



Government Performance Result Act (GPRRA) / Portfolio Decision Support (PDS)

**2009 DOE Hydrogen Program and Vehicle Technologies
Annual Merit Review**
May 19, 2009

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Sponsored by Lee Slezak



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Energy Efficiency and Renewable Energy

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Main Objectives

CAFÉ
Fuel Economy Standards



Baseline



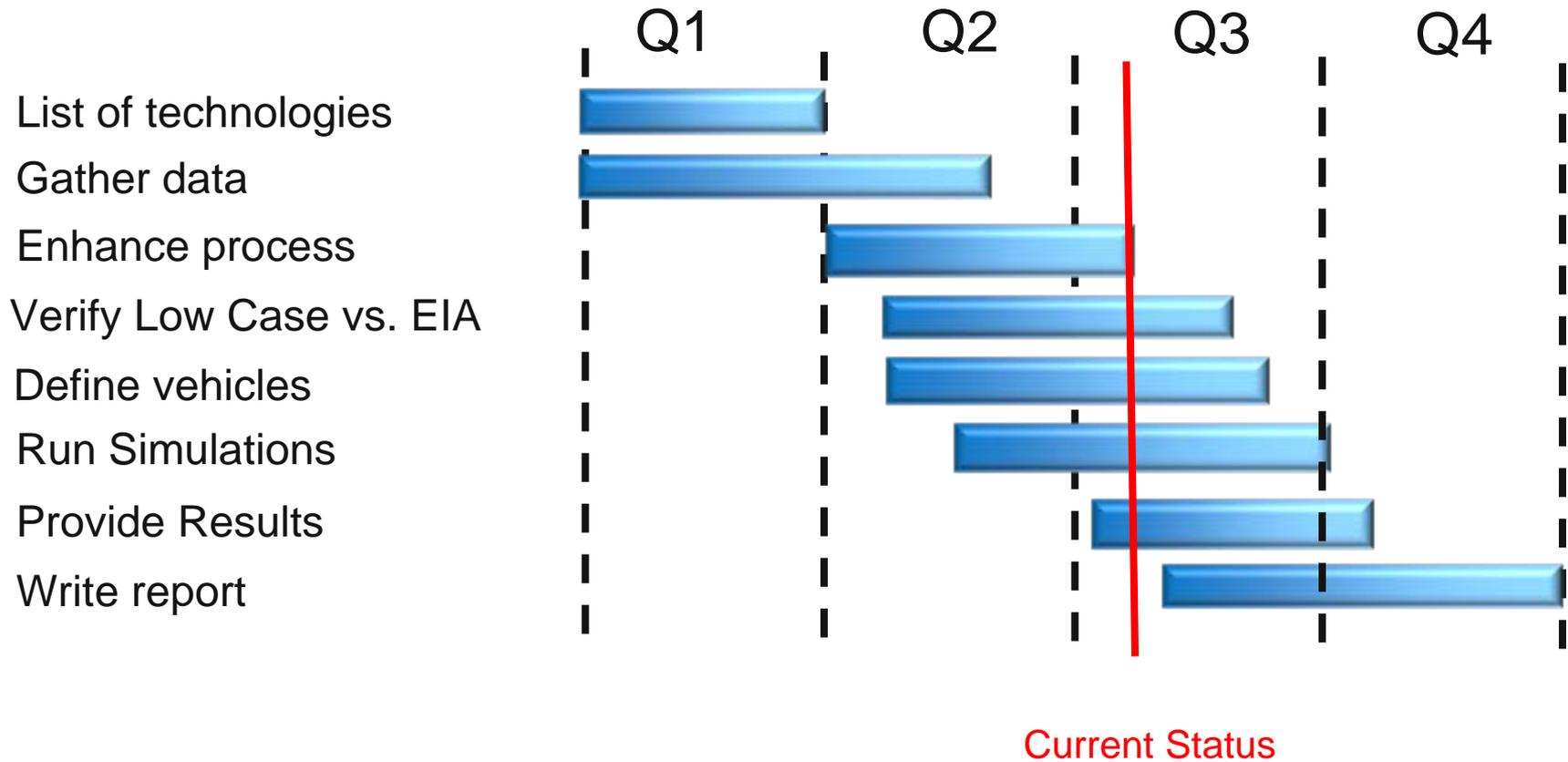
Additional
Improvements



Mandated
by
Congress

- What are the benefits of the FreedomCAR & Fuel Partnership in terms of petroleum displacement?
- How much additional petroleum could be displaced with additional funding?
- Assess technology potential to guide future research and development

Milestones



EIA = *Energy Information Administration*

Approach

Component & Vehicle Assumptions

Veh Classes



Timeframe

2010
2020
2030
2045

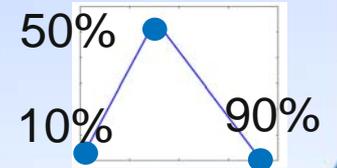
Powertrain



Fuels

Gasoline
Diesel
Ethanol
Hydrogen

Uncertainties

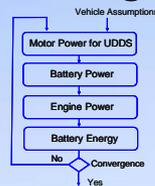


Vehicle Definition & Simulation

Vehicle
Technical
Specifications



Sizing

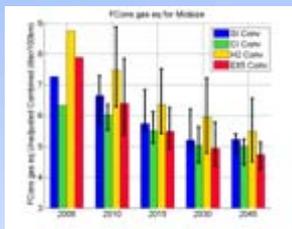


Simulation



Results Analysis & Validation

Results

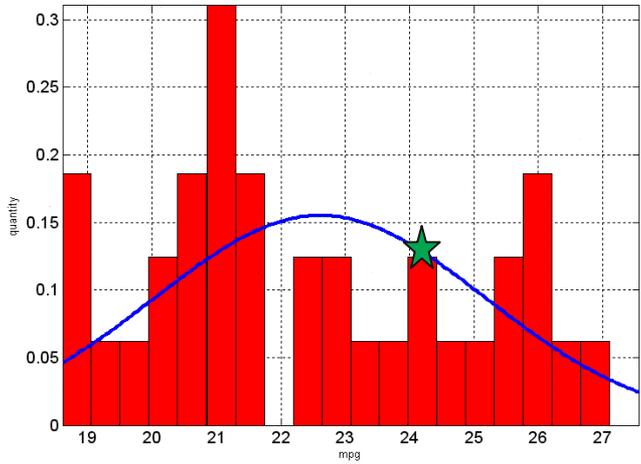


Validation

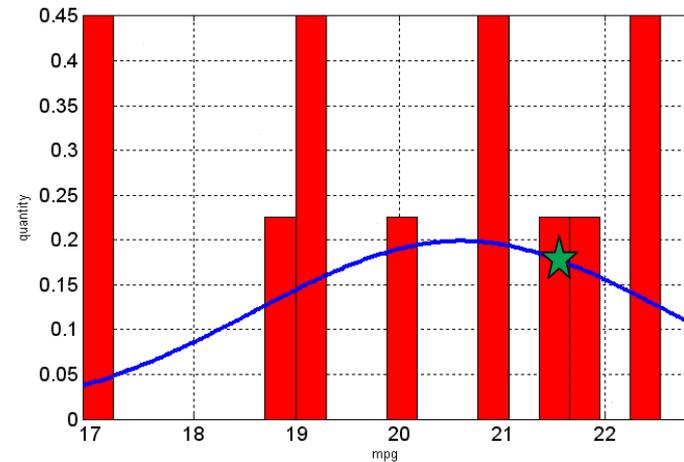


Reference Vehicles Fuel Economy Compared to Entire Class

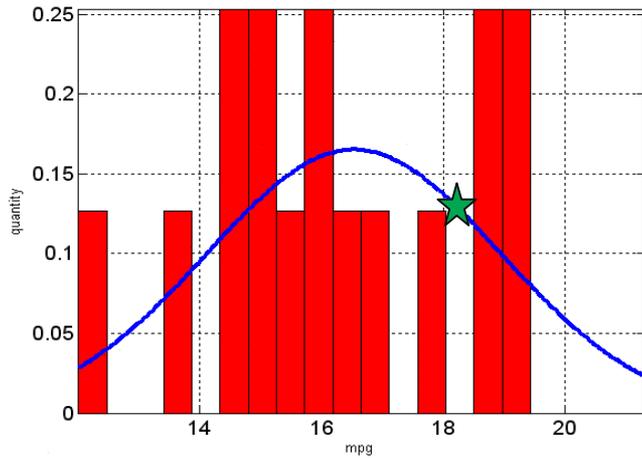
Midsize Car



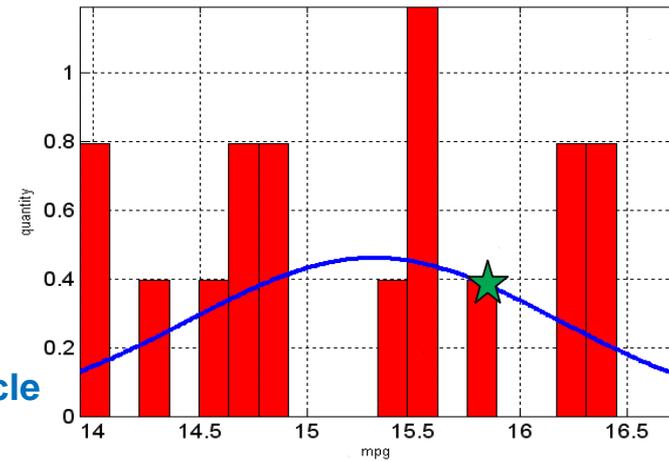
Small SUV



Midsize SUV



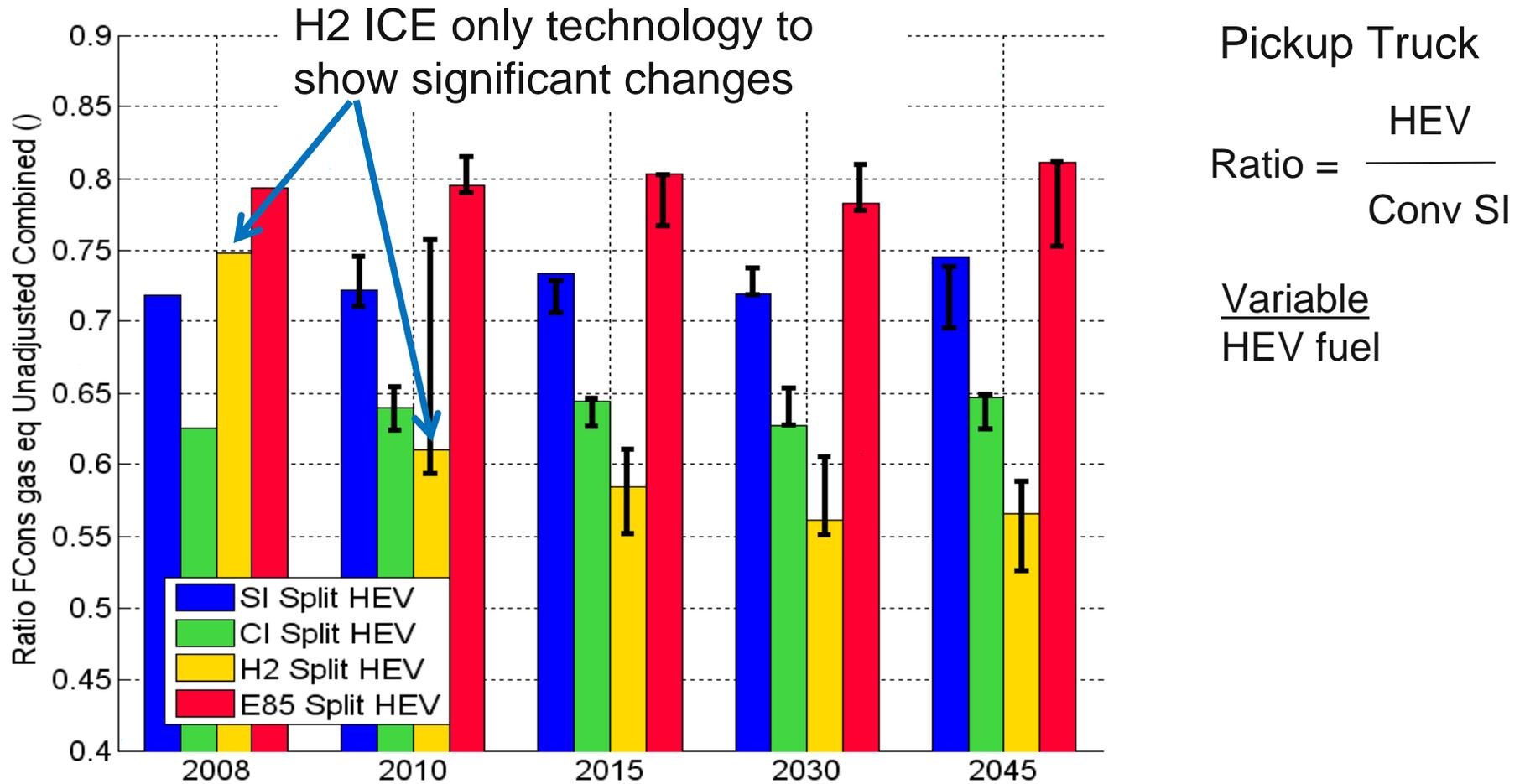
Pickup Truck



★ = Ref. Vehicle

GPRA/PDS 2008 Results

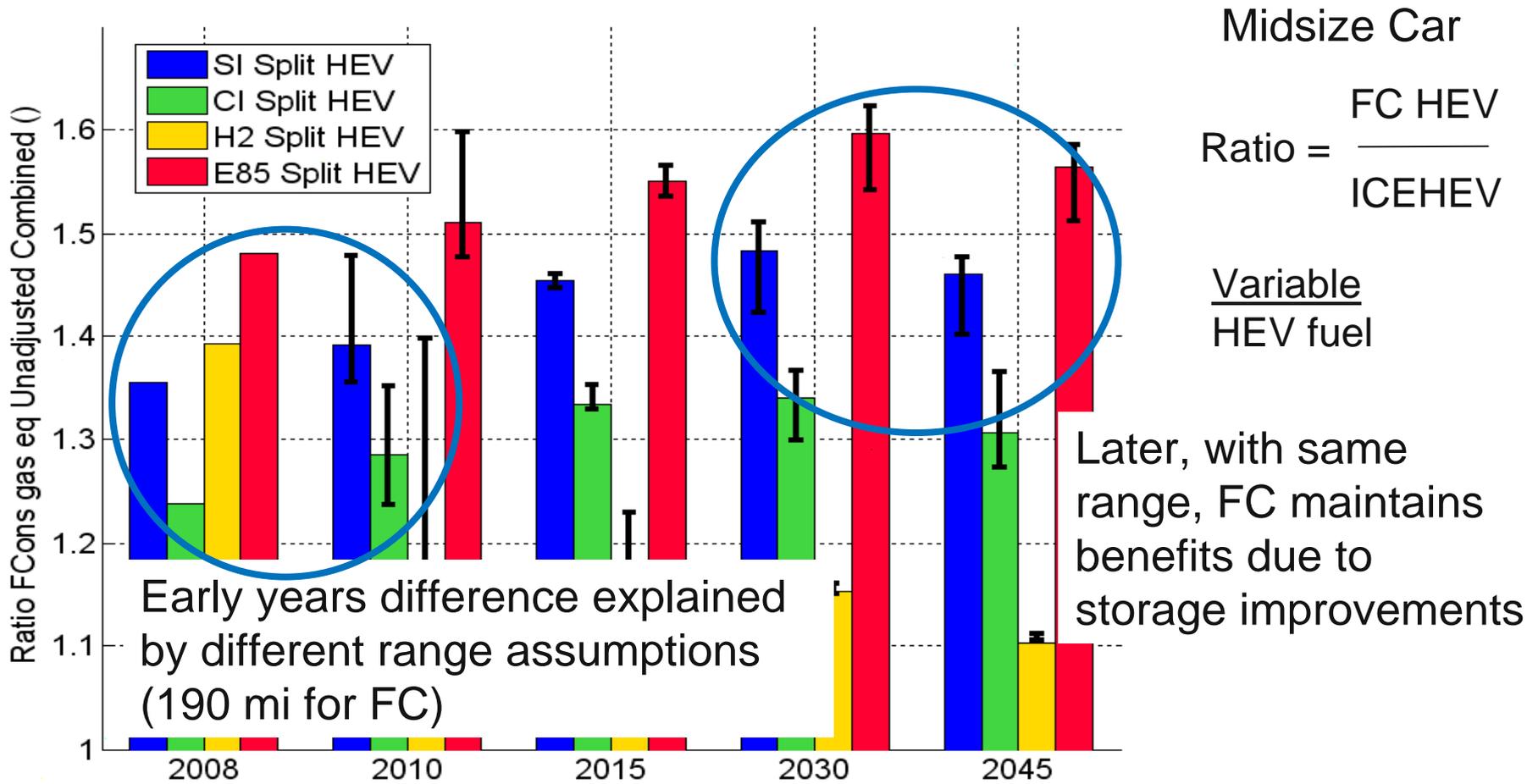
HEVs Fuel Consumption Remains Fairly Constant Compared to Conventional



Input Split Configuration Used

GPRA/PDS 2008 Results

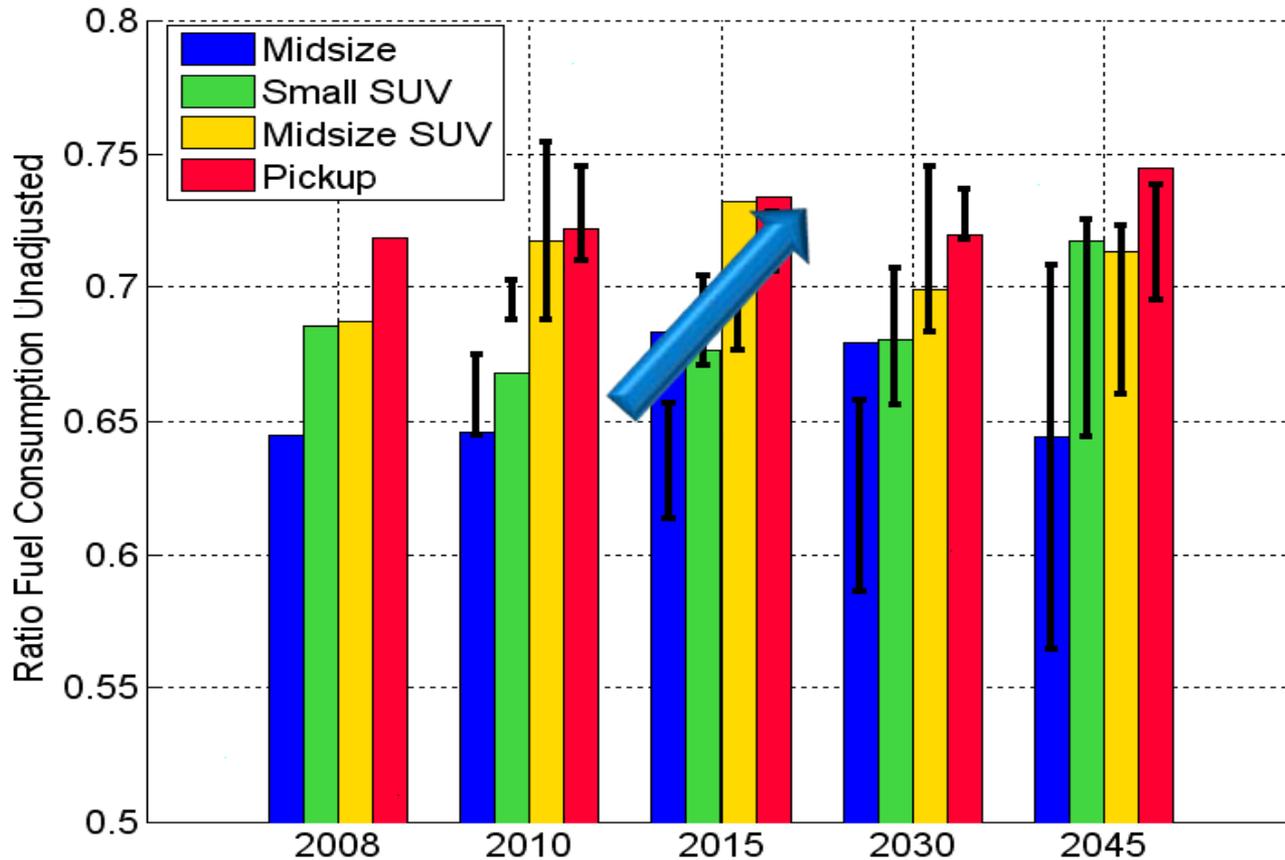
FC-HEVs Fuel Consumption Compared to ICE-HEVs Shows Largest Uncertainties



Input Split Configuration Used

GPRA/PDS 2008 Results

Hybridization Benefits Based on Ratio Reduced with Larger Vehicle Class



$$\text{Ratio} = \frac{\text{SI HEV}}{\text{Conv SI}}$$

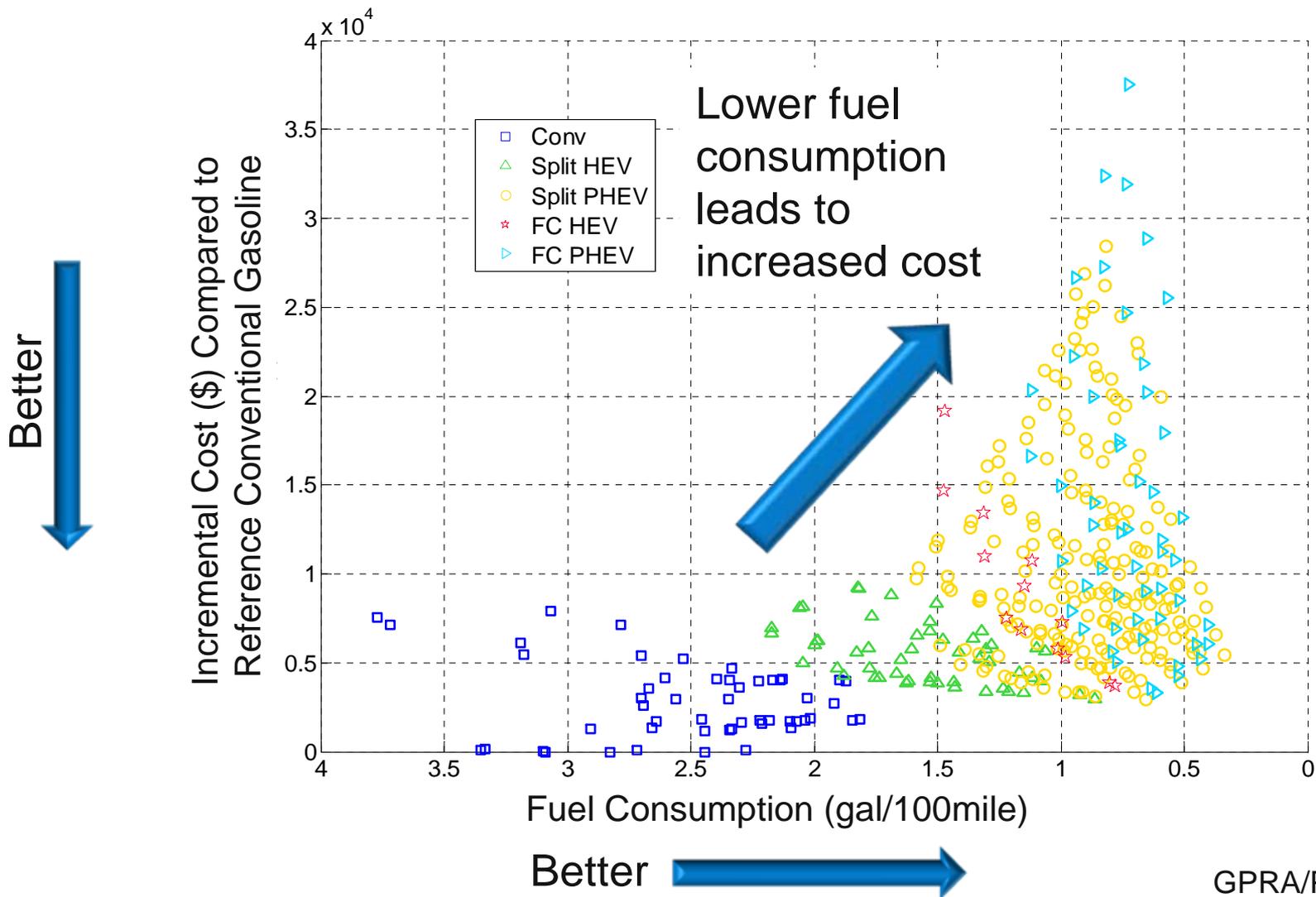
Variable
Vehicle Class

Input Split Configuration Used

GPRA/PDS 2008 Results

Trade-off Between Cost & Fuel Efficiency

All Vehicles

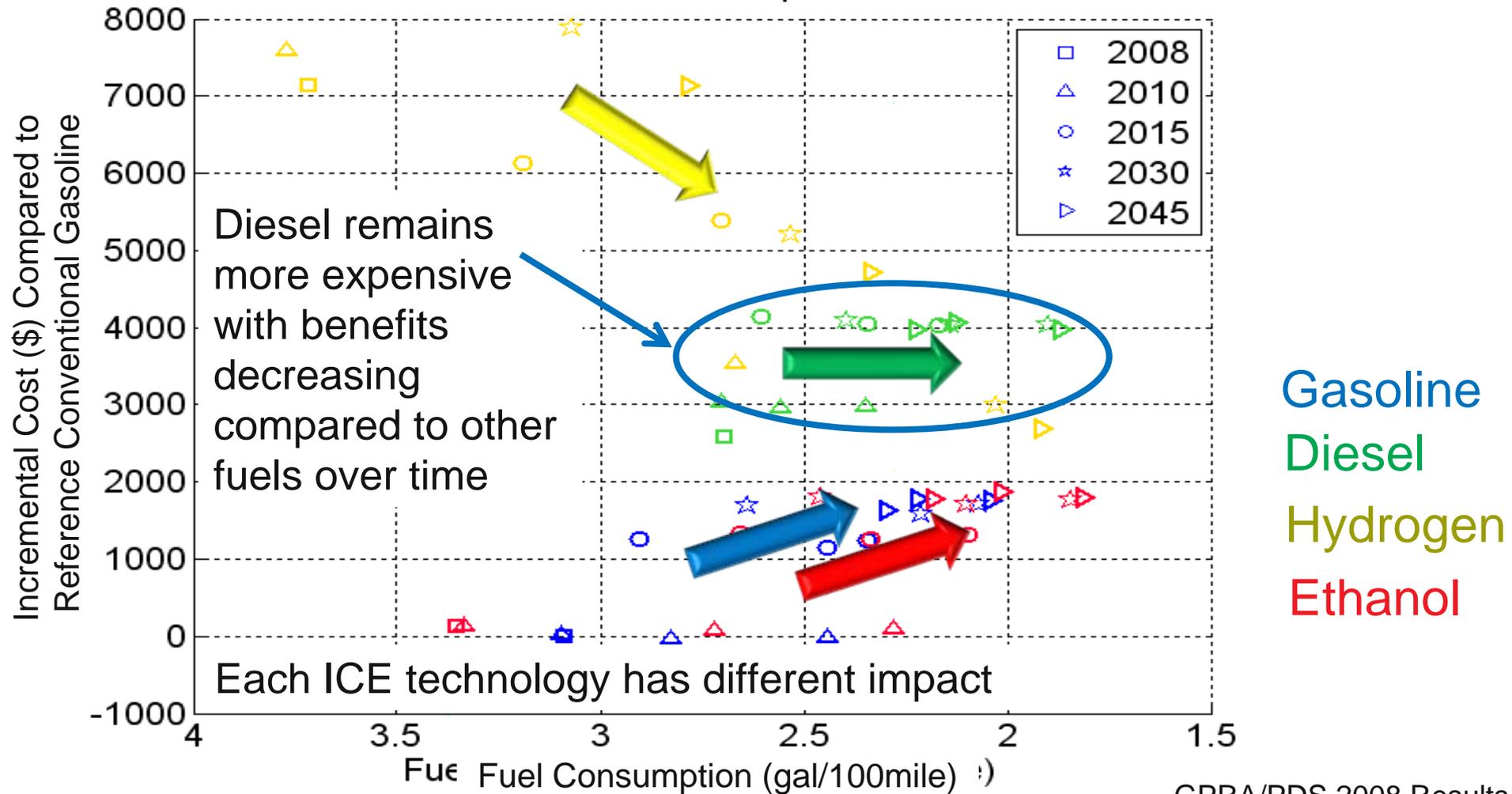


GPRA/PDS 2008 Results

Trade-off Between Cost & Fuel Efficiency

Conventional Vehicles

Incremental Cost vs fuel consumption for Midsize Conv

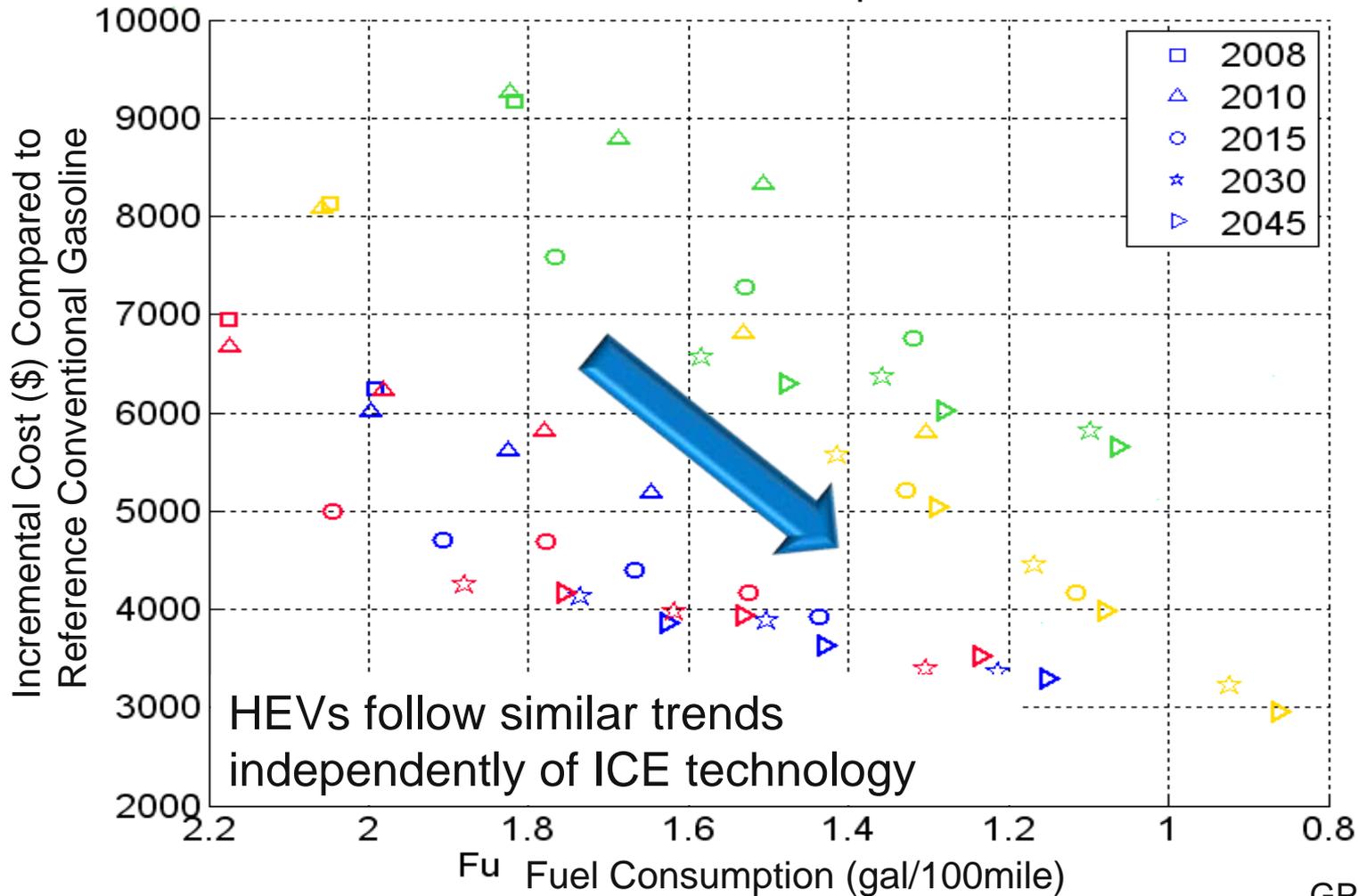


GPRA/PDS 2008 Results

Trade-off Between Cost & Fuel Efficiency

ICE-HEV Vehicles

Incremental Cost vs fuel consumption for Midsize HEV



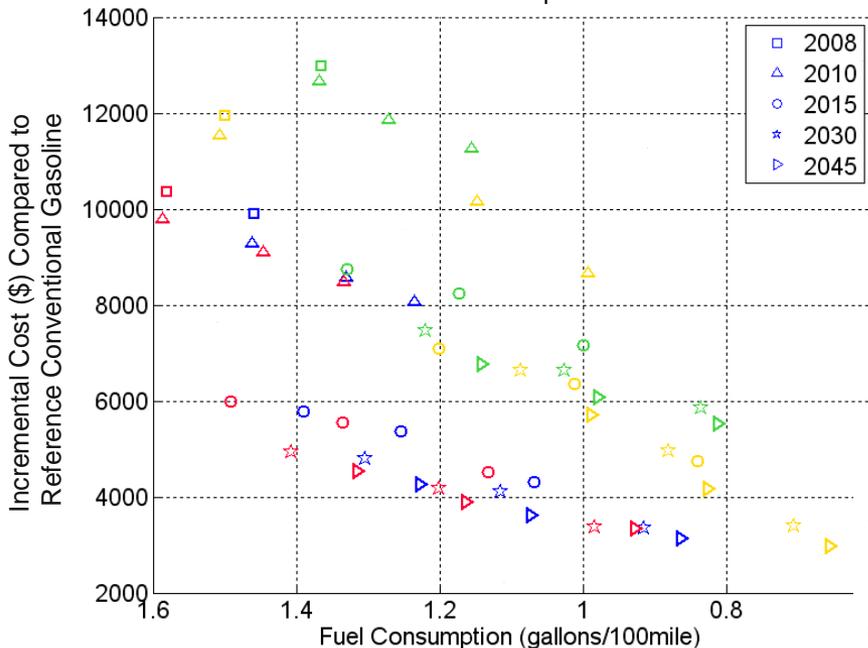
Gasoline
Diesel
Hydrogen
Ethanol

GPRA/PDS 2008 Results

Trade-off Between Cost & Fuel Efficiency

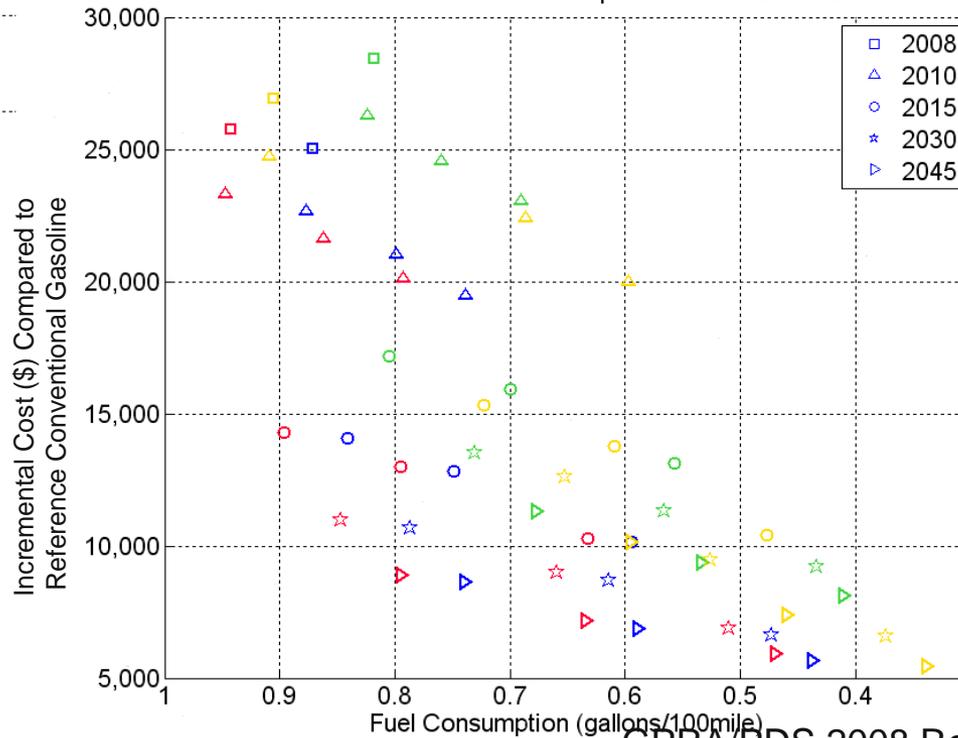
ICE-PHEV Vehicles

Incremental Cost vs fuel consumption for Midsize PHEV10



Higher efficiency ICEs offer less benefits than for HEVs and Conventional

Incremental Cost vs fuel consumption for Midsize PHEV40



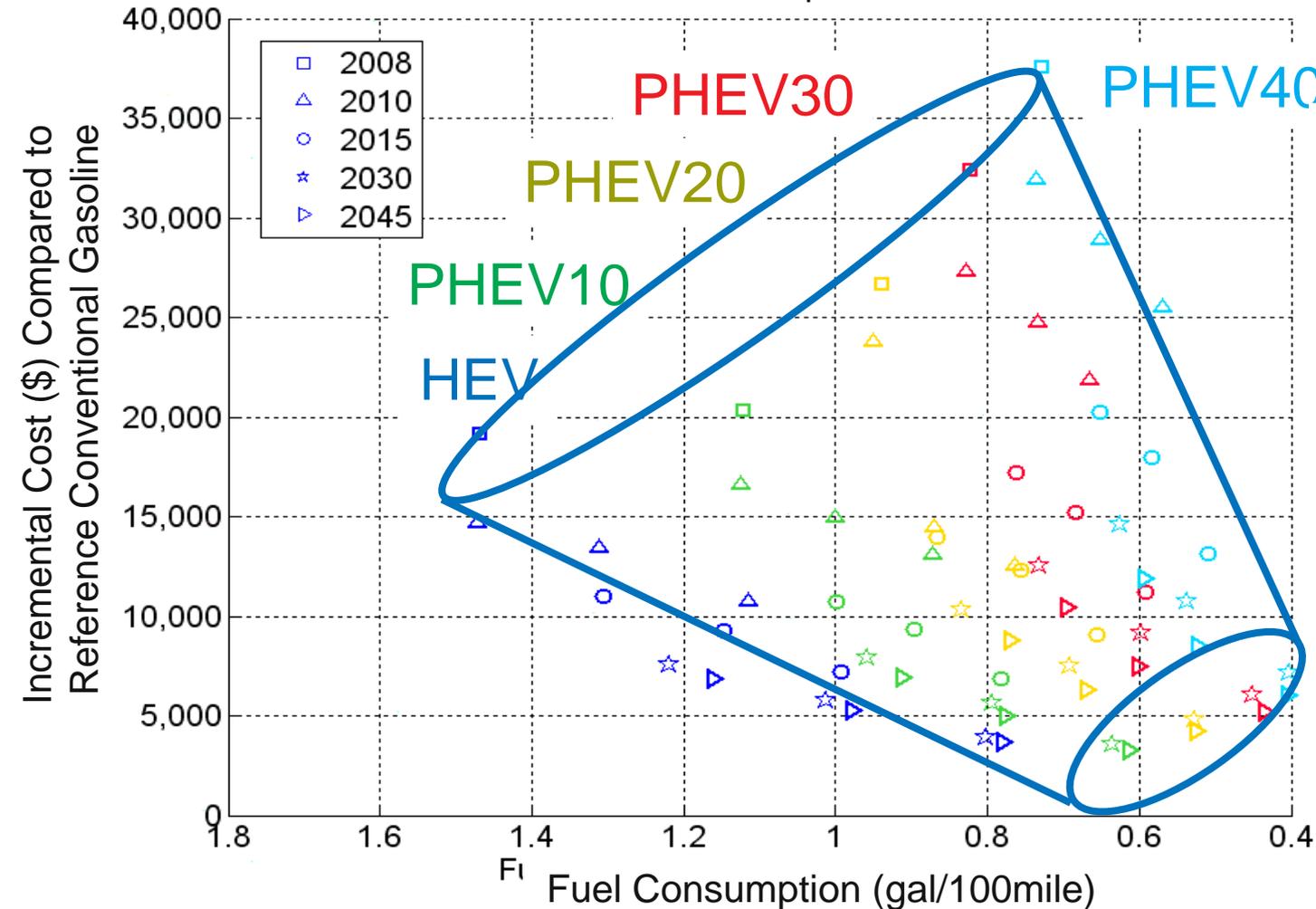
Gasoline
Diesel
Hydrogen
Ethanol

GPRA/PDS 2008 Results

Trade-off Between Cost & Fuel Efficiency

FC-HEV Vehicles

Incremental Cost vs fuel consumption for Midsize Fuel Cell



Based on the test procedure used, advanced powertrain do not benefit as much of high battery energy as current technologies

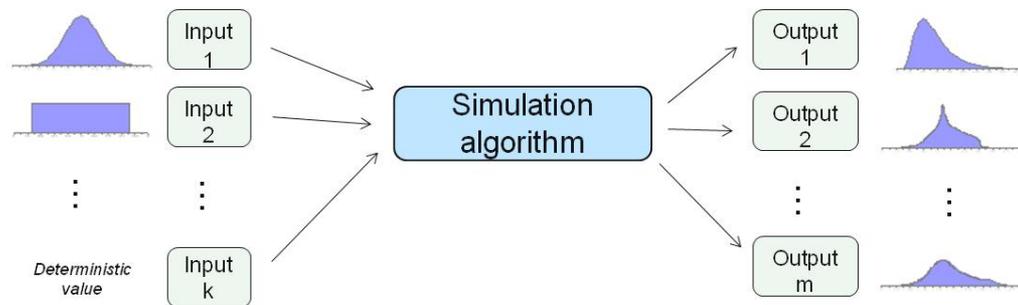
GPRA/PDS 2008 Results

In Addition to GPRA/PDS, the Results Are Used to Support Other Studies

- Component requirement uncertainties
- Fuel efficiency improvement of different
 - Fuels
 - Configurations
- Cost benefit analysis of each technology
- Provide inputs to
 - GREET (i.e., PHEV effort funded by Fred Joseck)
 - HyTrans Model
 - ...

MonteCarlo Analysis Implemented and Evaluated on a Single Vehicle

- Uncertainty is modeled by a probability density function (pdf)
- How is the uncertainty propagated?



- PHEV 10 miles All Electric Range (AER) midsize used as reference case





Future Activities

GPRA/PDS Studies Will Require Increased Complexity



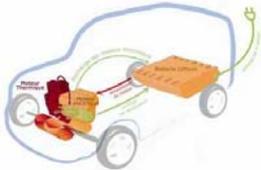
New Vehicle Classes



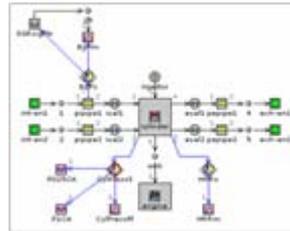
New Fuels



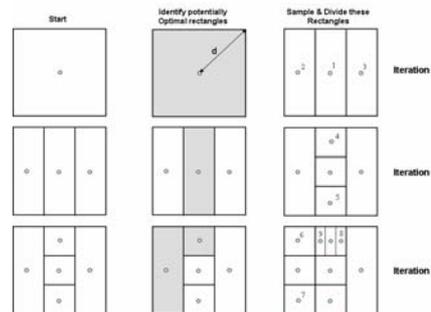
New Powertrain Configurations



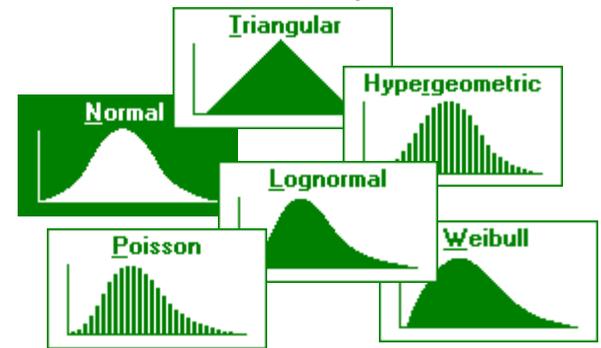
Detailed models required to represent future technologies



Use of optimization tool for component sizing and control strategy tuning



Monte-Carlo Risk Analysis



New Vehicle Test Procedures



$$\text{City FE} = 0.905 \times \frac{1}{\text{Start FC} + \text{Running FC}}, \text{ where}$$

$$\text{StartFC (gallons per mile)} = 0.33 \times \left(\frac{(0.76 \times \text{StartFuel}_{25}) + (0.24 \times \text{StartFuel}_{20})}{4.1} \right)$$

Summary

- GPRA/PDS study evaluates the benefits of the entire FreedomCAR and Fuels partnership in terms of petroleum displacement.
- The study assesses technology potential to guide future research and development by evaluating the benefits of the latest technologies both from a component and a control point of view.
- More than 600 vehicles were simulated for different timeframes (up to 2045), powertrain configurations, and component technologies.
- Both their fuel economy and cost were assessed to estimate the potential of each technology. Each vehicle was associated with a triangular uncertainty.
- The results of the study are used to support numerous studies within DOE.



References

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- A. Elgowainy & Co, “Well-To-Wheels Energy Use and Greenhouse Gas Emissions of Plug-in Hybrid Electric Vehicles”, SAE 2009-01-1309, World Congress, April 2009
- A. Rousseau, “ Evolution of Hydrogen Fueled Vehicles Compared to Conventional Vehicles from 2010 to 2045”, SAE 2009-01-1008, World Congress, April 2009
- A. Delorme, A. Rousseau, S. Pagerit, “ Fuel Economy Potential of Advanced Configurations from 2010 to 2045 “, IFP HEV Conference, Paris, Nov 2008