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Analytical Modeling Linking FASTSim and ADOPT Software Tools



Aaron Brooker
National Renewable Energy Laboratory
May 16, 2013

Project ID #: VAN004

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Overview

Timeline

Project Start Date: May 2012
Project End Date: Sept. 2013
Percent Complete: 60%

Budget

DOE Project Funding: $300K

Funding Received in FY12: $150K

Funding for FY13: $150K

Barriers

- **Barriers addressed:** Many
  - Assess impact that DOE R&D has on DOE goals

Partners

- **Interactions/ collaborations**
  - GM[1]/Ford/Chrysler/EIA[2]/ORNL[3]
  - ANL[4]/SRA International

- **Project lead:** NREL

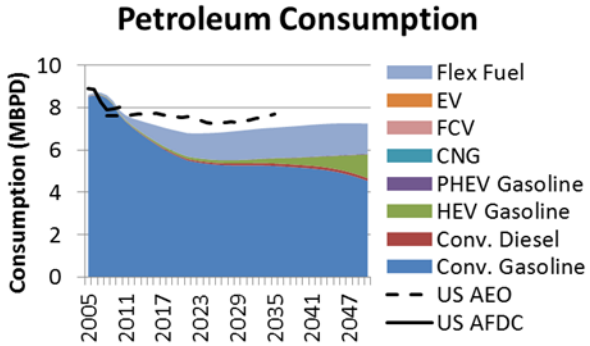
1. GM: General Motors
2. EIA: U.S. Energy Information Administration
3. ORNL: Oak Ridge National Laboratory
4. ANL: Argonne National Laboratory

Relevance/Objectives

Relevance

This project improves a tool that estimates the impact of vehicle technology improvements on U.S. light-duty petroleum use and GHGs[1]

Component Improvements



Objectives

- Reduce consumer choice model run time
- Improve the consumer choice validation with more recent sales data
- Link a powertrain model with the consumer choice model to optimize the powertrain for consumer choice
- Add diesel and CNG[2] to powertrain and consumer choice models
- Apply tool and compare cost effectiveness to consumer acceptance
- Improve model user friendliness and post online for others to leverage

1. GHGs: Greenhouse gases
2. CNG: Compressed Natural Gas

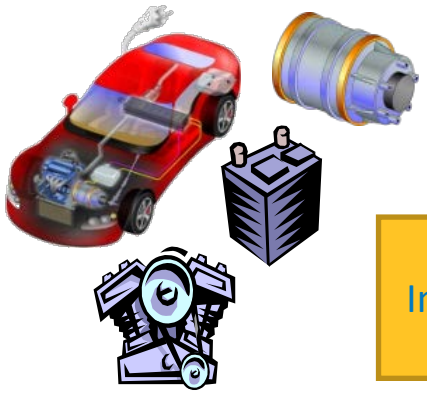
Milestones

Month/ Year	Milestone or Go/No-Go Decision	Description	Status
September 2012	Milestone	Preliminary Report: Analytical Modeling Linking the FASTSim and ADOPT Software Tools – Basic Framework Setup	Complete
March 2013	Milestone	Final Report: Analytical Modeling Linking the FASTSim and ADOPT Software Tools – Basic Framework Setup	Complete
September 2013	Milestone	Analytical Modeling Linking the FASTSim and ADOPT Software Tools – Usability and Feature Enhancements	On Schedule

Approach: Overview

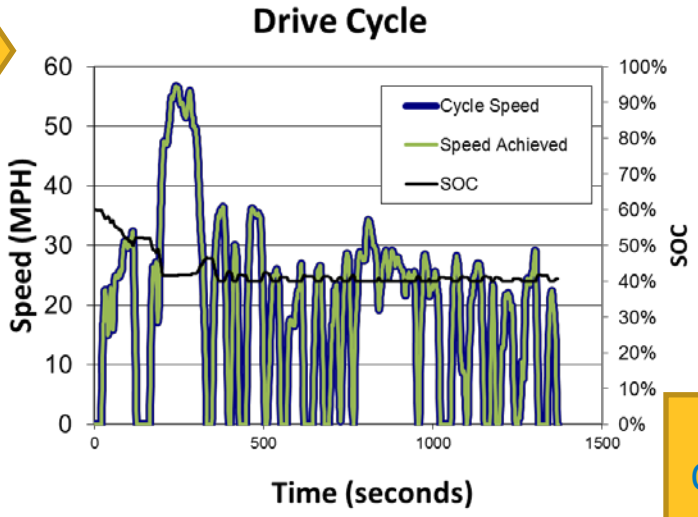
- **Feed component improvements into the vehicle model FASTSim to estimate:**
  - Efficiency
  - Acceleration
  - Cost
  - Battery life
- **Optimize component sizes for consumer preference by linking FASTSim to ADOPT**
  - Example: Reducing the engine size reduces cost, improves fuel economy, but slows acceleration times
- **Feed the optimized vehicle into ADOPT to estimate:**
  - Market share
  - U.S. fleet petroleum consumption
  - U.S. fleet GHG emissions

Approach: Vehicle Powertrain Modeling



Component Sizes and Vehicle Characteristics

Inputs



Simulated through a Drive Cycle

Outputs

Fuel Economy

Vehicle Price

Acceleration

Approach: Consumer Choice Modeling

Advanced Vehicle Characteristics

Photo by Keith Wipke, NREL 15986

Fuel Prices

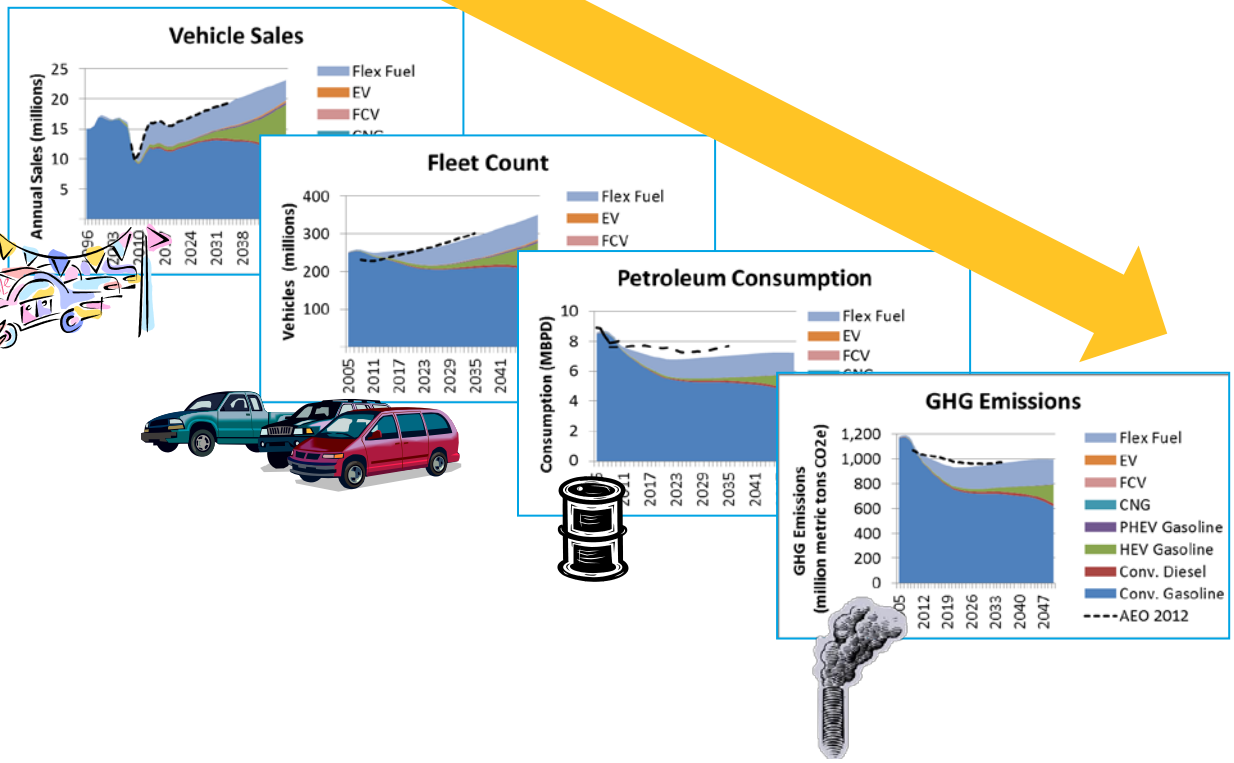
Income Distribution

Photo by Michael Penev, NREL 19206

Fueling Station Availability

Consumer Choice

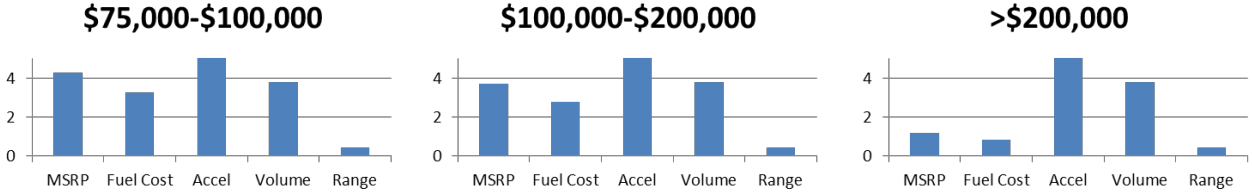
ADOPT



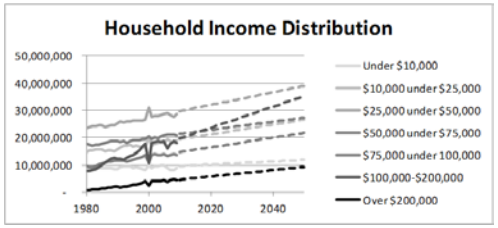
Approach: Unique Aspects that Provide Realism

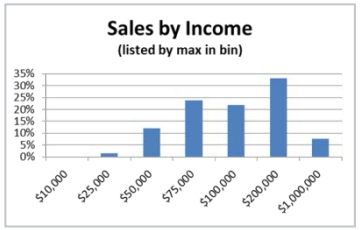
- **Consumer preferences change based on income**

  Relative importance by income bin

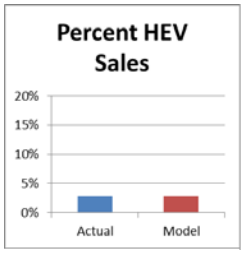


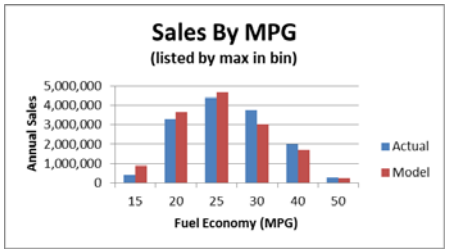
- **Income levels change over time, and number of sales vary by income**

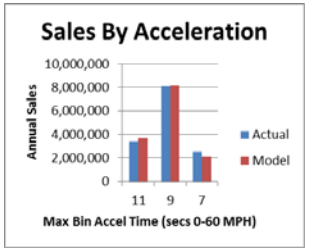




- **Extensively validated**
  - Multiple years
  - 10 different regions
  - 10 dimensions







- **Competes advanced vehicles with entire existing fleet**
- **Successful models are duplicated (more options for the consumer)**

Approach: Compare Consumer Preference to Cost-Effectiveness

Conduct a lightweighting cost-effectiveness study to compare to the consumer preference approach

- **Model several powertrains in FASTSim**
  - Conventional
  - Hybrid electric
  - Plug-in hybrid electric
  - Battery electric
- **Incrementally reduce the weight of the frame up to 150kg**
- **For each frame weight, downsize the engine and optimize the controls to:**
  - Reduce vehicle cost
  - Increase fuel economy
  - Maintain acceleration, gradability, and battery life
- **Account for key aspects**
  - Component mass scaling
  - Mass compounding (lighter components require less structural material)
  - Mass impacts on efficiency

Accomplishment: Improved ADOPT Runtime

Accomplishment

- **Reduced run time from four hours to one minute**
  - Replaced volatile functions that were causing entire sheet to recalculate
  - Reduced number of calculations
  - Turned off screen updating
  - Improved approach to duplicating successful models
  - Reduced the amount of data saved and loaded (file size reduced 25 megabytes to 8 megabytes)

Benefits

- **Improves:**
  - Usability
  - Robustness from more testing
  - Cost effectiveness of developing and using the tool

Accomplishment: Improved ADOPT Vehicle Database

Accomplishment

- **Expanded vehicle pool to include all existing light-duty options (more than 2,500, previously 273)**
  - Collected major powertrain aspects, including:
    - Fuel economy
    - Price
    - Range
    - Interior volume
    - Acceleration
    - More than 300 other aspects for future refinements
  - Includes all existing fuel types and powertrains
    - CNG
    - Diesel
    - Hybrid electric vehicles
    - Plug-in hybrid electric vehicles
    - Battery electric vehicles
  - Process automated to easily update in future years

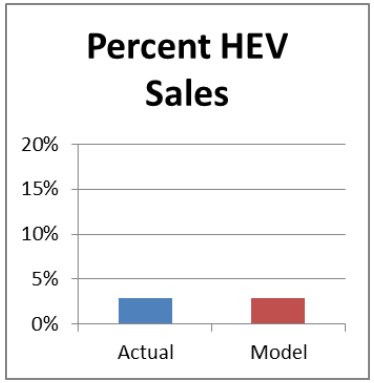
Benefit

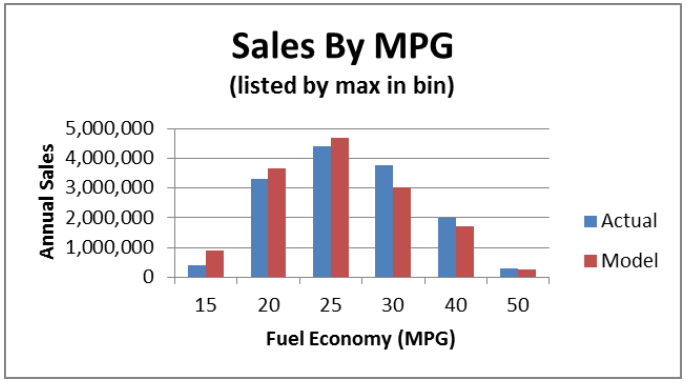
- **Improves realism when estimating sales of new advanced vehicles by competing them with all existing options**

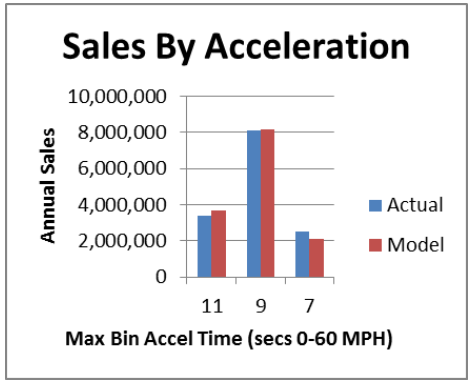
Accomplishment: Improved ADOPT Validation

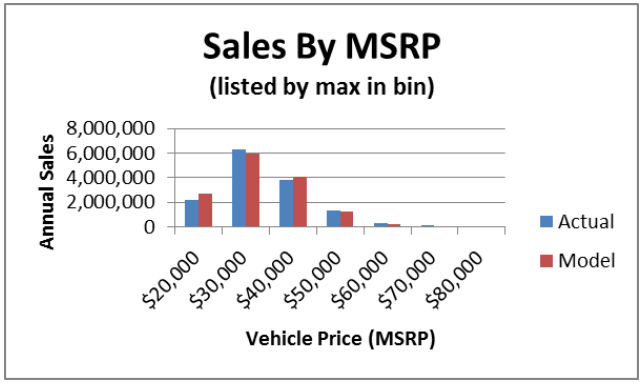
Accomplishment

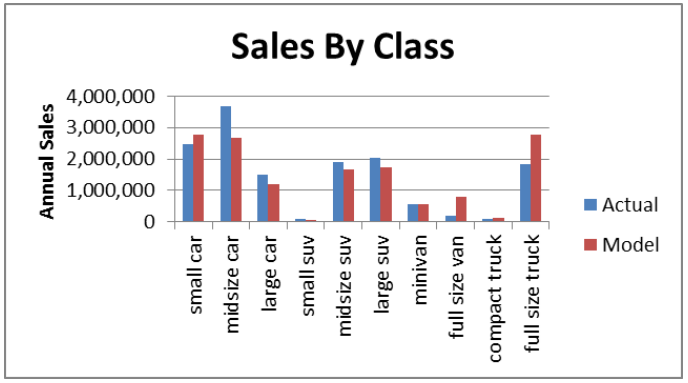
- Expanded validation with 2012 U.S. sales (previously only 2008 sales)











Benefit

- Improves confidence in petroleum projection results

Accomplishment: Improved ADOPT Projections

Accomplishment

- **Added the capability to evolve the vehicle fleet**
  - Linked powertrain model to consumer choice model (FASTSim – ADOPT)
  - Component sizes optimized based on the consumer choice model and market conditions
  - Example: Increasing fuel prices drive reductions in engine size to improve fuel economy

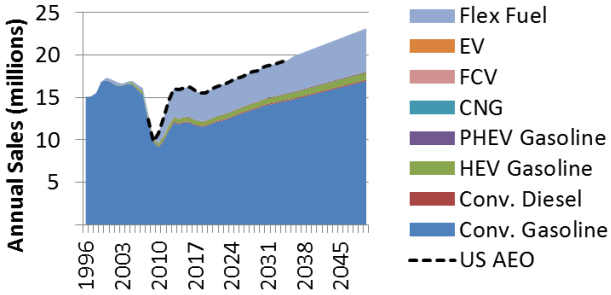
Benefit

- **Captures realism needed to project future vehicle sales**

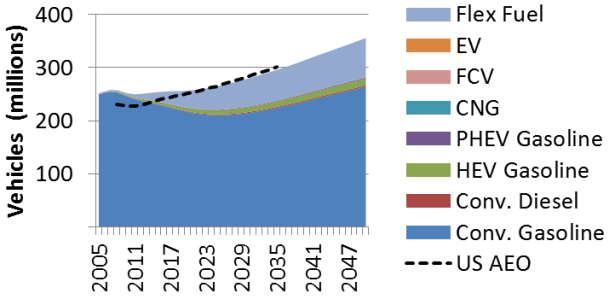
Accomplishment: Draft Results

Annual Energy Outlook 2013 Reference

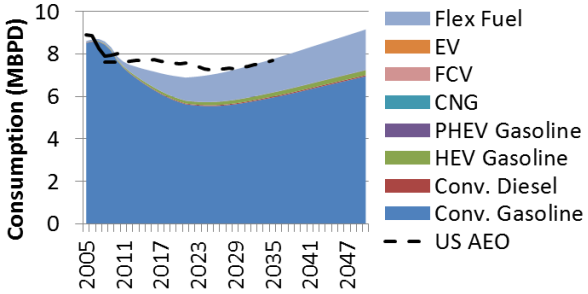
Vehicle Sales



Fleet Count



Petroleum Consumption

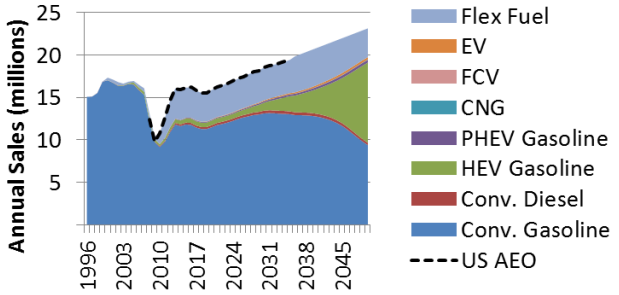


Draft Results

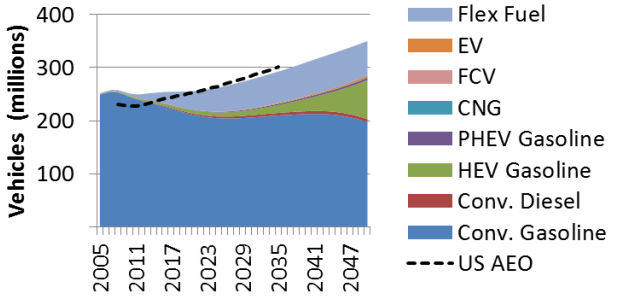
Assumes No Battery Cost Reductions

High Petroleum Price

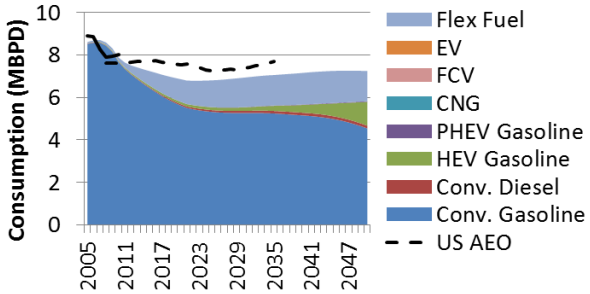
Vehicle Sales



Fleet Count



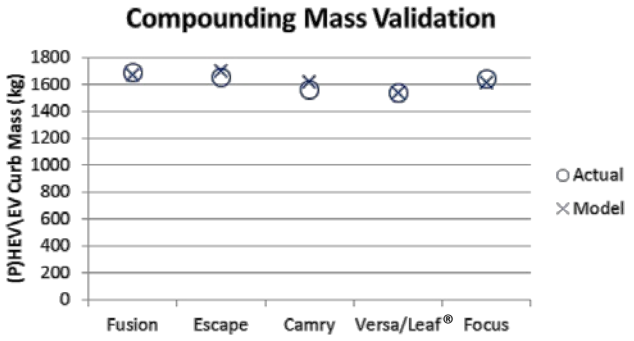
Petroleum Consumption

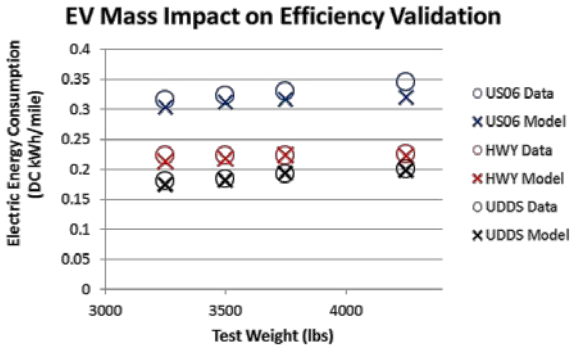


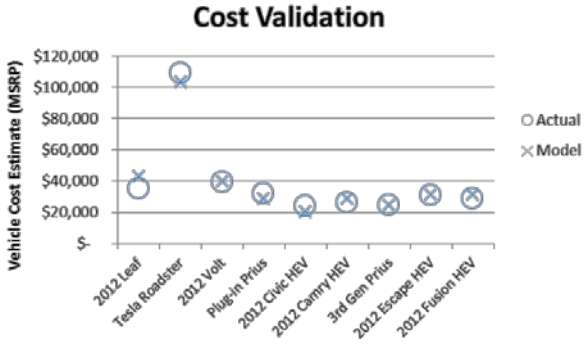
Accomplishment: Completed Lightweighting Cost Effectiveness Study to Compare to Consumer Preference

Accomplishment

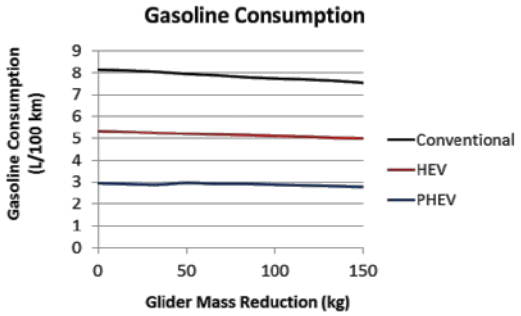
- Accurately modeled key aspects

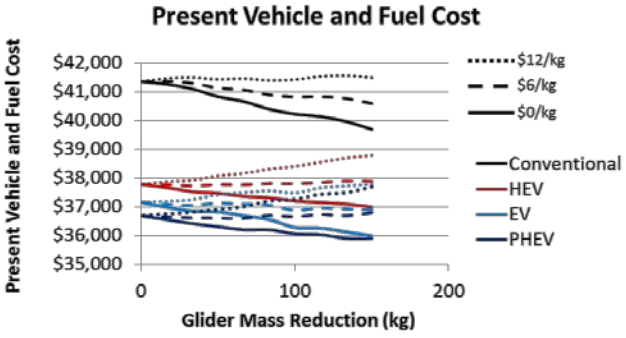






- Estimated lightweighting impacts and published SAE paper






SAE International

Lightweighting Impacts on Fuel Economy, Cost, and Component Losses

2013-01-0381
Published
04/08/2013

Aaron David Brooker
National Renewable Energy Laboratory

Jacob Ward
Department Of Energy

Lyrean Wiesp
National Renewable Energy Laboratory

ABSTRACT

INTRODUCTION

Benefits

- Improves understanding of lightweighting impact on petroleum use and cost
- Provides results to compare to consumer preference approach

Collaboration and Coordination

- **Received input and feedback from:**
  - Industry
    - Chrysler
    - Ford
    - GM
  - Government
    - ANL
    - EIA
    - ORNL

- **Data provided by:**
  - PA Consulting Group
  - Polk
  - SRA International (Sentech)

Proposed Future Work

FY13

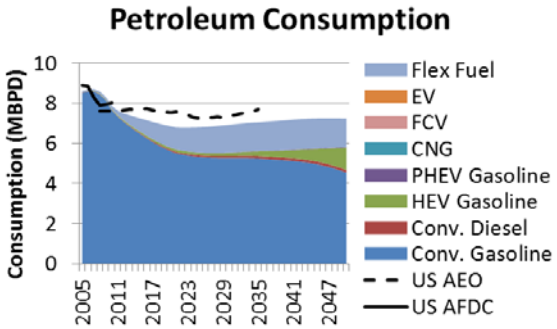
- **Improve confidence in projections**
  - Run ADOPT through historical periods and compare the model to actual sales and vehicle changes
- **Expand the evolving capabilities to CNG vehicles**
  - Add CNG engine map
- **Add ability in FASTSim to optimize the powertrain for consumer choice from ADOPT**
- **Enhance flexibility to consider more technology improvement options**
- **Improve user friendliness and post online**

Potential FY14 Work

- **Link vehicle miles traveled to fuel cost and efficiency**
- **Expand vehicle evolution to allow vehicles to change in class size**
- **Add CAFE effects**
- **Add penalty that captures battery electric vehicles' slow recharge time and low range**
- **Refine ADOPT based on shortcomings found in FY13 projection validation**
- **Complete framework to run in parallel with other models for comparison**
- **Apply to key technology target areas (batteries, fuel cells, CNG)**
- **Estimate sensitivity to external factors (fuel prices, income projections, refueling station availability)**

Summary

- **Projecting vehicle technology impacts on petroleum use and GHGs is key for effective research planning**



- **ADOPT linked with FASTSim provides realism through**
  - Extensive validation
  - New technologies competing with all existing options
  - Consumer preferences depending on income
  - Vehicles evolving over time

- **A few additional improvements need to be explored to improve confidence in the projections**

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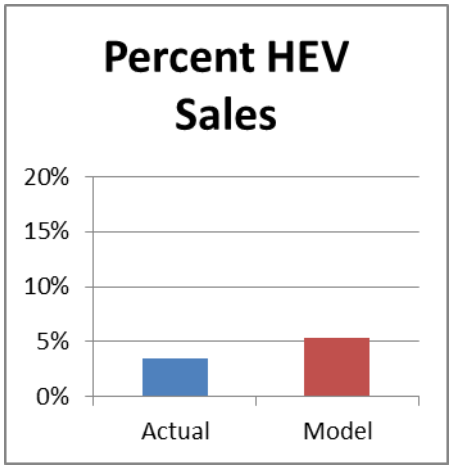
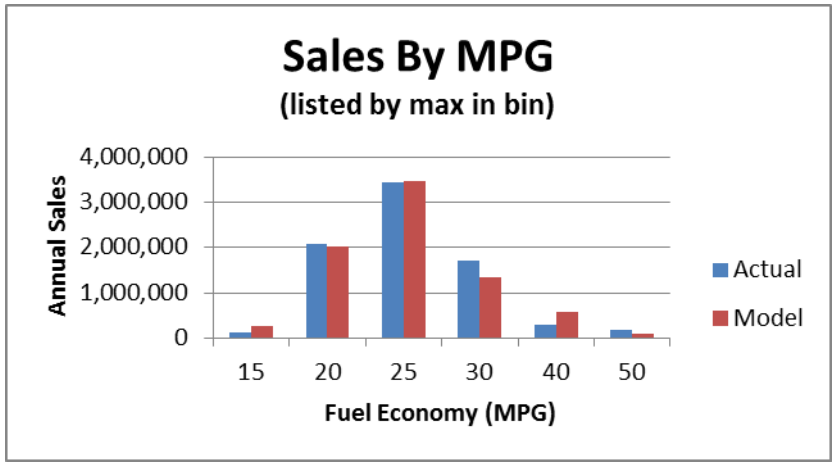
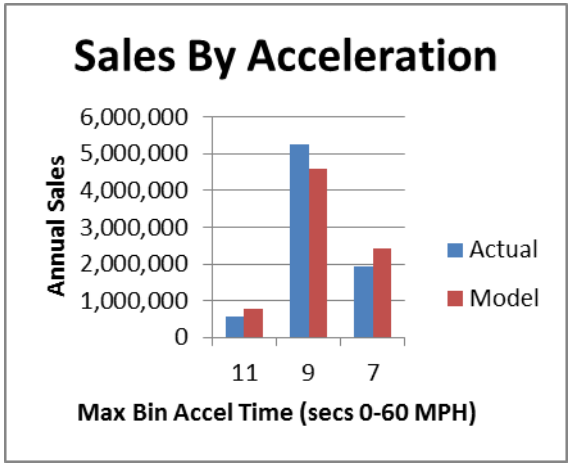
Technical Back-Up Slides

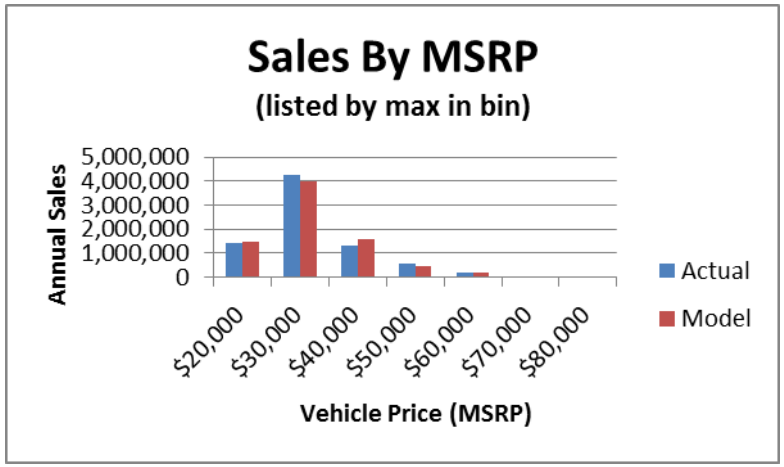
ADOPT Validation

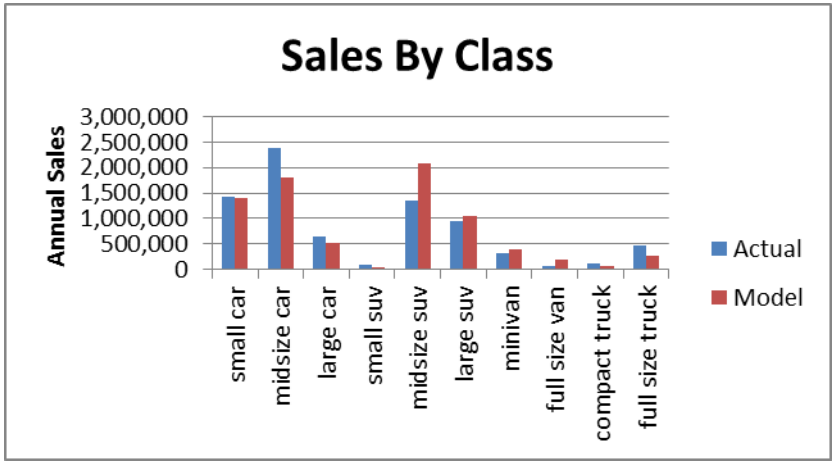
- 2008 U.S. Sales





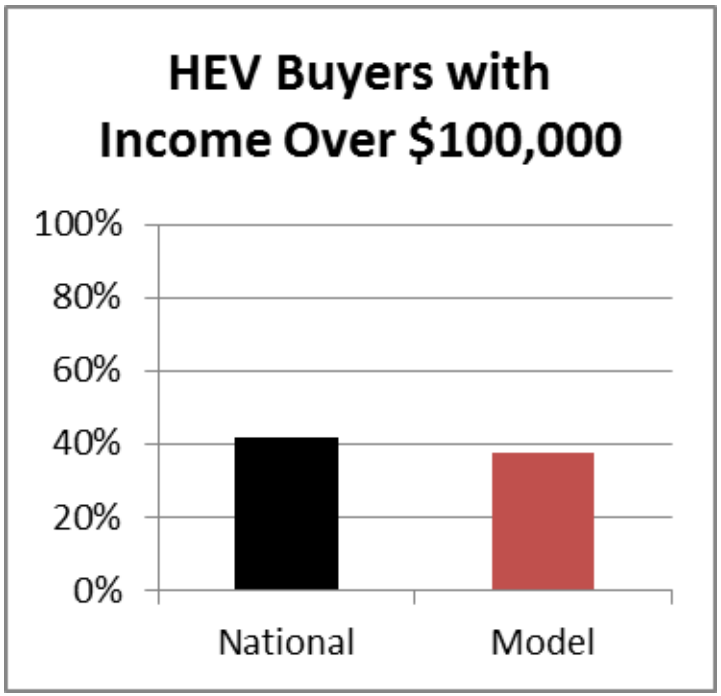


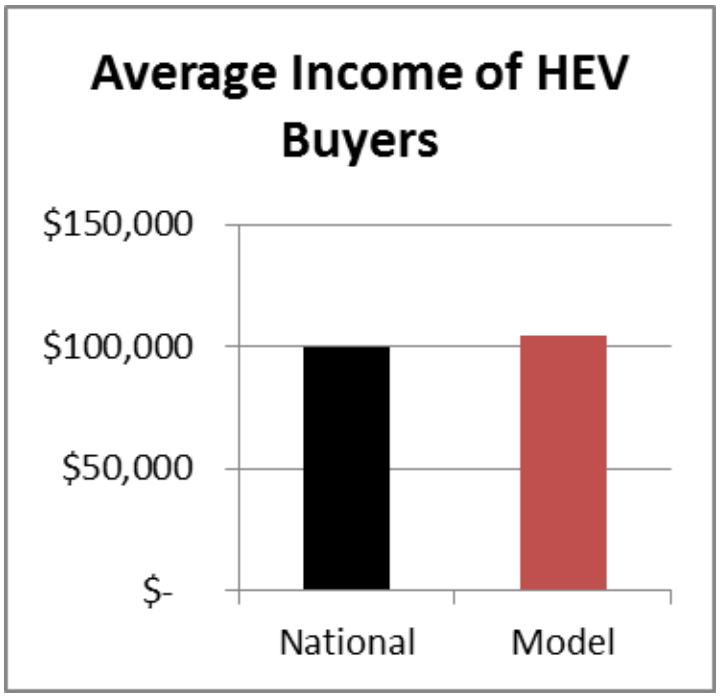




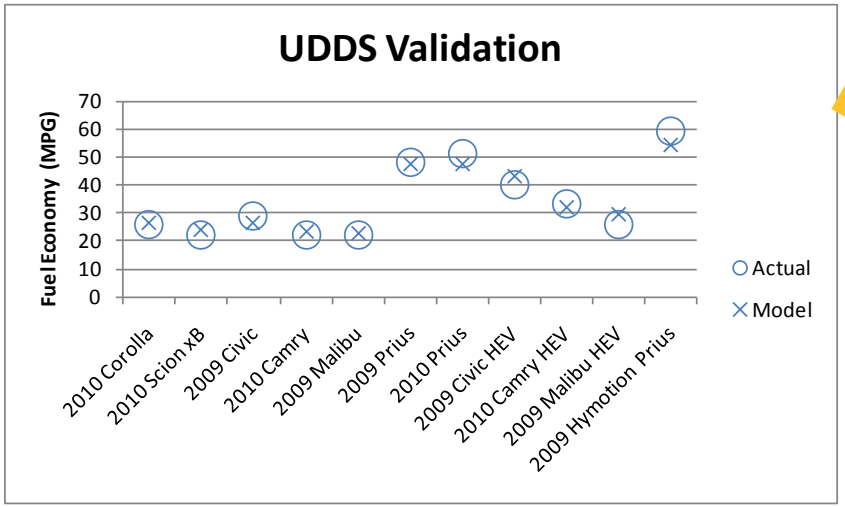
ADOPT Validation

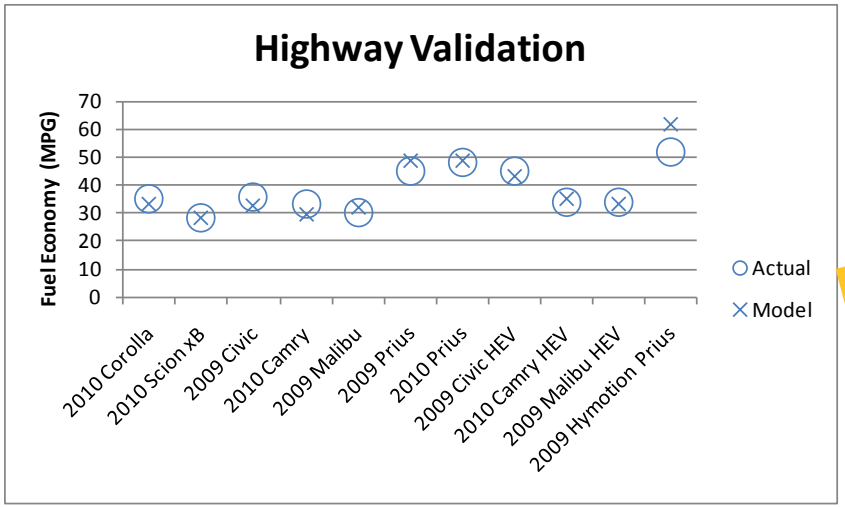
- **2012 U.S. Sales**
  - Model matches *who* is purchasing hybrids

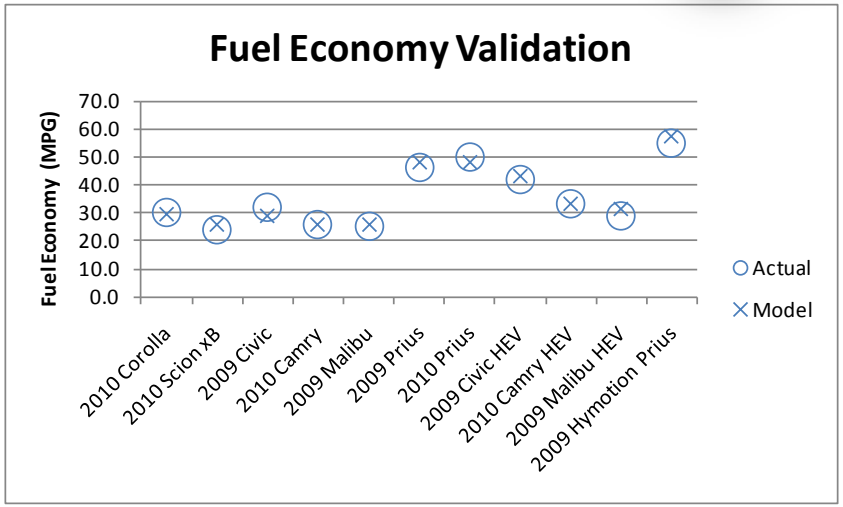




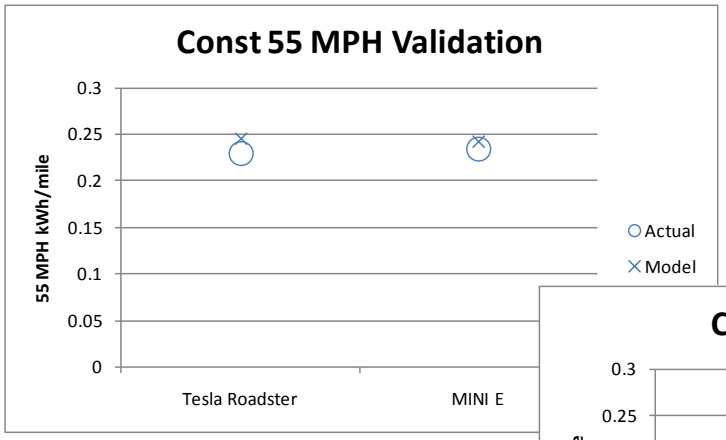
FASTSim Fuel Economy Validation

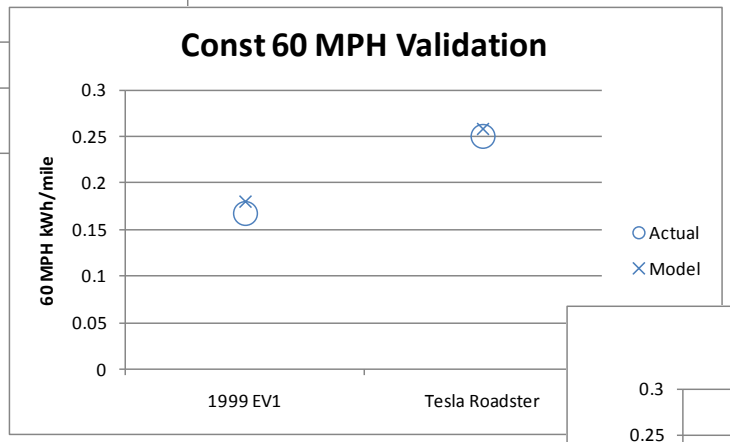


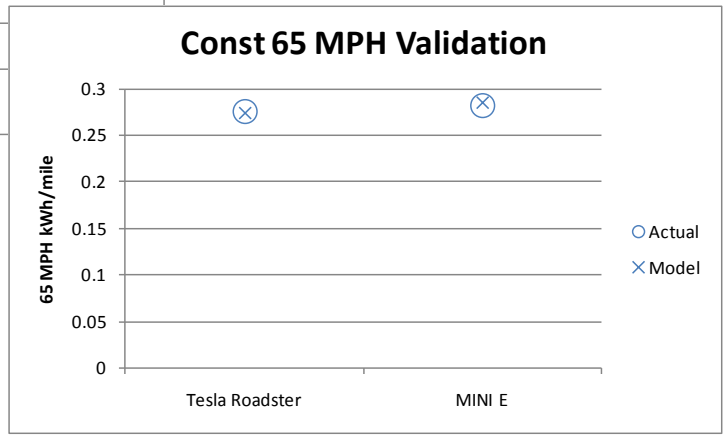




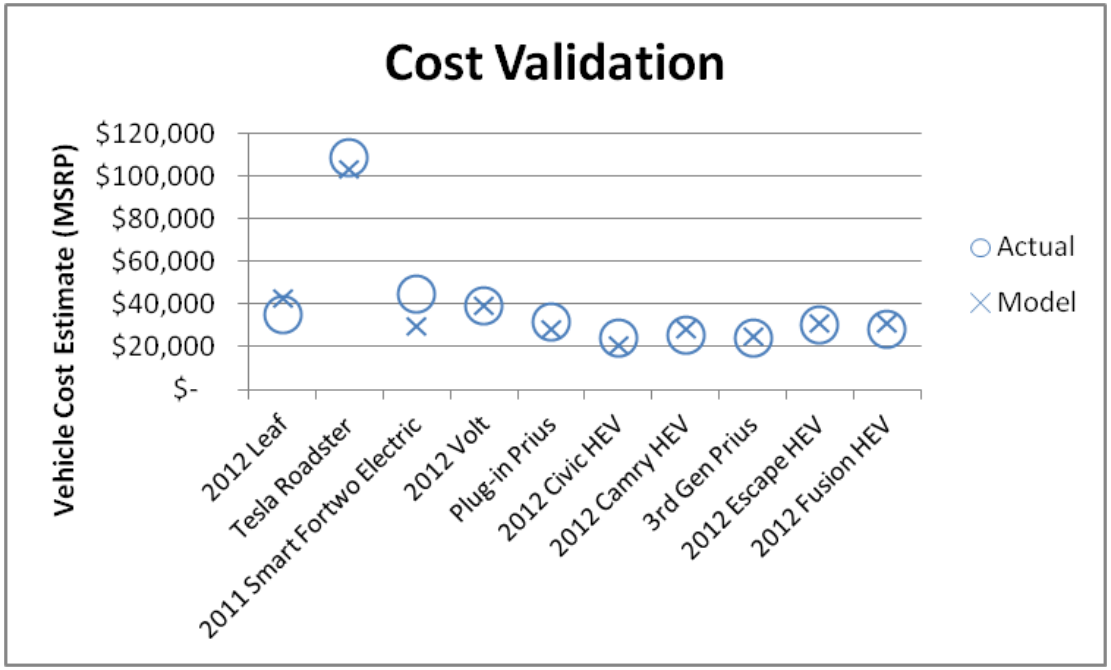
FASTSim EV Efficiency Validation







FASTSim Cost Validation



Battery[1,2]	**$22/kW + $500/kWh + $680**
Motor and controller[1]	**$21.7/kW + $425**
Engine[1]	**$14.5/kW +$531**
Markup factor[3]	**1.5**

1. Based on Simpson, A., "Cost-Benefit Analysis of Plug-In Hybrid Electric Vehicle Technology," 22nd International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exhibition (EVS-22), Yokohama, Japan, October 23-28, 2006, with battery cost adjustments to match DOE's 2012 goal and today's vehicle prices.
2. Howell, D., "Annual Merit Review Energy Storage R&D and ARRA Overview, June 8, 2010.
3. Rogozhin, A., et al., "Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry," International Journal of Production Economics (2009), doi:10.1016/j.ijpe.2009.11.031