Fuel Consumption and Cost Benefits of DOE Vehicle Technologies Program

2012 DOE Hydrogen Program and Vehicle Technologies Annual Merit Review

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Sponsored by David Anderson

Project ID # VSS077

U.S. Department of Energy

Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Project Overview

Timeline

- Start: September 2011.
- End: September 2012.
- Status: 50% complete.

Barriers

- Evaluate the benefits of DOE VTP activities.
- Provide guidance on future funding decisions.
- Assess dozens of technologies on approximately 2000 vehicles.

Budget

- FY12
  - $390K (Vehicle System)
  - $50K (Fuel Cell Specific runs)
  - $75K (link with market analysis)

Partners

- All tech-teams.
- All national laboratories.
- Inputs from industry and academia.

Relevance

One of the main objective of the Vehicle and Systems Simulation and Testing (VSST) is to *"collect and analyze advanced vehicle characteristics that are used to predict market potential and petroleum displacement, which then inform program-wide research"*(1)

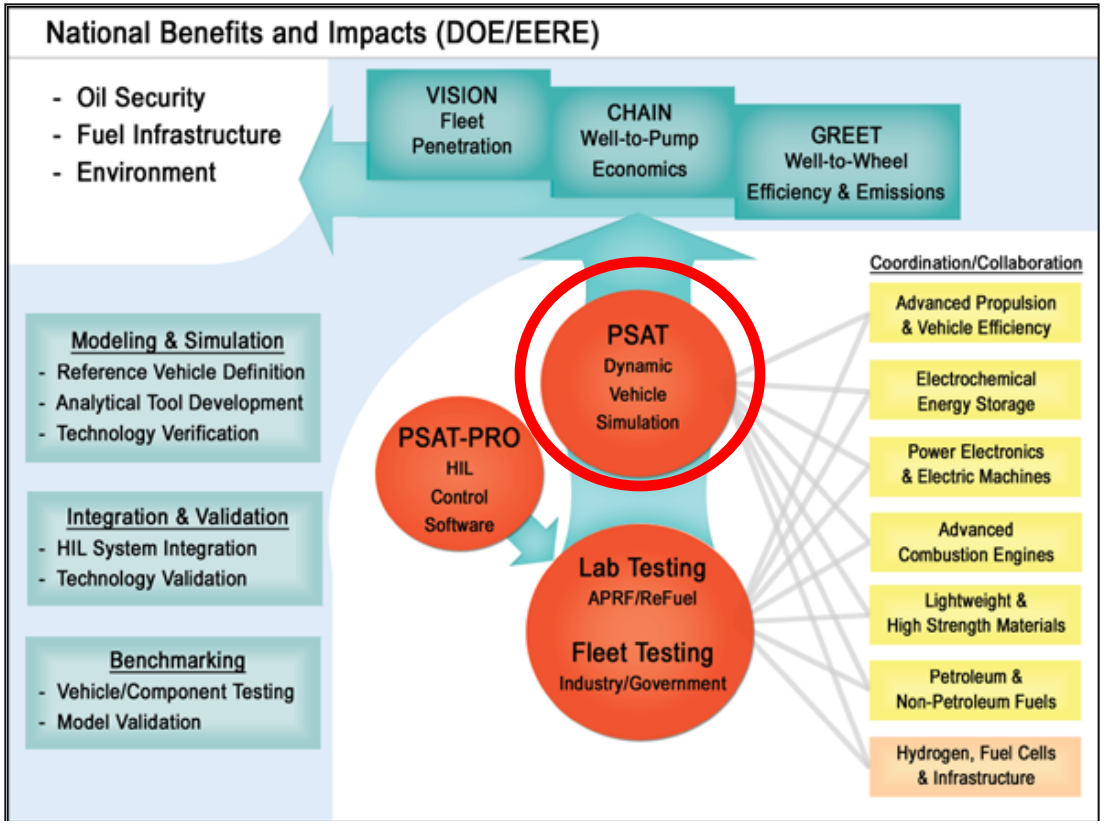


Figure 3.2 from the Vehicle Technologies Program Plan 2011 – 2015 , section on portfolio management .

(1) – page 2.2-1 from the Vehicle Technologies Program Plan 2011 – 2015, http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/vt_mypp_2011-2015.pdf

Relevance – What is the Fuel Displacement Potential of the Vehicle Technologies Program?

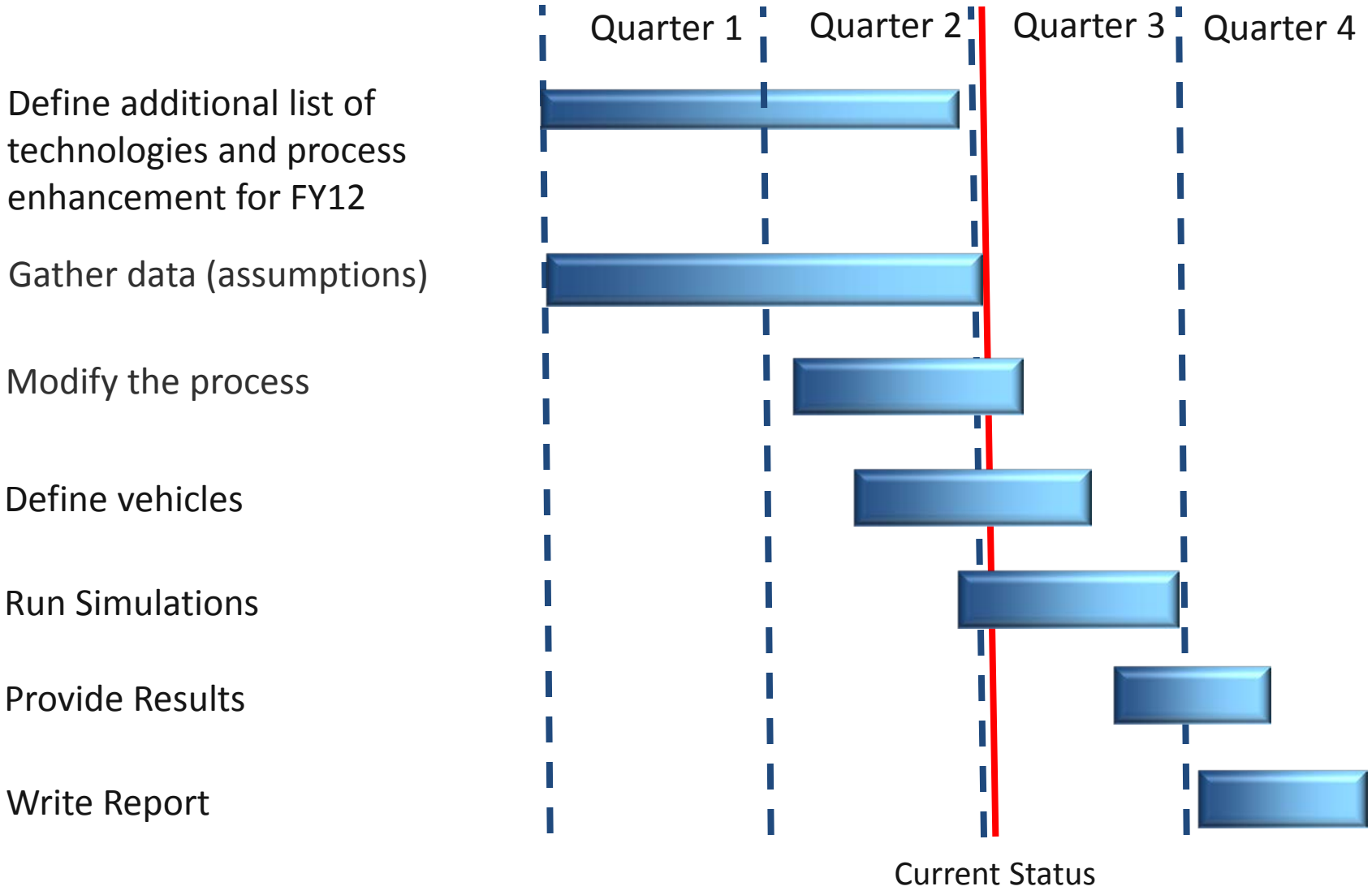
Use of current technology to determine baseline technology

Additional Improvements

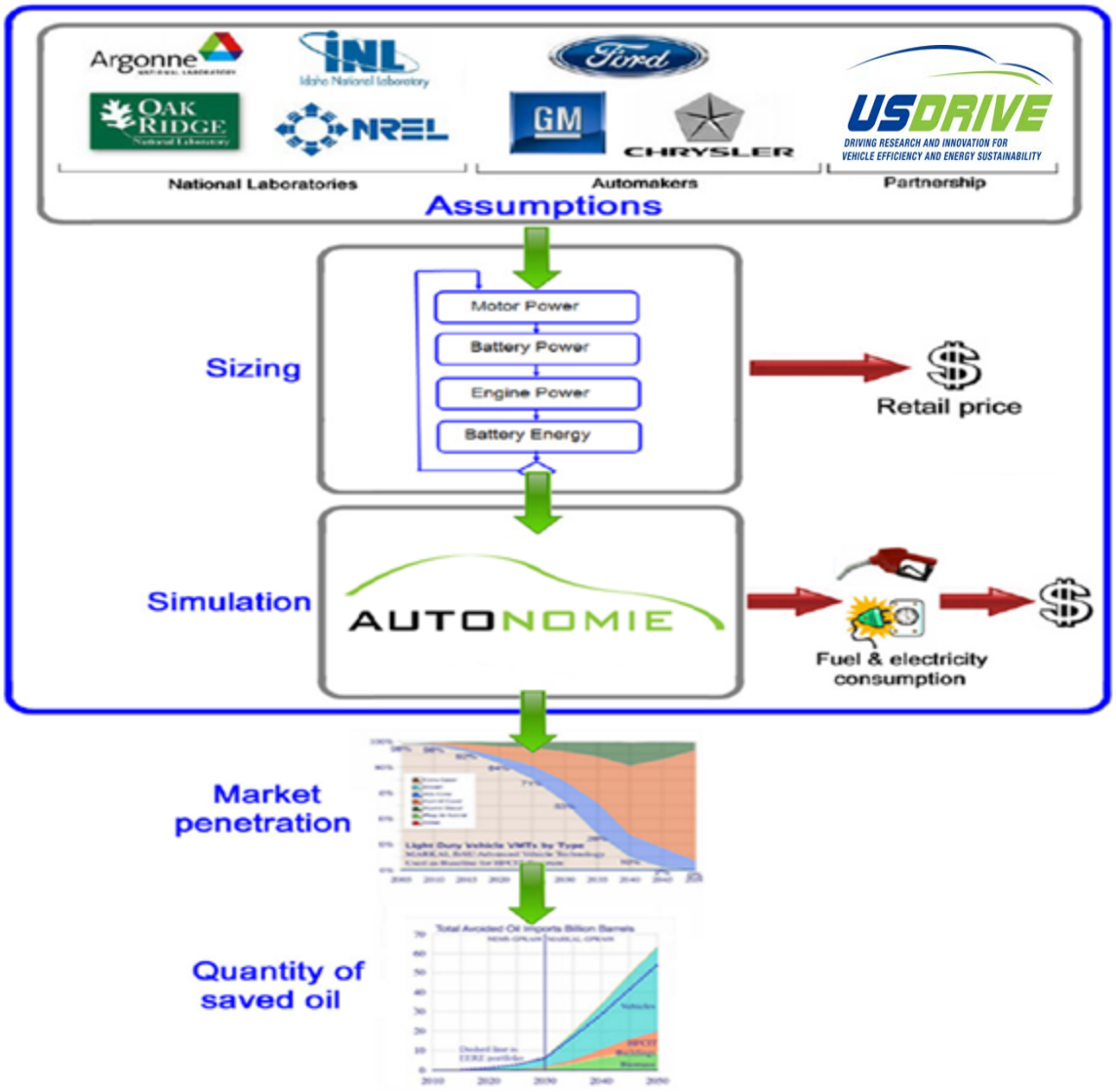
- Evaluate the benefits of DOE vehicle technologies program in terms of petroleum displacement through 2045.
- Provide guidance on future research priorities by evaluating the potential of technologies to accelerate petroleum displacement.
- Provide vehicle consumption inputs to DOE's market penetration software (MA3T) and vehicle lifecycle cost analysis tool.

The Government Performance Results Act (GPRA) process is mandated by the U.S. Congress

Milestones


Quarter 1
Quarter 2
Quarter 3
Quarter 4
Define additional list of technologies and process enhancement for FY12
Gather data (assumptions)
Modify the process
Define vehicles
Run Simulations
Provide Results
Write Report
Current Status

Approach – Overall GPRA process



Very Large Number of Technologies Considered

Vehicle Classes





⊗

Timeframes

Current

2015

2020

2030

2045

⊗

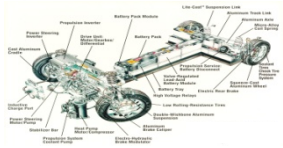
Powertrain Configurations

Conventional 


ICE HEV

PHEV 


Fuel Cell

Electric 

> 2000 Vehicles

⊗

Fuels

Gasoline 

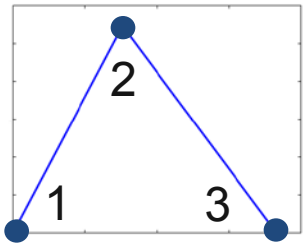

Diesel

Ethanol 

H_2

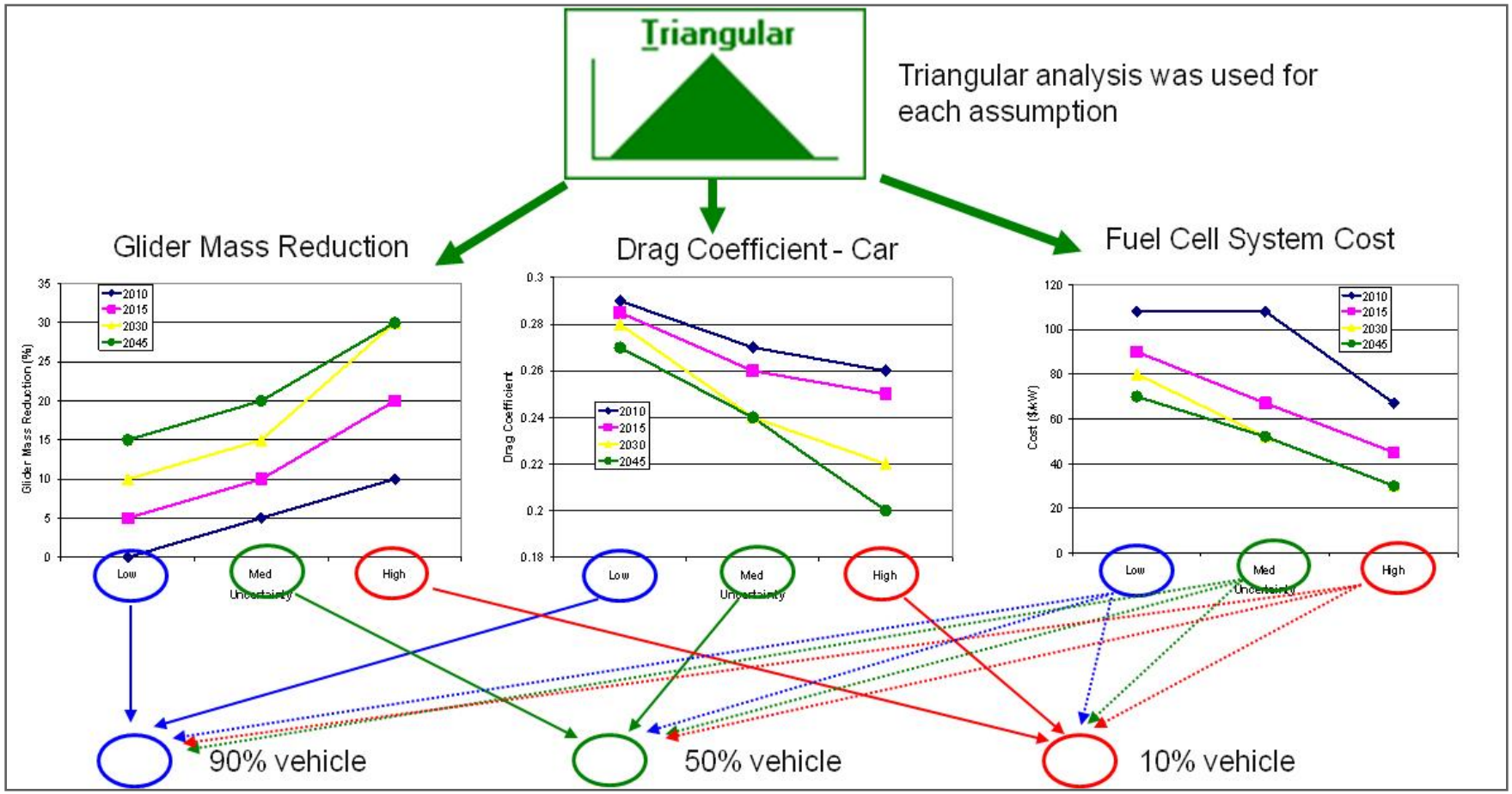
⊗

Triangular Uncertainty



1 = 10%
2 = 50%
3 = 90%

Triangular Uncertainty Used to Model Risk Analysis of Each Technology and Cost Assumptions

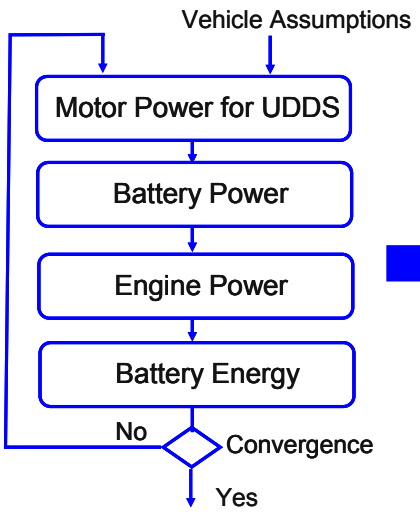


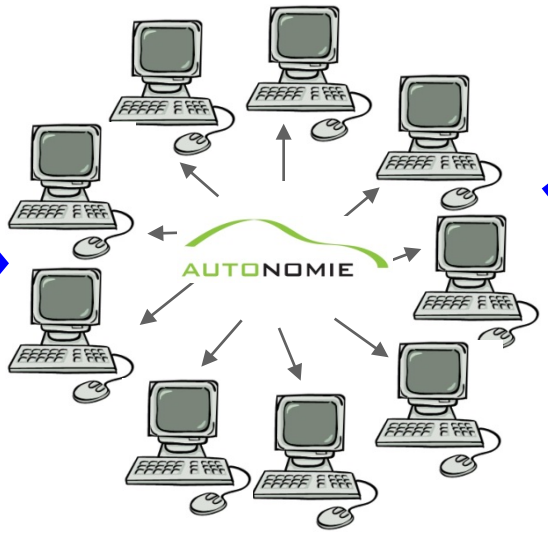
Automated Process Developed for Large Number of Vehicles and Uncertainty Scenarios

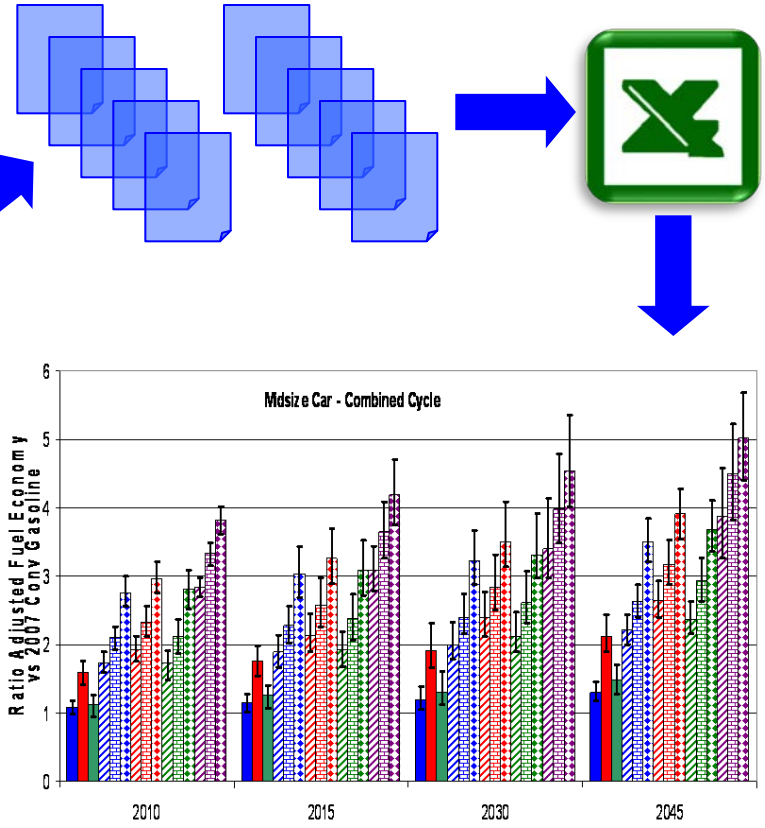
Vehicles Automatically Sized

Distributed Computing

Automated Post-processing





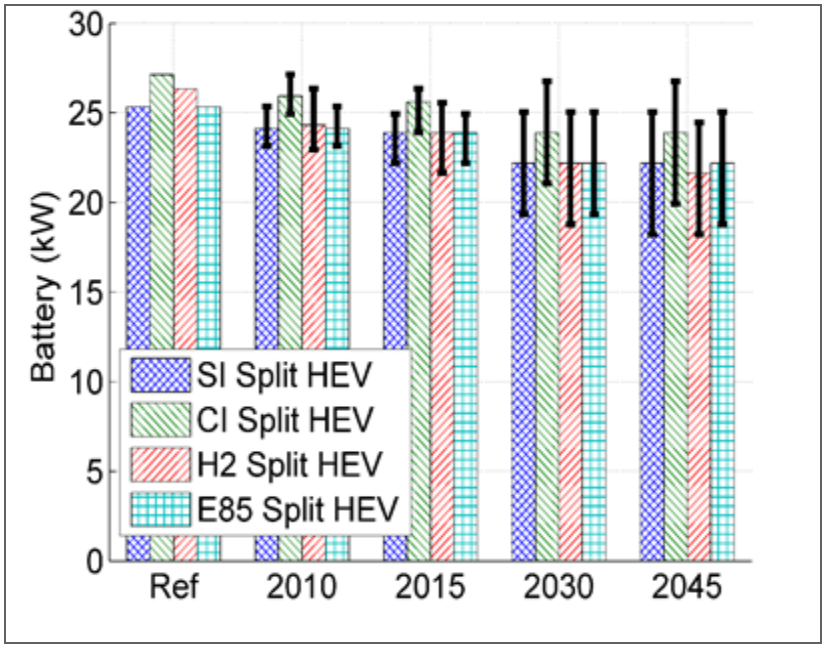


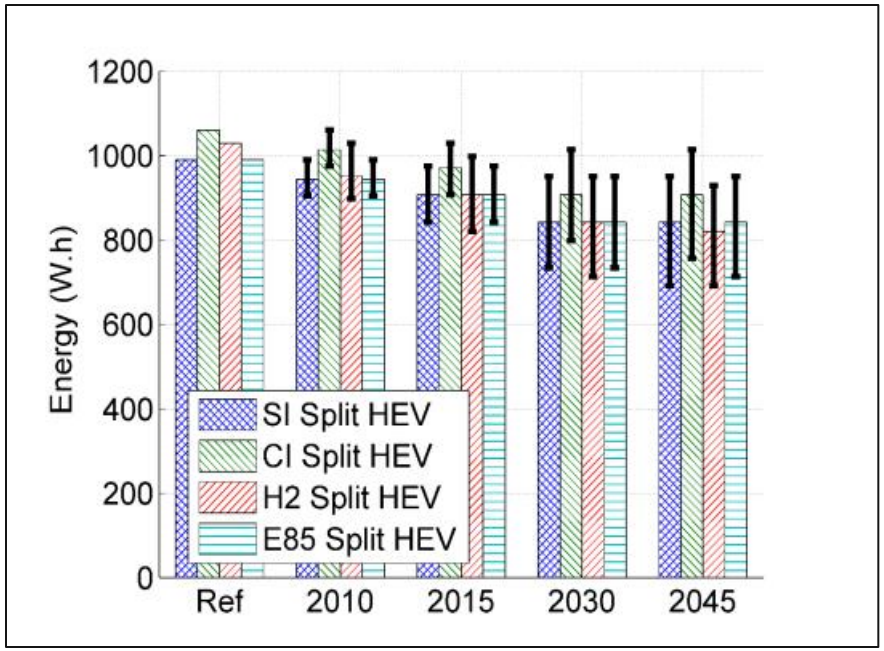
Technical Accomplishments
Latest Enhancement to the GPRA Process

- New state-of-the-art component data
  - Engine maps for current and future technologies updated based on USDRIVE inputs, including CNG (new fuel).
  - Electric machine…
- Battery electric vehicles (BEV) with gear ratio (2 speed transmission) and two EV ranges – 100 mi and 300 mi on the UDDS.
- HEV and PHEV sizing algorithms modified –> engine sized to meet 70% of peak power requirement (i.e., IVM – 60 mph in 9 sec).
- Fully integrated the component and vehicle cost models into Autonomie®
- Matlab® script to directly feed fuel consumption and cost outputs to MA3T and DOE economic analysis.

Technical Accomplishments
Evaluation of Component Requirements Over Time

HEV battery power and energy requirements decrease over time.





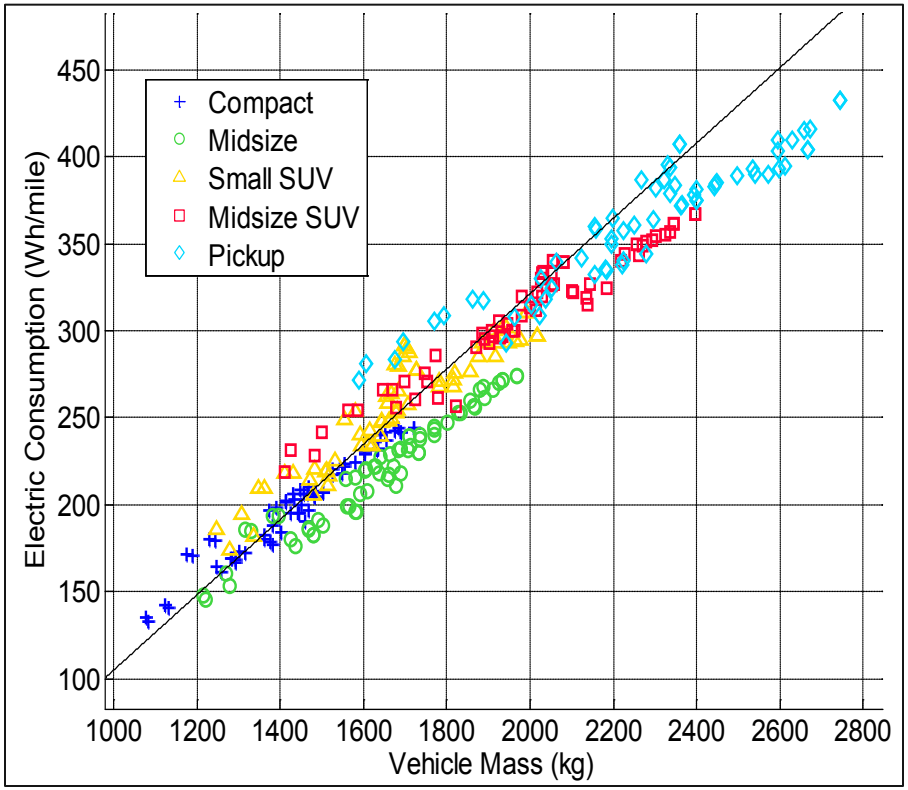
One of the main objective of VSST is to evaluate "*performance targets for vehicle platforms and their components*" (1)

(1) – page 2.2-1 from the Vehicle Technologies Program Plan 2011 – 2015,

Technical Accomplishments

Success of All Component Technologies is Critical

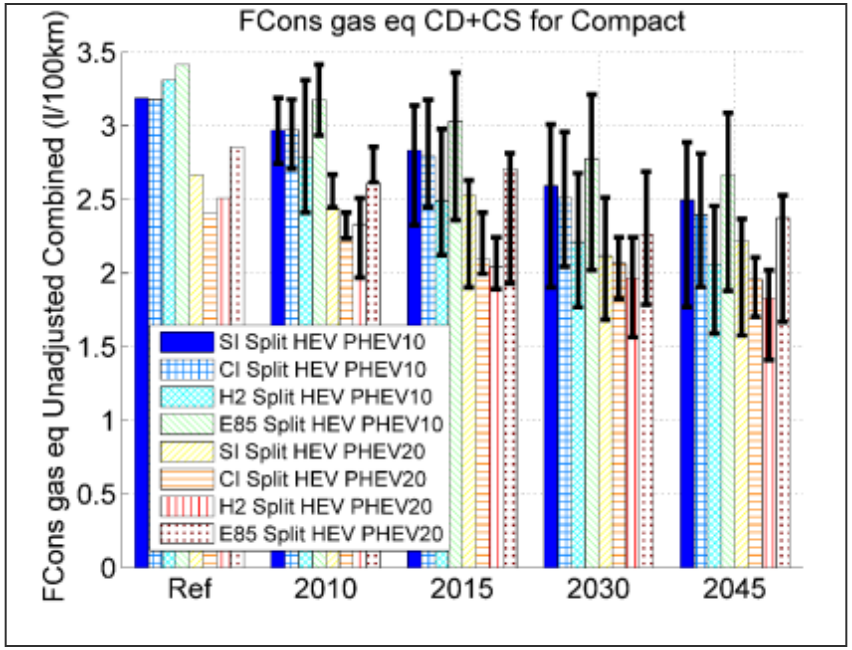
The linear relationship between vehicle weight and electrical consumption highlights the benefit of lightweighting relative to battery size and cost

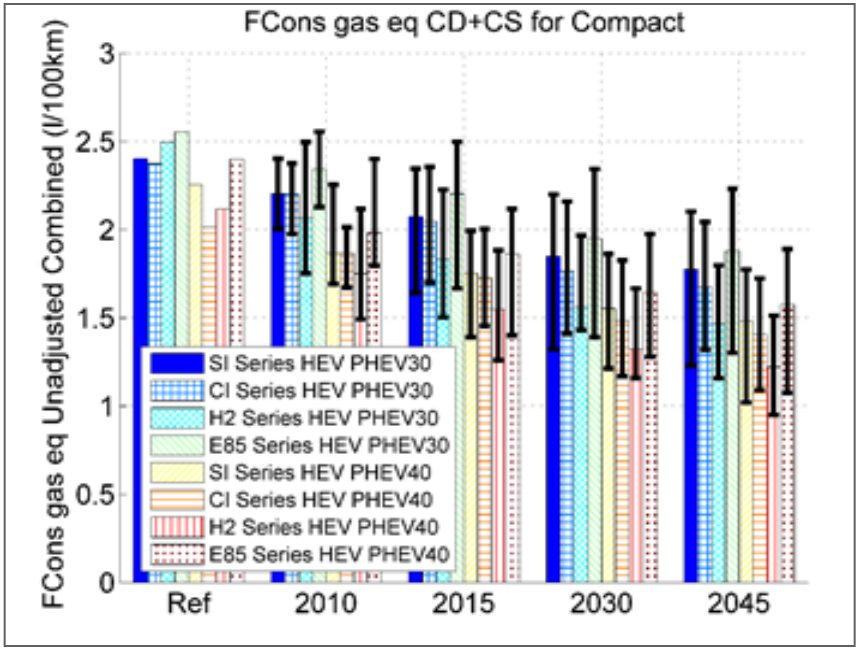


=> 25 Wh/mi reduction in electrical consumption for every 100 kg decrease in vehicle mass.

Technical Accomplishments

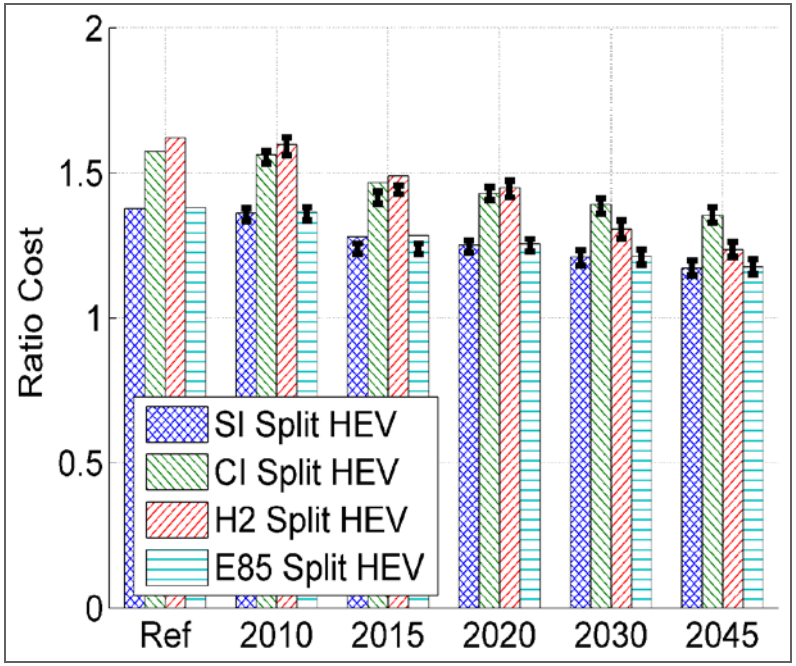
Evolution of fuel displacement across different powertrain technologies

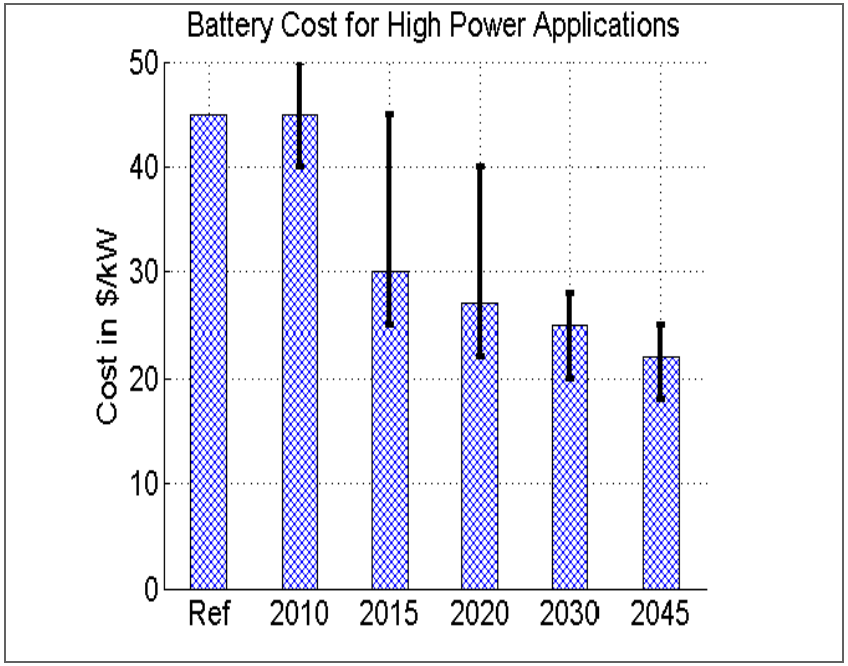




DOE VTP Program diverse portfolio will increase fuel displacement across all powertrain configurations

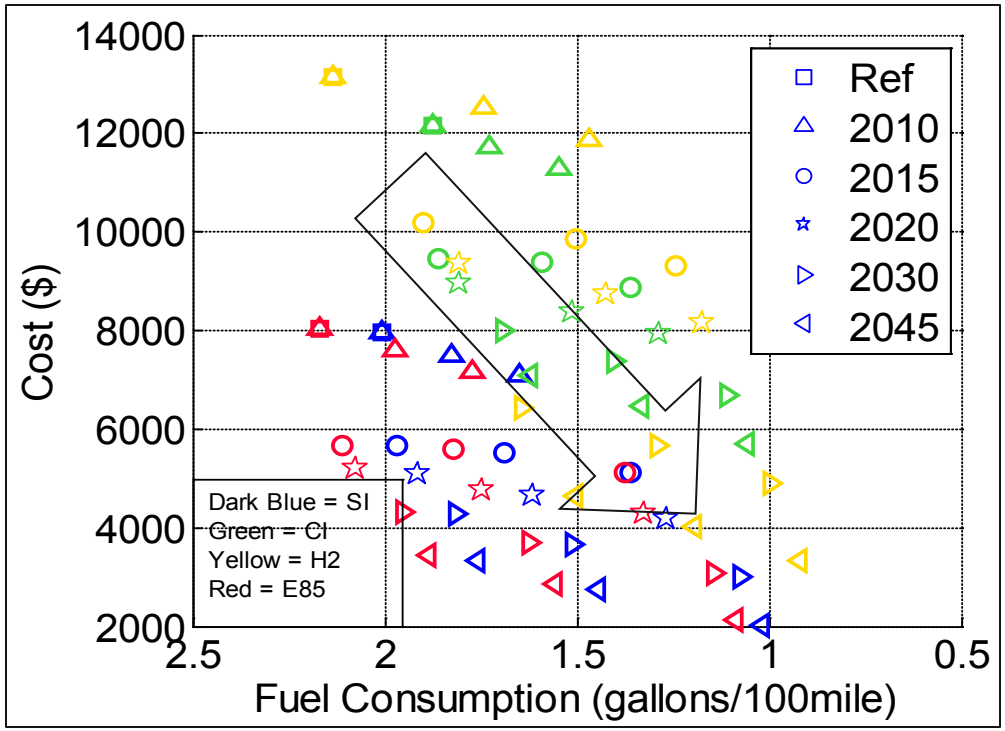
Manufacturing Cost Difference Between HEVs and Conventional Vehicles Will Significantly Decrease





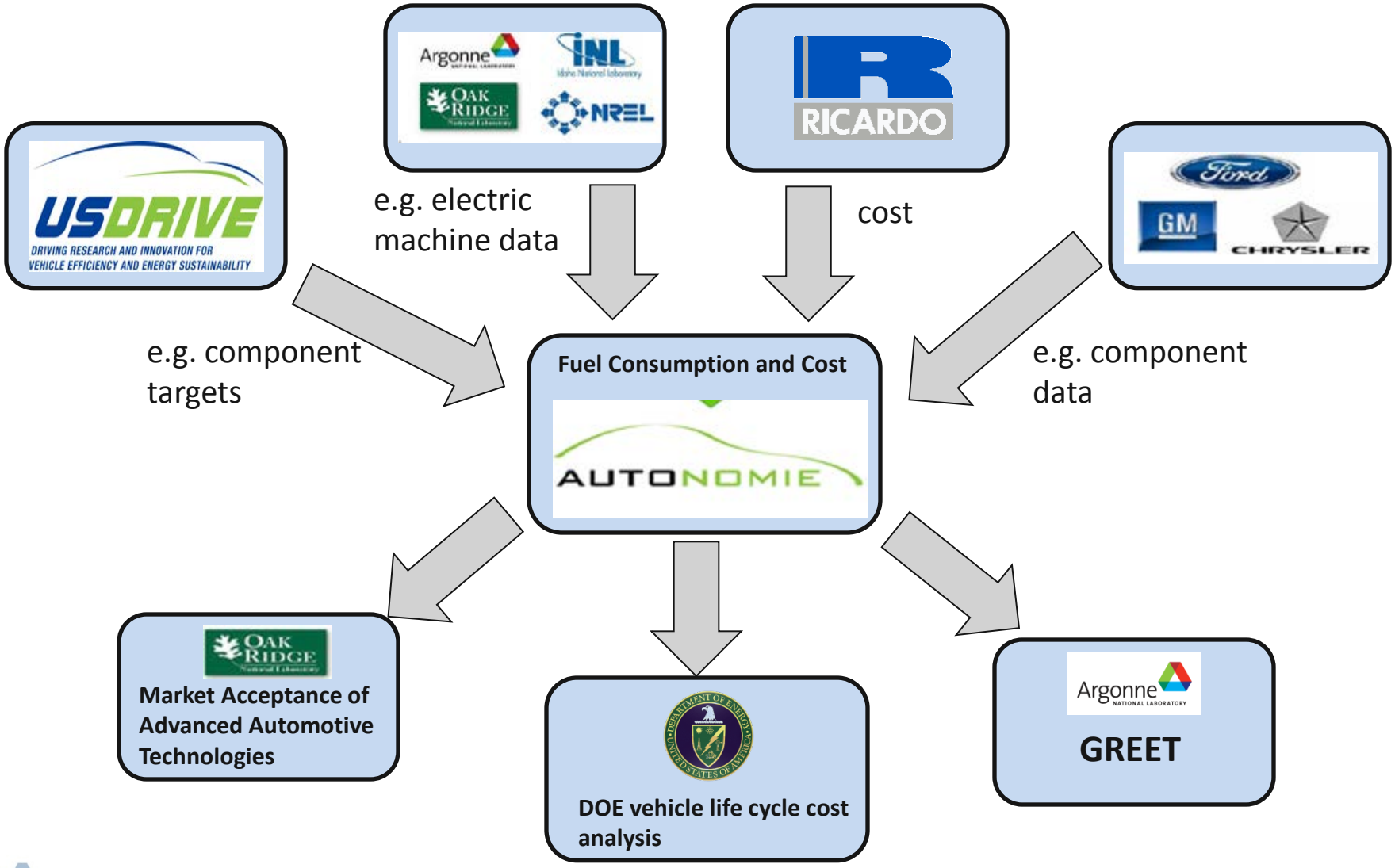
- HEVs continue to be more expensive to manufacture than conventional vehicles.
- Manufacturing cost difference between the HEVs and conventional vehicles decreases with time.
- Manufacturing costs associated with batteries and electric machines fall faster than those of conventional technologies (i.e., engine, transmission…).

For all HEVs, Incremental Cost Decreases over Time, Independent of Engine Technology



- Hydrogen HEVs show the largest drop in incremental cost over time, as well as the largest reduction in fuel consumption. This is because of significant improvements in Hydrogen engine efficiency and hydrogen storage over time.
- Gasoline and E85 HEVs offer the lowest absolute cost over time.

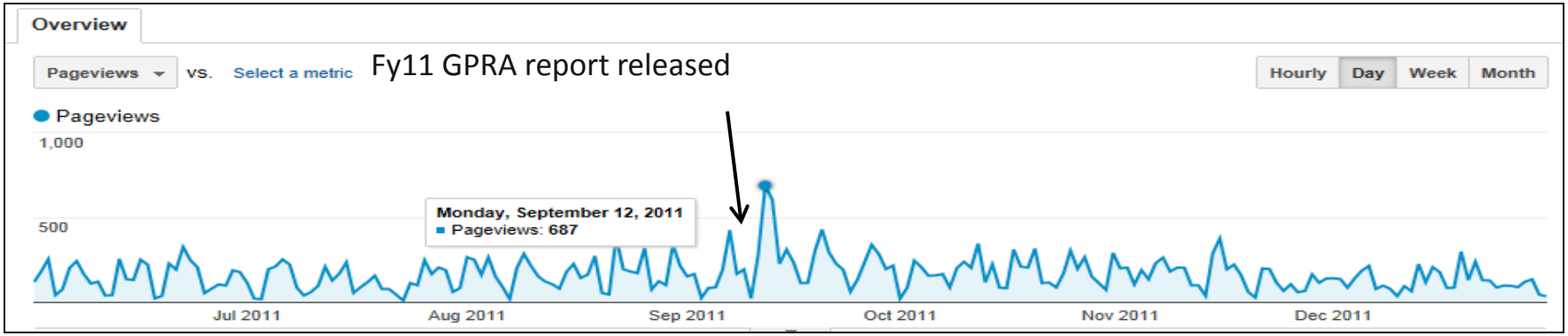
Collaboration and Coordination with Other Institutions



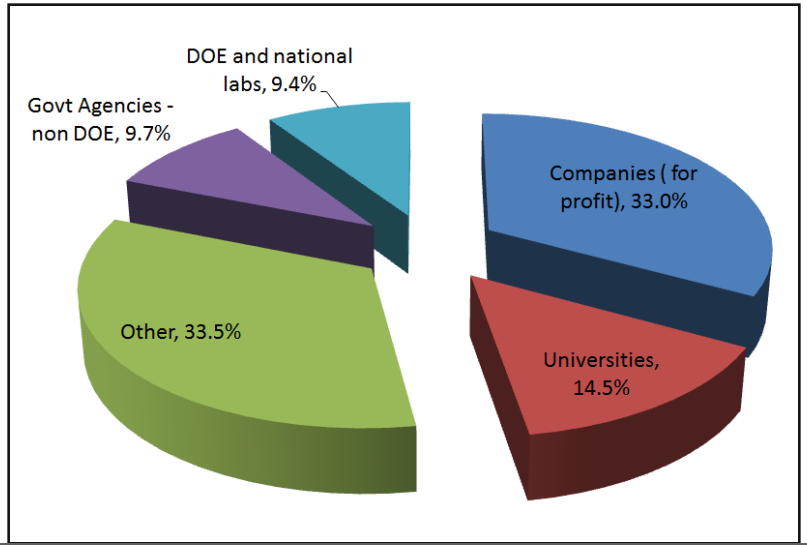
GPRA 2011 Report is Being Widely Accessed by Industry and Academia.

http://www.autonomie.net/publications/fuel_economy_report.html

~ 250 page report stating all assumptions, sizing rules, results and analysis plots



- Additional benefits:
  - Enhance understanding of technology trends by providing a macroscopic comparison of technologies.
  - GPRA process and vehicle library used by numerous other studies [1,2].



[1] N.Kim, et.al, 'Fuel Consumption Potential of Different Plug-in Hybrid Vehicle Architectures in the European and American Contexts', presented at EVS 26, LA, California.
[2] A.Moawad, et al,' Impact of vehicle performance on cost effective way to meet CAFE 2017-2025', VPPC 2011

Future Work

On going work for FY12

- Complete the implementation of new component technologies, fuels and vehicle control strategies
- Validate the new process, including vehicle sizing, linkage with MA3T, DOE vehicle life cycle cost analysis
- Run all the simulations for light duty vehicles
- Update the process for Medium and Heavy duty vehicles
- Run all the simulations for light duty vehicles

Future activities

- Continue to enrich study with additional technologies.
- Improve process using additional automation to shorten simulation time.
- Enhance results and reporting to provide easier access to information for different users.

Summary

- Study evaluates the benefits of entire USDrive program in terms of petroleum displacement.
- Study assesses technology potential to guide future research .
- More than 2000 vehicles simulated for different time frames.
- Both fuel economy and cost are assessed to estimate the potential of future technology.
- Each vehicle is associated with triangular uncertainty.
- Results of the study are used to support market penetration tool, DOE vehicle lifecycle cost analysis and GREET.