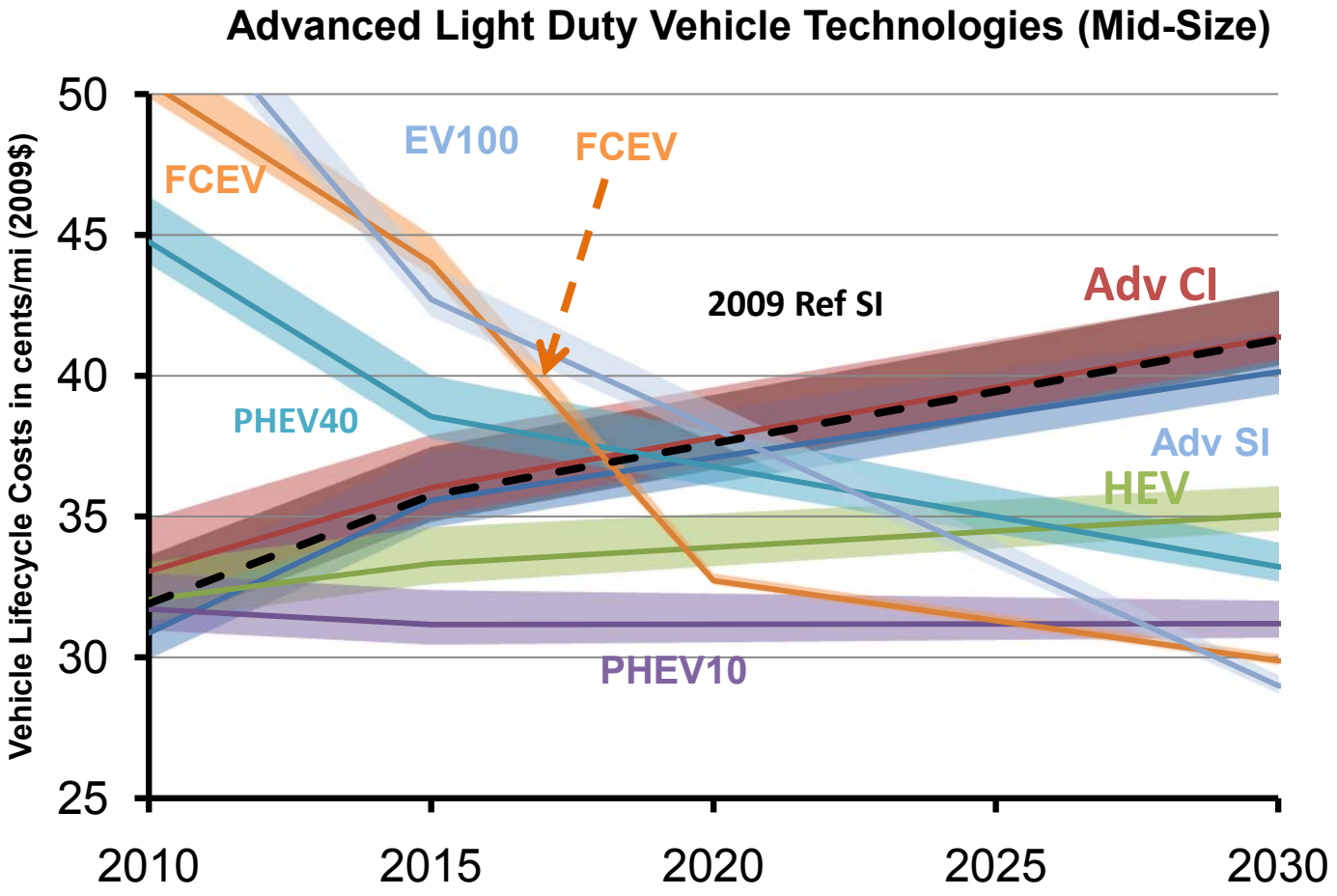
2020

- Fuel cell vehicles become competitive with gasoline-based vehicles

2030

- Fuel cell vehicles are competitive with other alternate fuel vehicles

Analysis includes FCTP, OBP, VTP, and ANL.



* No state, local or utility incentives are included. Federal subsidy policies (e.g., Recovery Act 09 credits for PHEVs) are also excluded. Fuel prices follow AEO09 high oil projections (gases rises from $3.07 in 2010 to $5.47 in 2030; diesel increases from $3.02 in 2010 to $5.57 in 2030); fuel taxes are included in EIA estimates. The vehicle cost range represents a range of potential carbon prices, from $0 to $56 (the centerline is plotted at a carbon price of $20). Technology costs are estimated based on a 50% (“average”) likelihood of achieving program goals.

Early Market Analysis

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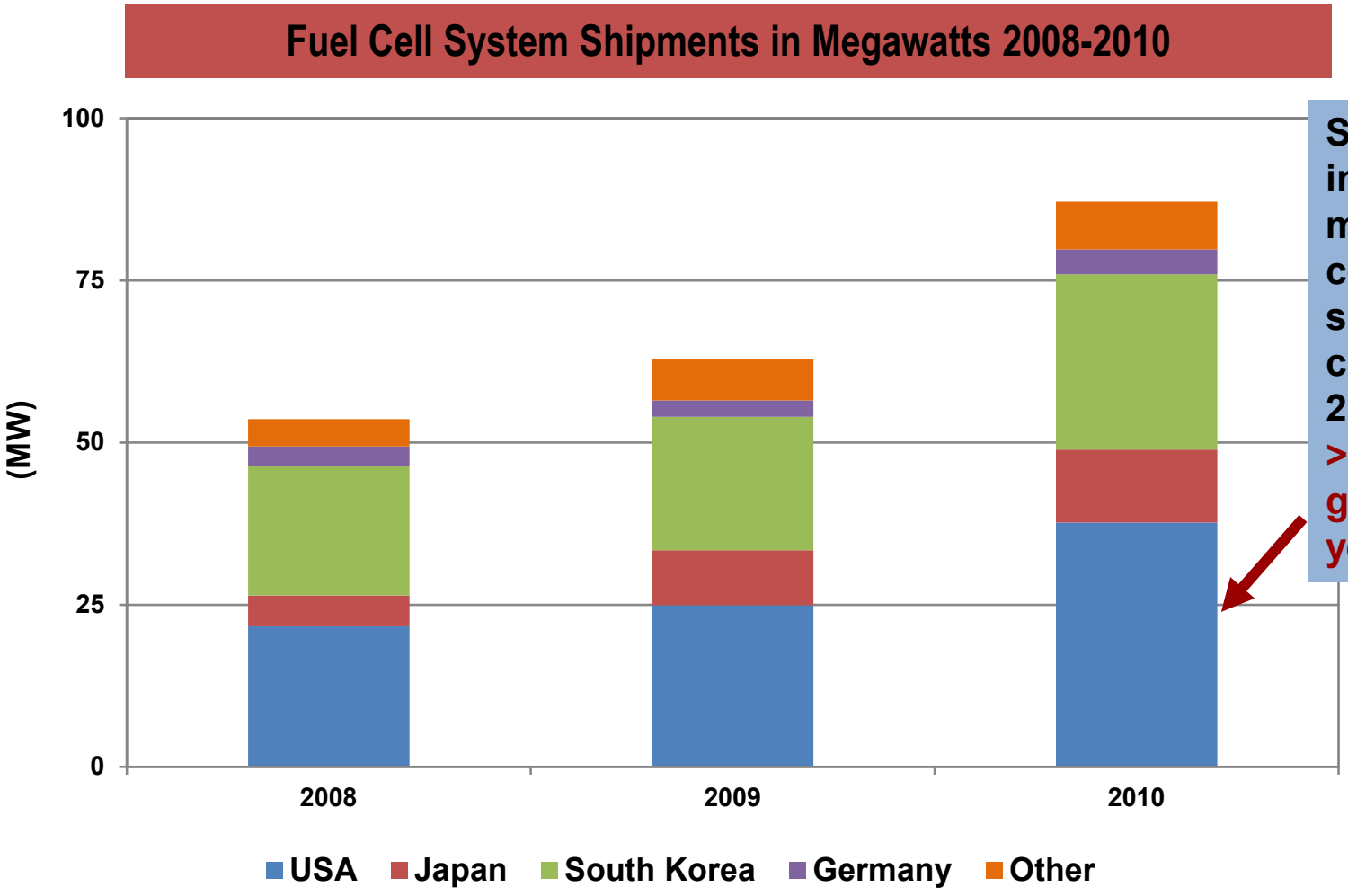

Significant increase in megawatts of fuel cell systems shipped by US companies from 2009 to 2010 year: >50% market growth in just one year

Source: Pike Research, www.pikeresearch.com

Early Market Analysis: Infrastructure Requirements

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Infrastructure workshop with multiple stakeholders provided valuable insight for cost reduction and gaps to assess.

Workshop Summary

Objectives

Identify:

- Cost reduction opportunities from
  - Economies of scale (e.g., station standardization, number and size of installations)
  - Learning-by-doing resulting from growth in material handling equipment (MHE), backup power, transit bus, and light-duty vehicle markets.
- Cost reduction opportunities from focused R&D.

Participants included:

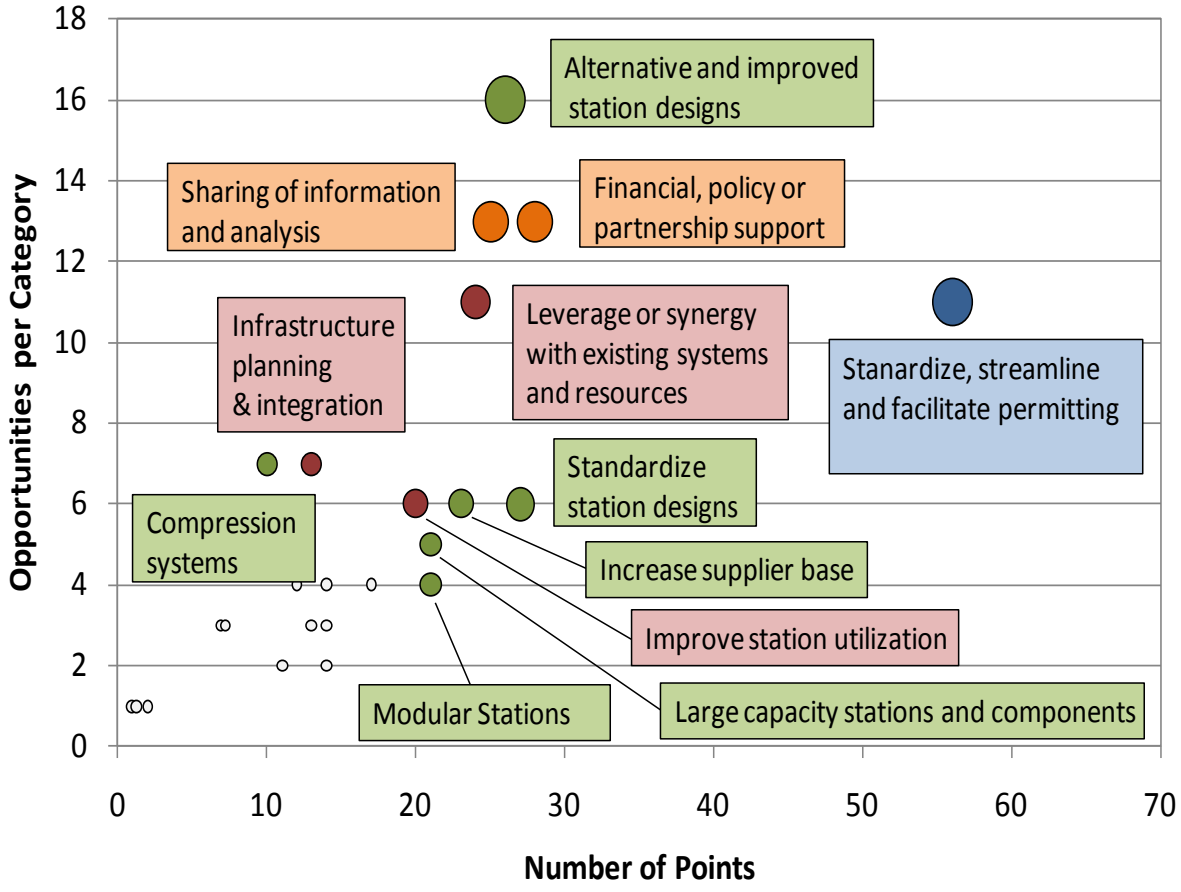
- ***Countries***

US	Germany
Japan	Norway

- ***Companies***

GM	Toyota	Nissan
Honda	Linde	StatOil
Shell	Sprint	Plug
ReliOn	Nuvera	Proton
Air Products	Air Liquide	Daimler
Chevron		

Preliminary Summary of Workshop Results



Source: NREL from Infrastructure Workshop 2011

Early Market Analysis: Station Cost Reduction

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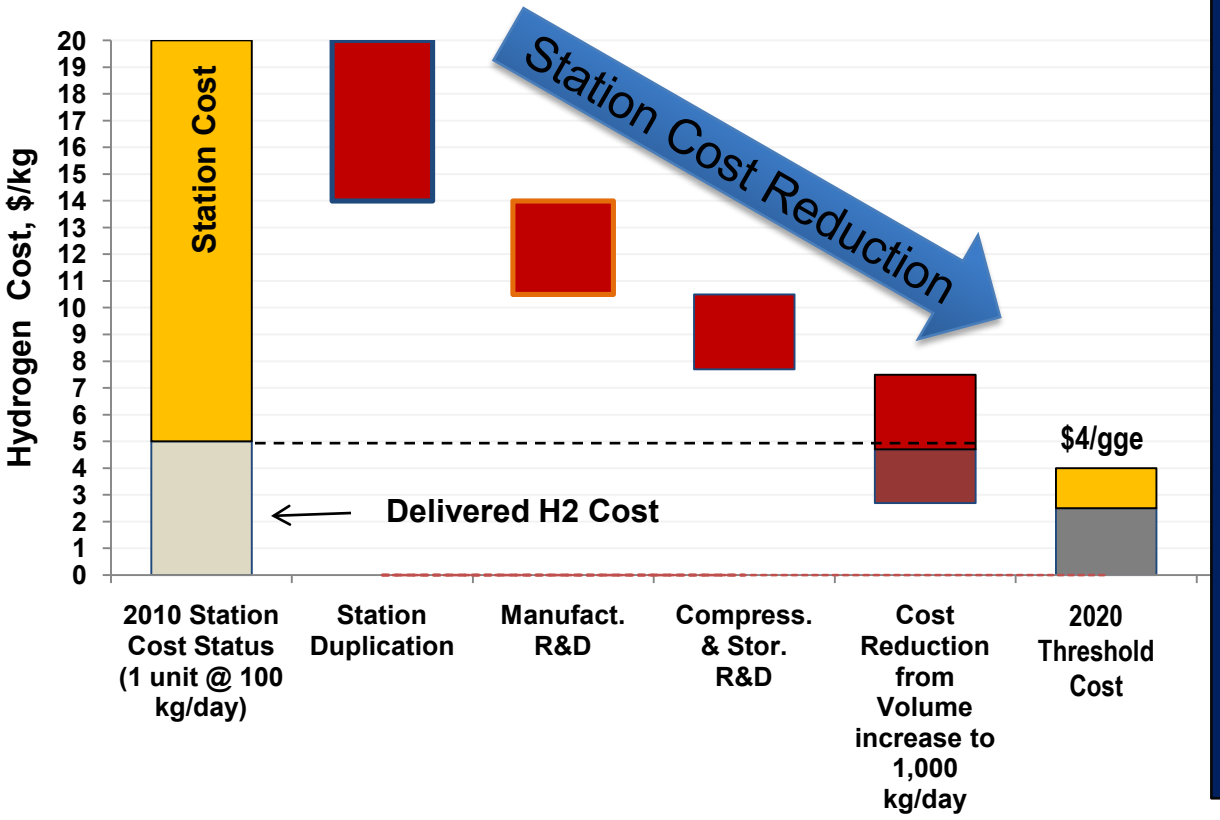
Developed cost reduction opportunity assessment

Preliminary Analysis: Cost Reductions for Stations



Preliminary results of Infrastructure Workshop highlighted current station costs can be reduced through

- **Economies of scale**
- **Standardized station design**
- **Multiple station installations**
- **Continued R&D of manufacturing station components, compressors and hydrogen storage**
- **Increase the number of station installers and component suppliers**

1. Cost reduction from station duplication will required ~120 stations and was based on 3% reduction for a doubling of capacity. Reference: "A portfolio of power-trains for Europe: a fact-based analysis" by McKinsey & Co.
2. Cost of hydrogen delivered to station is ~$5/kg based on TTC Hydrogen Market Study 2009.
3. Station cost reductions based on ANL Hydrogen Delivery Systems Analysis Model (HDSAM).
4. The current station cost is based on costs from the current California state funded stations. The capital cost for the station was assumed to be $2.5 million.
5. The starting station capacity is 100 kg/day.

Socio-Economic Analysis: Fuel Cell Industry Impact on Employment

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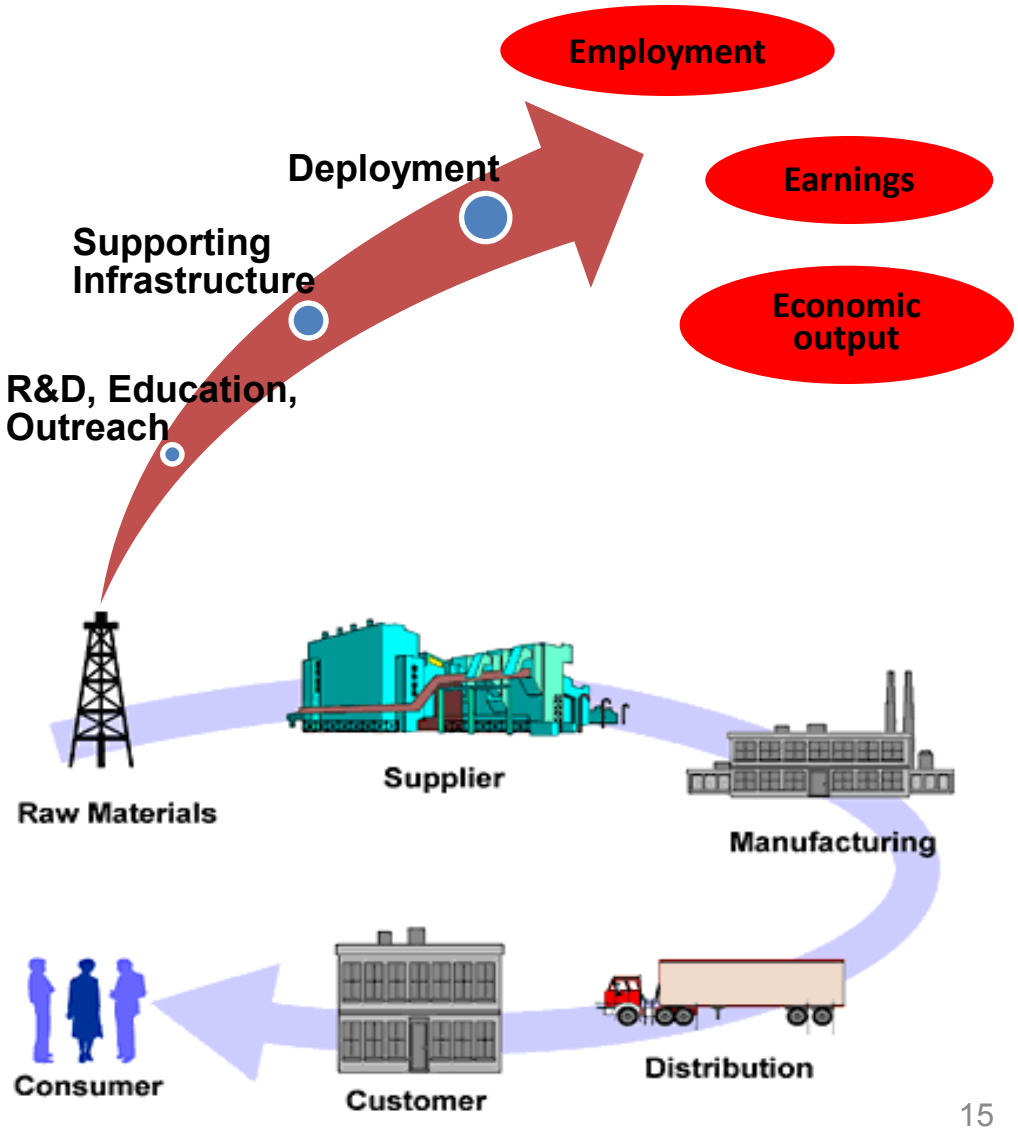
Developed employment model for job creation potential for states and regions

- ANL-RCF developing employment and economic impact tool to estimate stationary FC industry impacts:
  - Production (PEMFC, PAFC and MCFC) in target applications
  - Installation of FCs and required infrastructure
  - O&M including fuel
  - Construction/expansion of manufacturing capacity
- State, regional and national level analyses including supply chain impacts
- Applications included forklifts, back-up power, specialty vehicles, etc.

Systems Analysis and Education Subprograms are collaborating on the model development and analysis



Key Milestones & Future Plans

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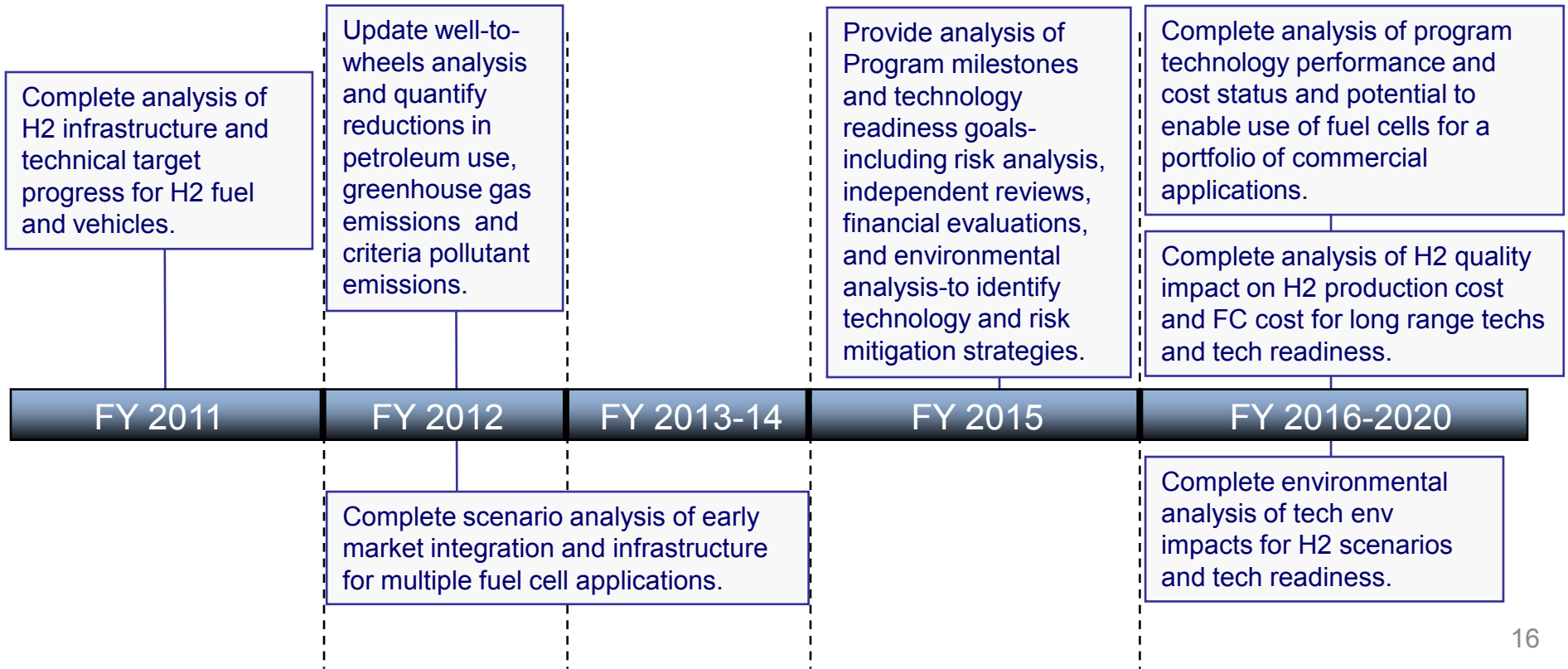
- Diverse portfolio and expanded capability of models developed by the Systems Analysis sub-program are enabling analysts to address barriers to technology development and commercialization.
- Emphasis on *early market and infrastructure analysis* :
  - Focus on utilizing biogas as a resource for an alternative fuel.
  - Comprehensive approach to evaluate a portfolio of fuel cell applications for light duty transportation, stationary generation, backup power and material handling equipment, and the electric sector to realize economic, environmental and social benefits.
- Plans continue to enhance existing models and expand analyses.



Systems Analysis Collaborations

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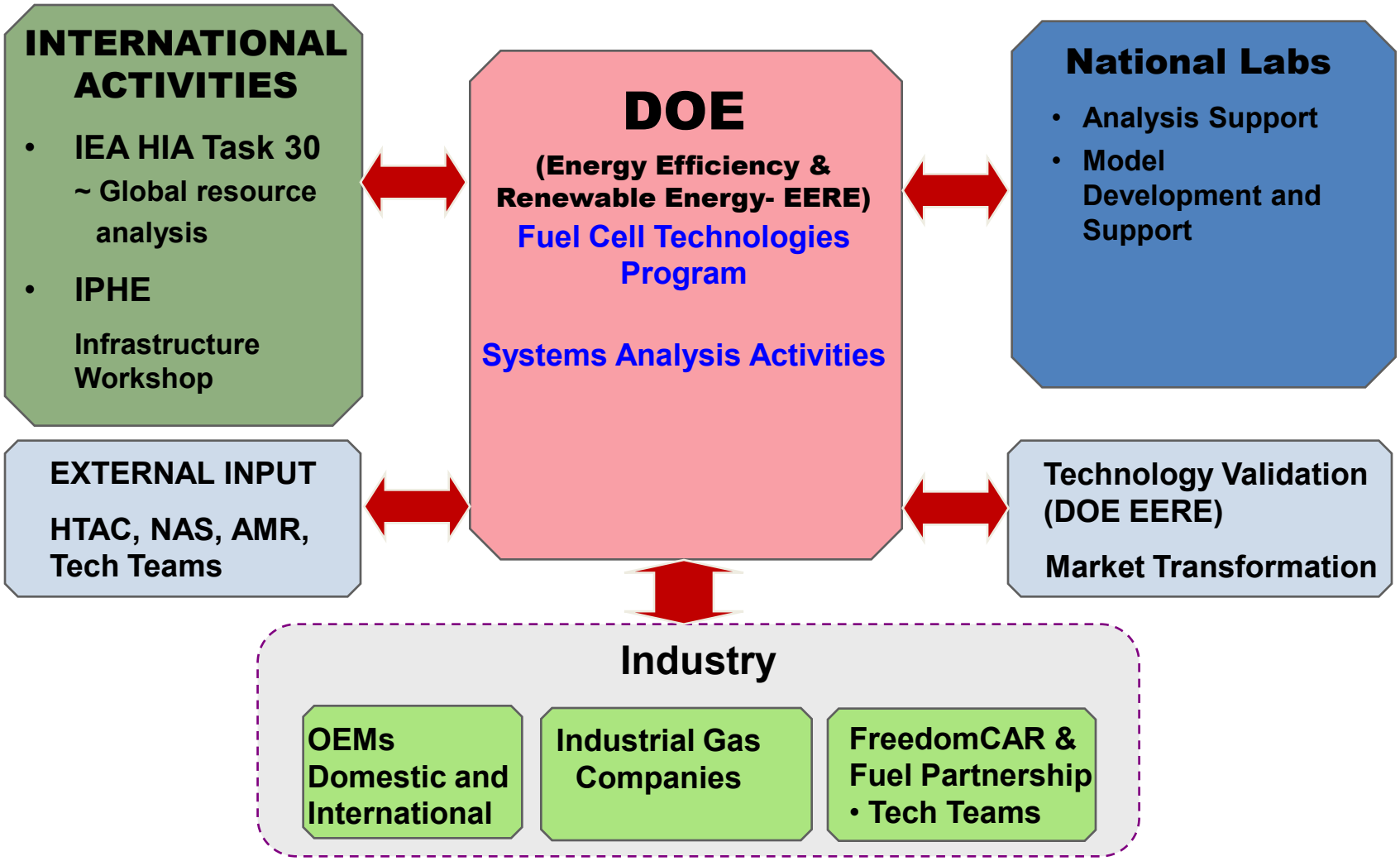
Analysis and peer review input coordinated among national and international organizations



Summary

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Systems Analysis is an integral component of EERE and the Fuel Cell Technologies Program.

- Continue to provide program guidance and support by reviewing and updating programmatic targets
- Identify gaps and opportunities for continued program R&D through analysis and input from multiple sources such as the early market infrastructure analysis
- Confirm through transparent analysis and peer review the impact of the FCT Program on market penetration and product development such as the ORNL report, Fuel Cells 2000 and Pike Research Market report and the PNNL Commercial Product report
- Assess the impact of Government policies on industry and market introduction and technology growth
- Provide transparent analysis and illustrations of the climate, economic and socio-economic benefits of fuel cell applications for transportation, stationary power generation, material handling equipment and other markets

For More Information

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