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Unified Modeling, Simulation, and Market Implications: FASTSim and ADOPT



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National Renewable Energy Laboratory
6/18/2014

Project ID # VAN004

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

Overview

Timeline

Project Start Date: Oct. 2013
Project End Date: Sept. 2014
Percent Complete: 60%

Budget

Total Project Funding: $450
Funding Received in FY13: $150K
Funding for FY14: $150K

Barriers

- **Barriers addressed:** Many
  - Assess the impact that DOE vehicle technology targets have on DOE end 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

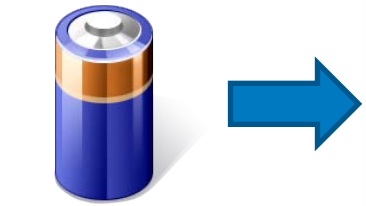
Relevance

VTO Goals (http://www1.eere.energy.gov/vehiclesandfuels/about/fcvt_mission.html):

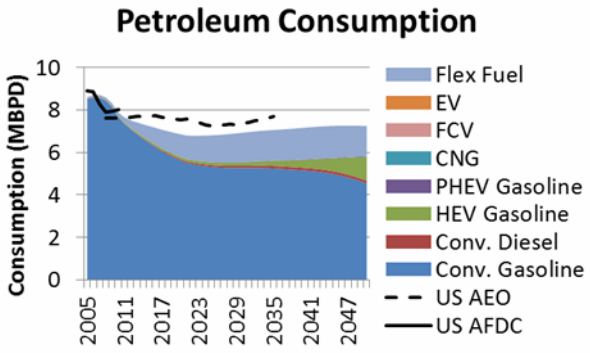
- Reduce dependence on foreign oil and GHG emissions

Relevance

- This project improves the estimation of the impact of vehicle technology improvements on overall VTO goals

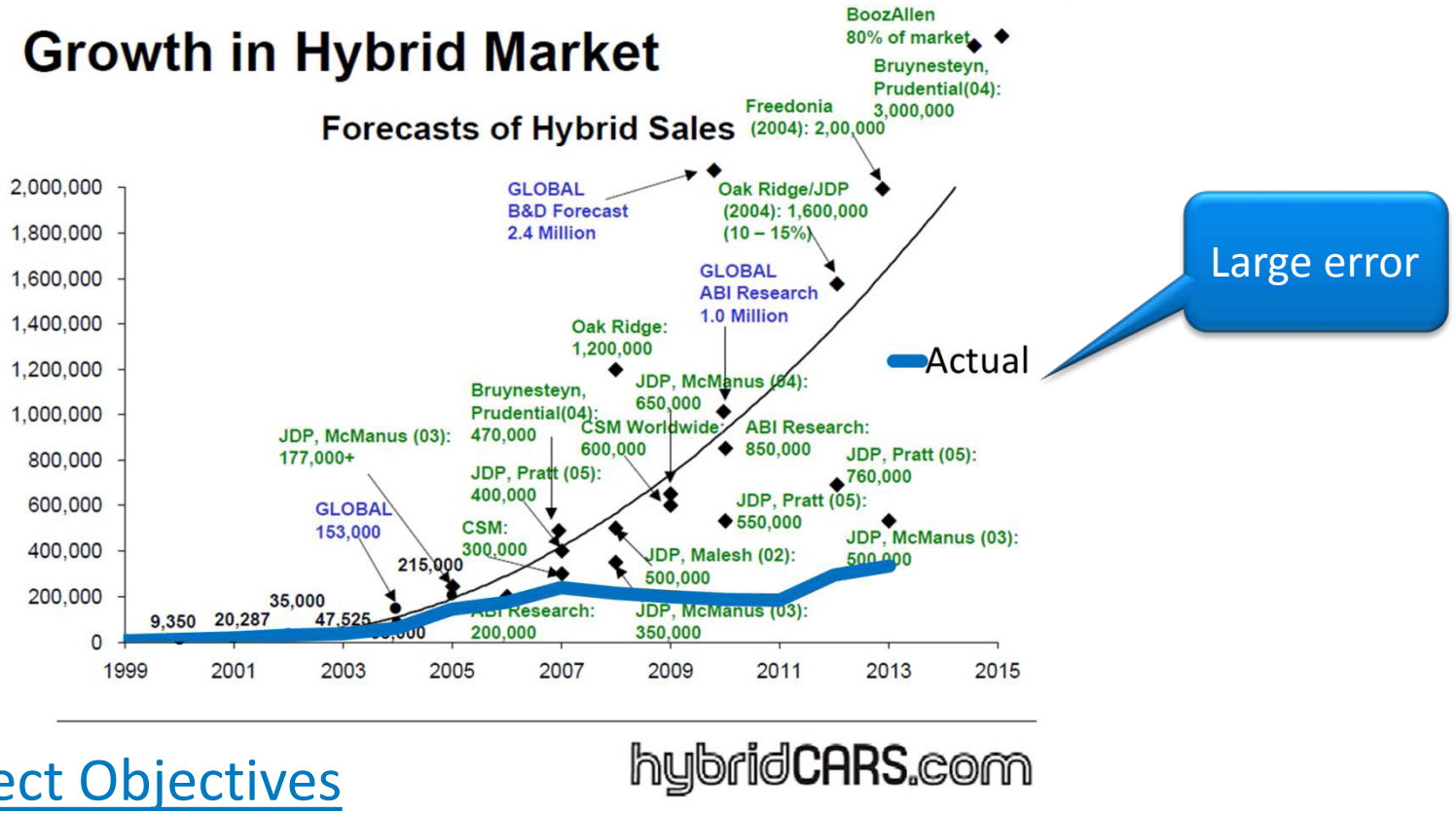


Component Improvements



VTO = Vehicle Technologies Office
GHG = greenhouse gas

Relevance: Improve Accuracy (Confidence)



- Project Objectives
  - Improve confidence and functionality
  - Estimate technology impacts on plug-in electric vehicle sales
  - Publish on FASTSim/ADOPT's approach, validation, and results

ADOPT = Automotive Deployment Options Projection Tool
FASTSim = Future Automotive Systems Technology Simulator

Milestones

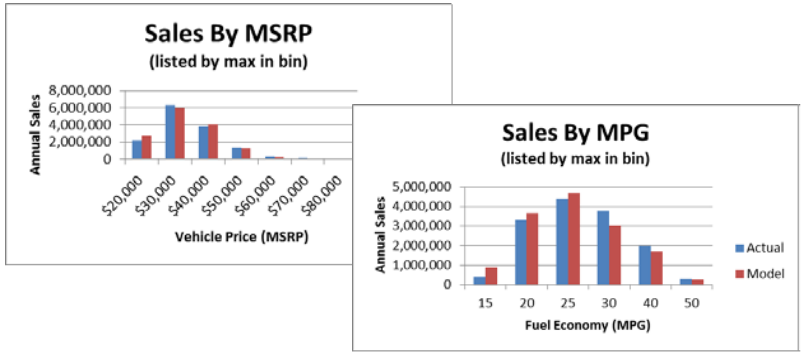
Month/ Year	Milestone or Go/No-Go Decision	Description	Status
Dec. 2013	Quarterly update	Added technology improvements over time, consumer heterogeneity, comparison with other models	Complete
March 2014	Quarterly update	Improved interface, run times, CAFE compliance, validation, and approach to adding model options	Complete
June 2014	Analysis progress update	Estimate technology impacts on plug-in electric vehicle sales.	On schedule
Sept. 2014	Milestone & Paper	Publish paper describing tool, approach, validation, and results.	On schedule

CAFE = corporate average fuel economy

Approach: FASTSim/ADOPT Overview

- **Estimate advanced technology impact on U.S. light-duty (LD) vehicles**
  - Petroleum use
  - GHG emissions

- **ADOPT's choice model**
  - Uses a logit function
  - Competes all LD vehicles
    - Over 1,000 makes, models and trims
  - Validates well with historical sales



- **ADOPT's stock model captures key aspects**
  - Change in vehicle travel distance with vehicle age
  - New model creation
  - Scrap rates with vehicle age

Approach: Estimated Petroleum Use

Price, acceleration, efficiency, range, size

Photo by Keith Wipke, NREL 15986

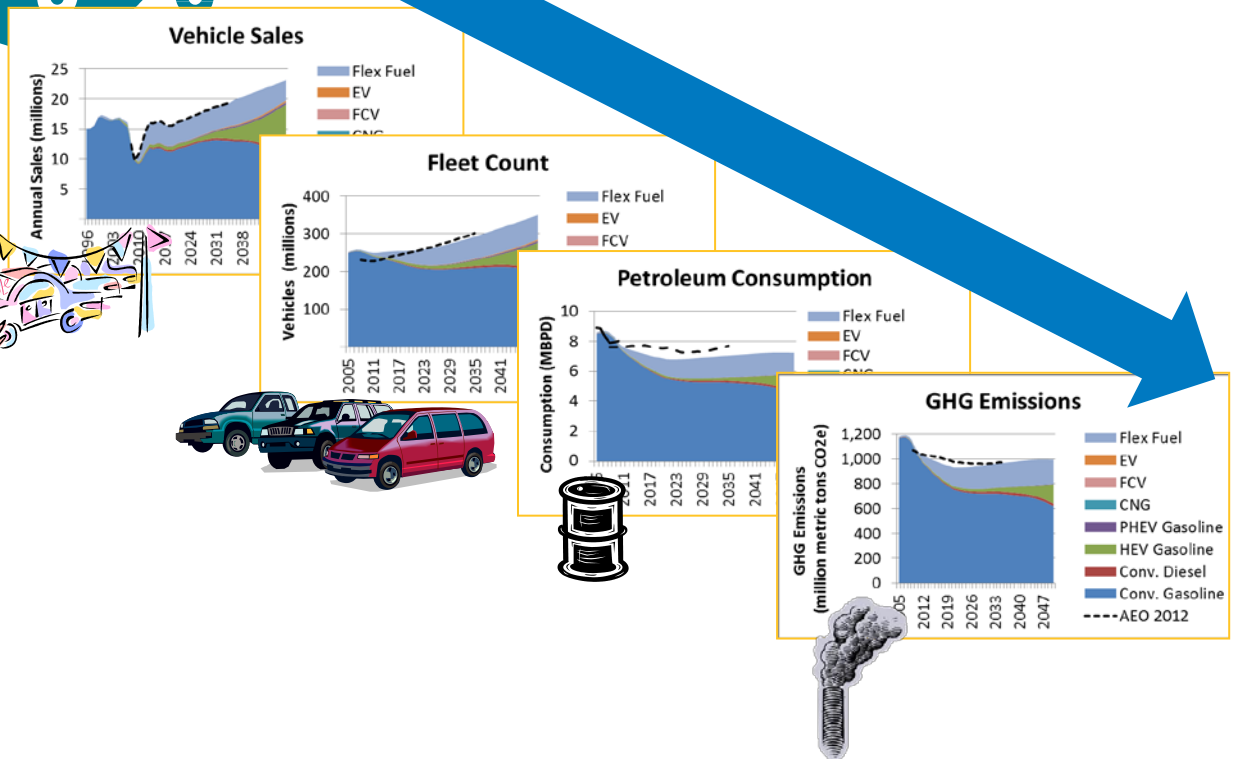
Fuel prices

Income distribution

Photo by Michael Penev, NREL 19206

Fueling station availability

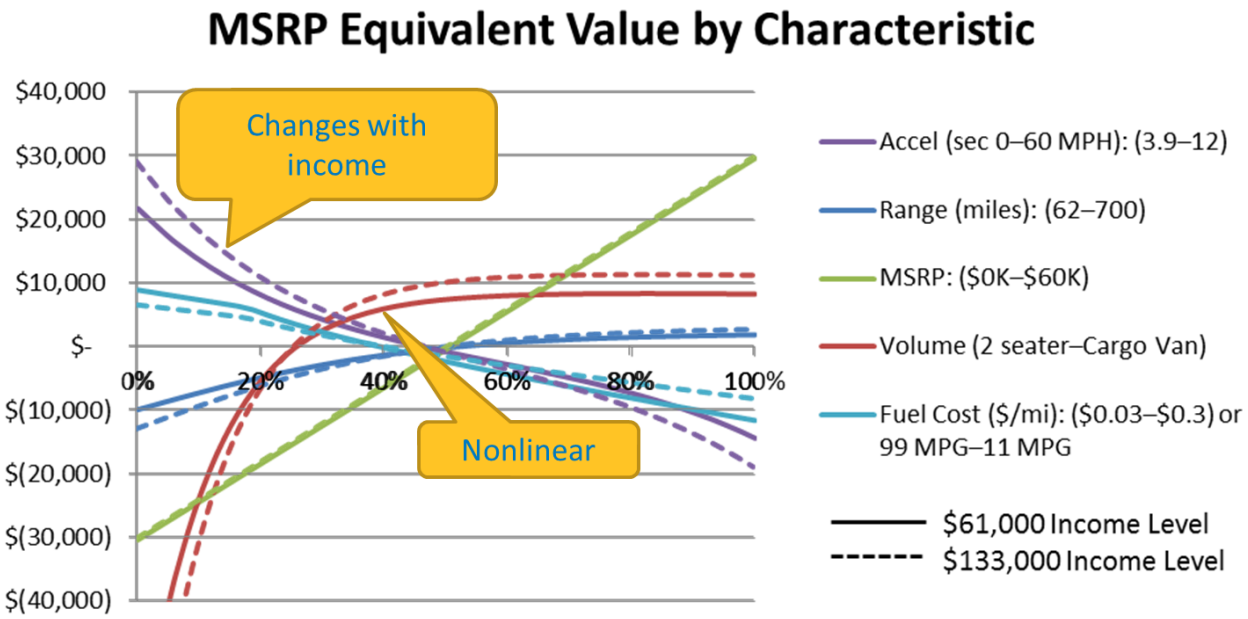
Consumer Choice



Approach: ADOPT's Consumer Choice Function

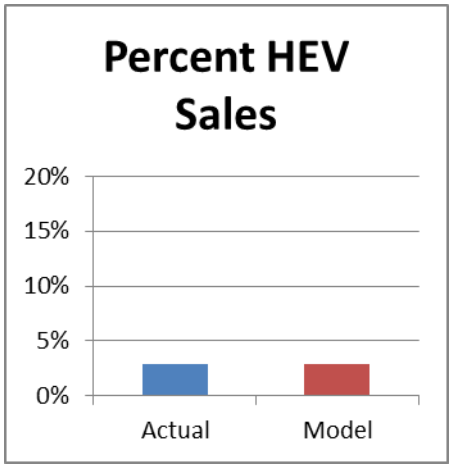
- **Logit function uses weighting factors to capture relative importance of each attribute**
  - S_v: Market share for vehicle model V
  - E_A: Coefficient for attribute A
  - V_A: Value of attribute A for vehicle V
  - x: Sales distribution factor

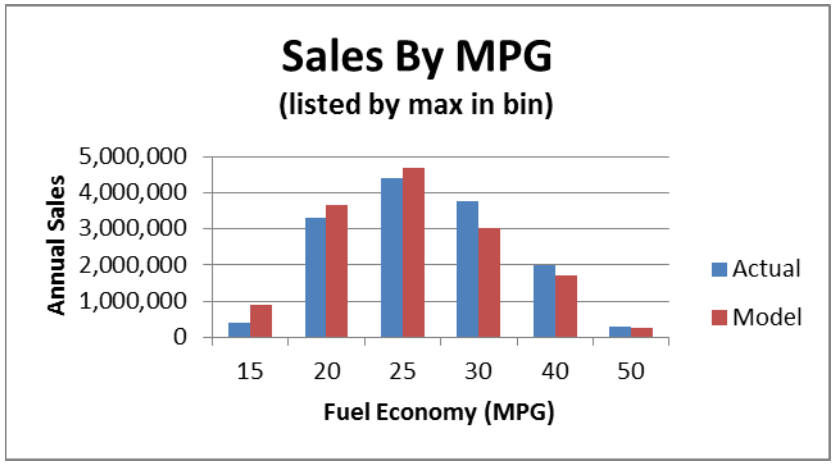
$$S_V = \frac{EXP(\sum_A (E_A \times V_A))^x}{\sum_V (EXP(\sum_A (E_A \times V_A))^x)}$$

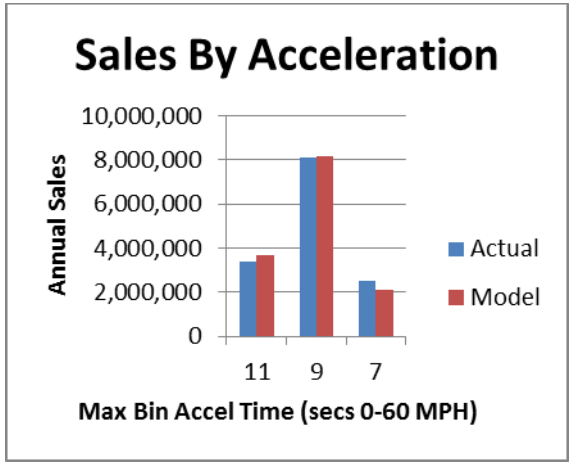


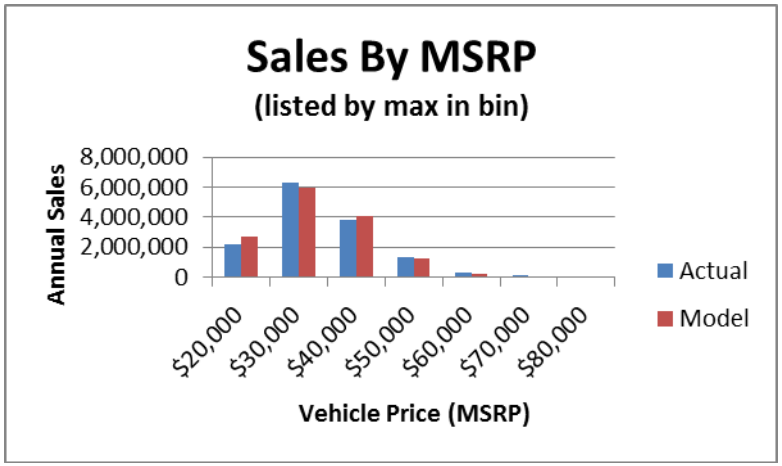
Approach: Validation

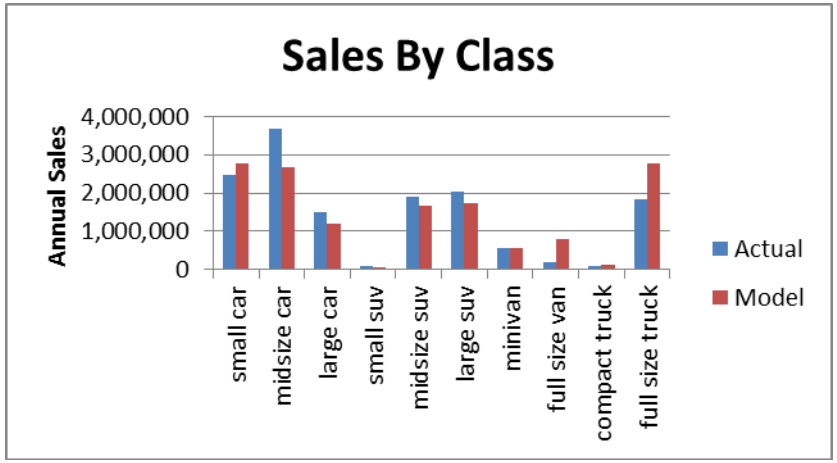
Example: 2012 U.S. Sales











HEV = hybrid electric vehicle; MPG = miles per gallon
MPG = miles per gallon
MSRP = manufacturer's suggested retail price

Accomplishments: Improved Confidence

- **Expanded vehicle attributes to change by year**
  - Example: Volt MSRP drops from $40k to $35k (2011 – 2013)
  - More accurate validation

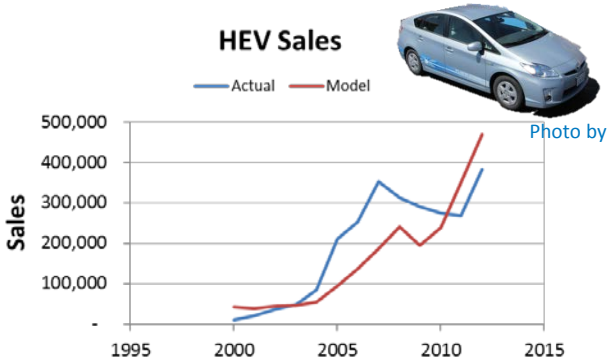


Photo by Michael Penev

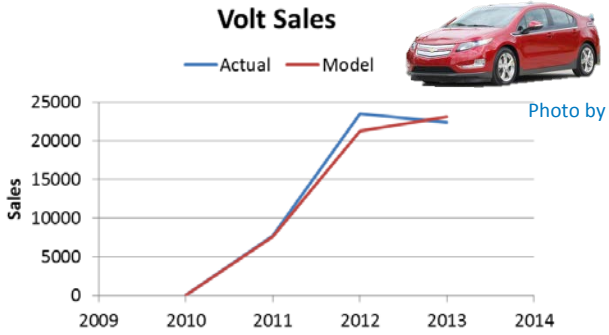


Photo by George Beard

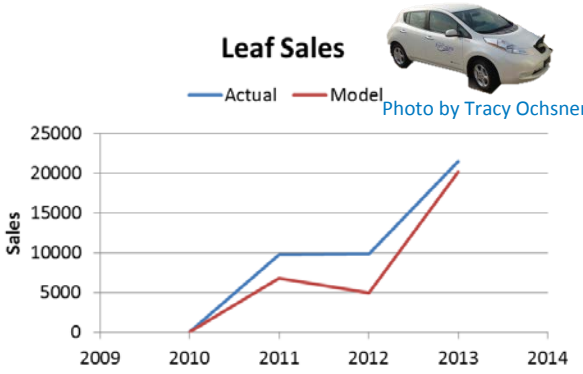
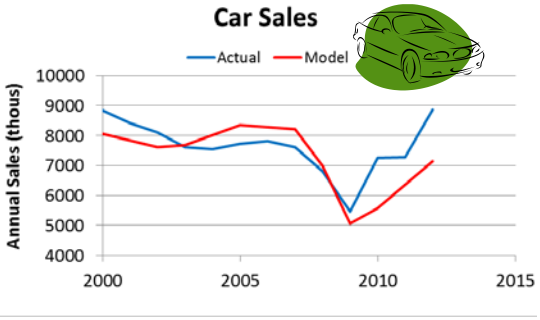
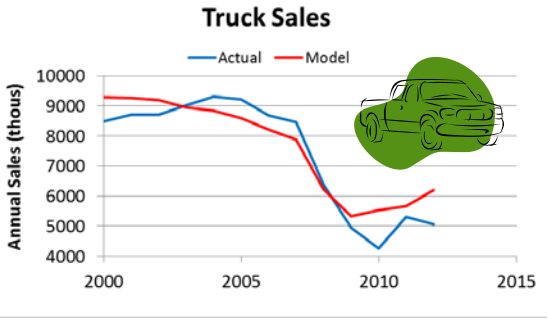


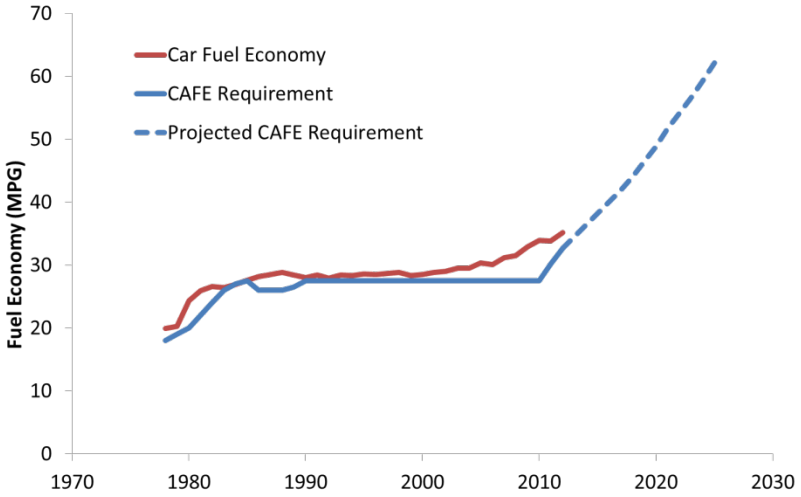
Photo by Tracy Ochsner





Accomplishments: Improved Confidence

- **Added techniques to meet CAFE**
  - CAFE drives fuel economy



  - CAFE is based on vehicle footprint – added data to all vehicles
  - Added CAFE drivers
    - Engine downsizing: Reduces fuel economy, cost, and acceleration
    - Incentives/penalties
    - Future: Add many more options using FASTSim and other models

Accomplishments: Improved Confidence

- **Increased consumer heterogeneity (mixing) to improve substitution patterns**
  - Use a distribution of consumer tastes (E_A values) for:
    - Fuel cost
    - Acceleration
    - Size
  - Improved historical HEV sales validation
    - Compared model to actual sales for 47 different HEVs

$$S_V = \frac{EXP(\sum_A (E_A \times V_A))^x}{\sum_V (EXP(\sum_A (E_A \times V_A))^x)}$$

S_v: Market share for vehicle model V
E_A: Coefficient for attribute A
V_A: Value of attribute A for vehicle V
x: Sales distribution factor

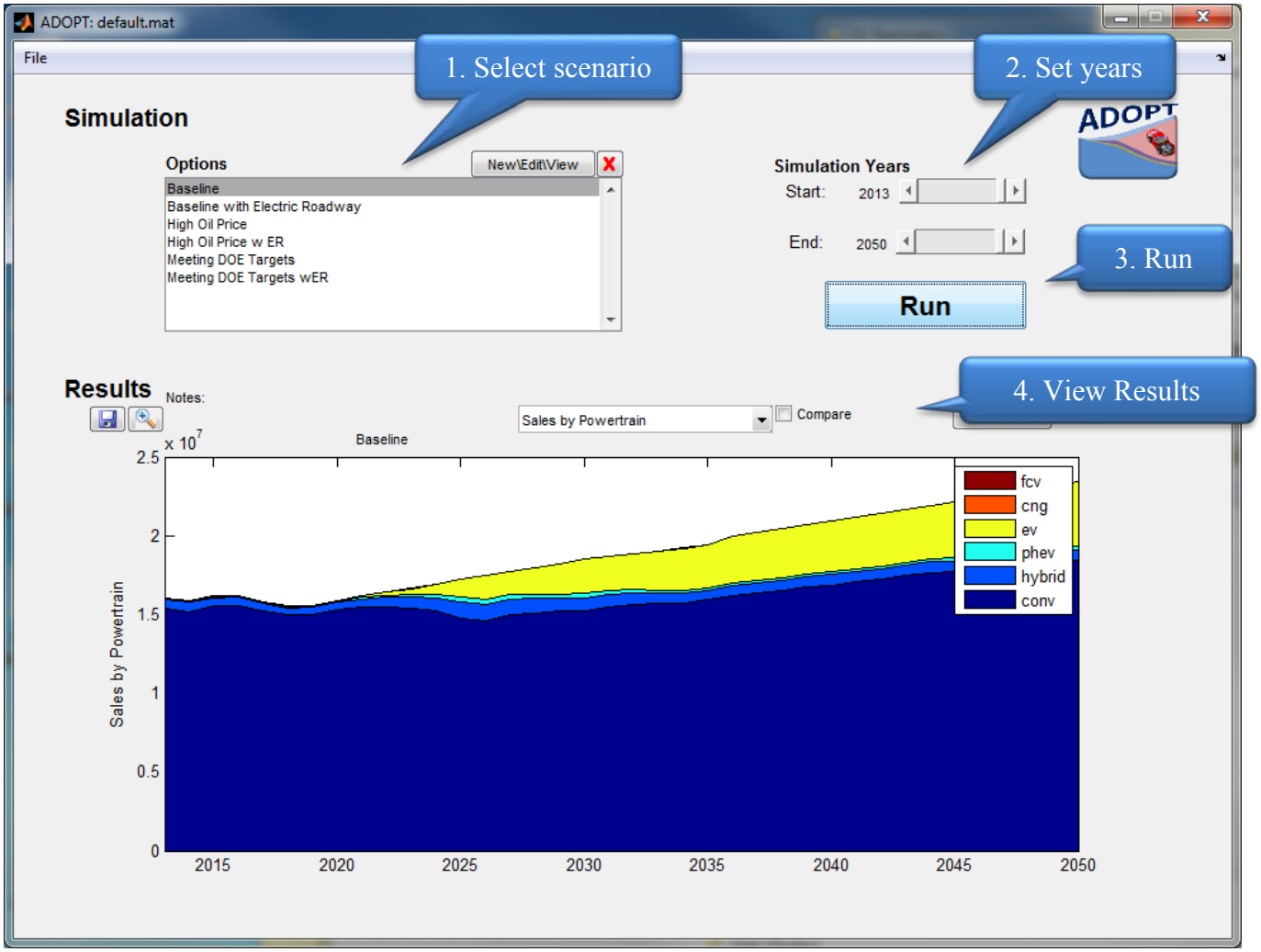
Accomplishments: Improve Functionality

- **Added technology improvements over time**
  - Battery price
  - Motor price
  - Gasoline engine efficiency
  - Diesel engine efficiency
  - Atkinson engine efficiency
  - Lightweighting
  - Benefit: Used to estimate benefits of achieving DOE progress toward technical targets

- **Increased speed**
  - Run time increased to 30 minutes after adding mixing
  - Decreased to less than 30 seconds
    - Moved to MATLAB
    - Used vectorization (minimized “for loops”)
    - Pre-allocated space for all growing variables
  - Benefit: Allows for more model testing and analysis

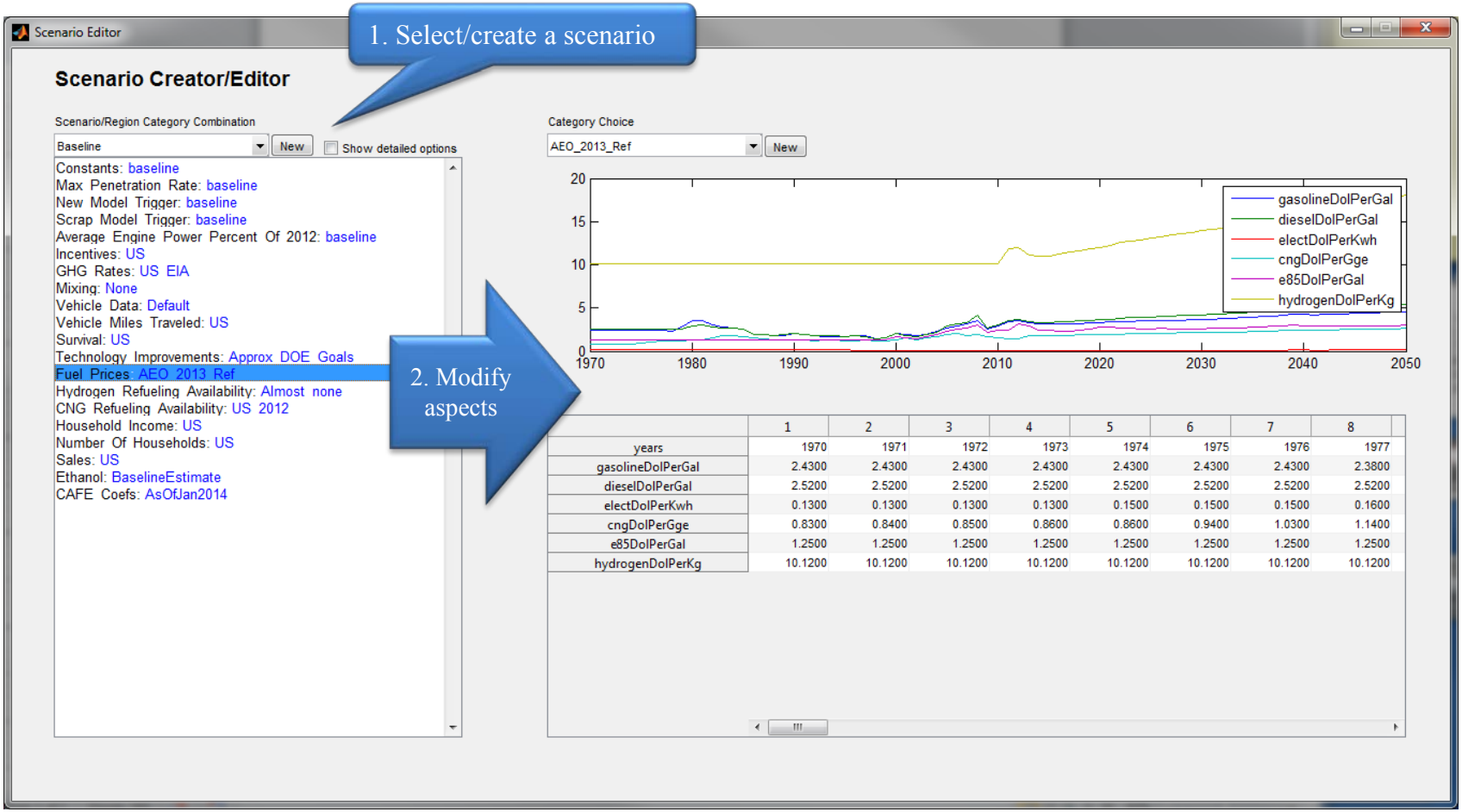
Accomplishments: Improve Functionality

Simplified user interface



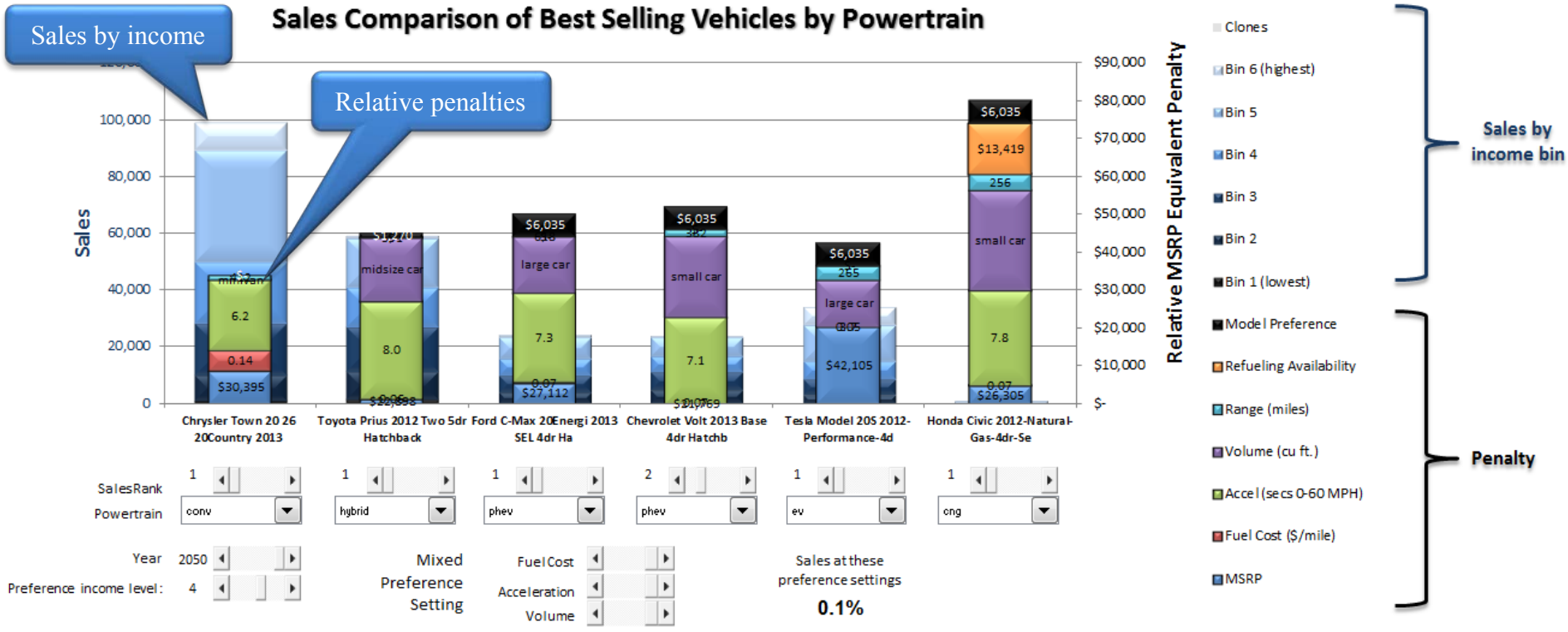
Accomplishments: Improve Functionality

Simplified user interface: Scenario Editor



Accomplishments: Improve Functionality

- **Added plot that shows why the sales occur**



Responses to Previous Year Reviewers' Comments

- **Comment: "…it seemed superfluous to add all of the current models to a simulation that extends to 2050, since all of the current types will be replaced in the future."**
  - Improves validation (model-by-model historical comparisons)
  - Helps capture more variations like the Prius
  - Helps calibrate preferences (different combinations of attributes)
  - Other reviewer: "…expanding the number of represented vehicles and having the capability to evolve vehicles is beneficial to adding realism."
- **Comment: "…the effect of CAFE will be important."**
  - We have started adding approaches to meet CAFE
  - We are proposing additional work in this area

Collaboration and Coordination

- **Received input and feedback from:**
  - Industry
    - Chrysler
    - Ford
    - GM
  - Government
    - U.S. Department of Transportation
    - ANL
    - EIA
    - ORNL
  - Universities
    - UC Davis

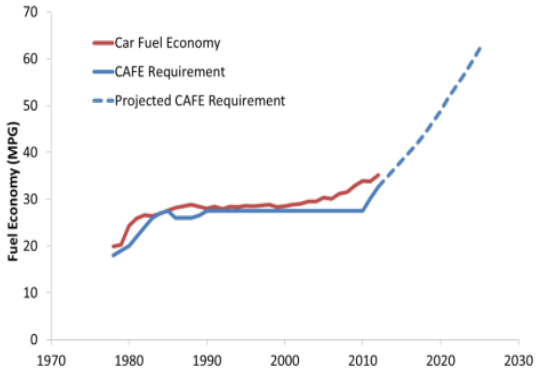
- **Data provided by:**
  - PA Consulting Group
  - Polk
  - SRA International (Sentech)

Remaining Challenges

- Account for battery electric vehicle range and recharge time interaction (FY14)
- Improve approach to meeting CAFE
- Further improve model accuracy (confidence)
- Expand on capturing technology improvements

Proposed Future Work

- **VTO Vision: Robust analysis**
  - Expand on approach to meeting CAFE
    - Current: Engine downsizing, incentive/penalty, advanced powertrains, DOE targets
    - Additions from EPA document* including:
      - Final drive ratio (acceleration vs. efficiency)
      - Start/stop
      - Improved accessories
    - Evaluate impact of CAFE (trucks vs. cars)



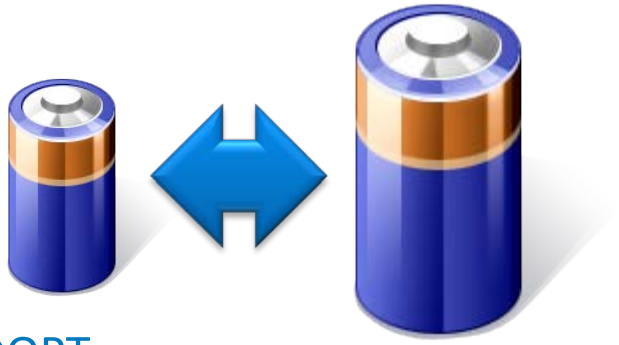
  - Add regions to capture
    - State tax credits
    - Regional fuel/electricity prices

  - Add learning curve option for technology improvements

* United States Environmental Protection Agency, "Regulatory Impact Analysis Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards", report EPA-420-R-12-016, August 2012.

Proposed Future Work

- **VTO Vision: Robust analysis**
  - Expand and improve vehicle evolution
    - Evolve battery size
    - Expand across class sizes
    - Seed one model with a technology and let ADOPT expand options
    - Speed up evolution algorithm

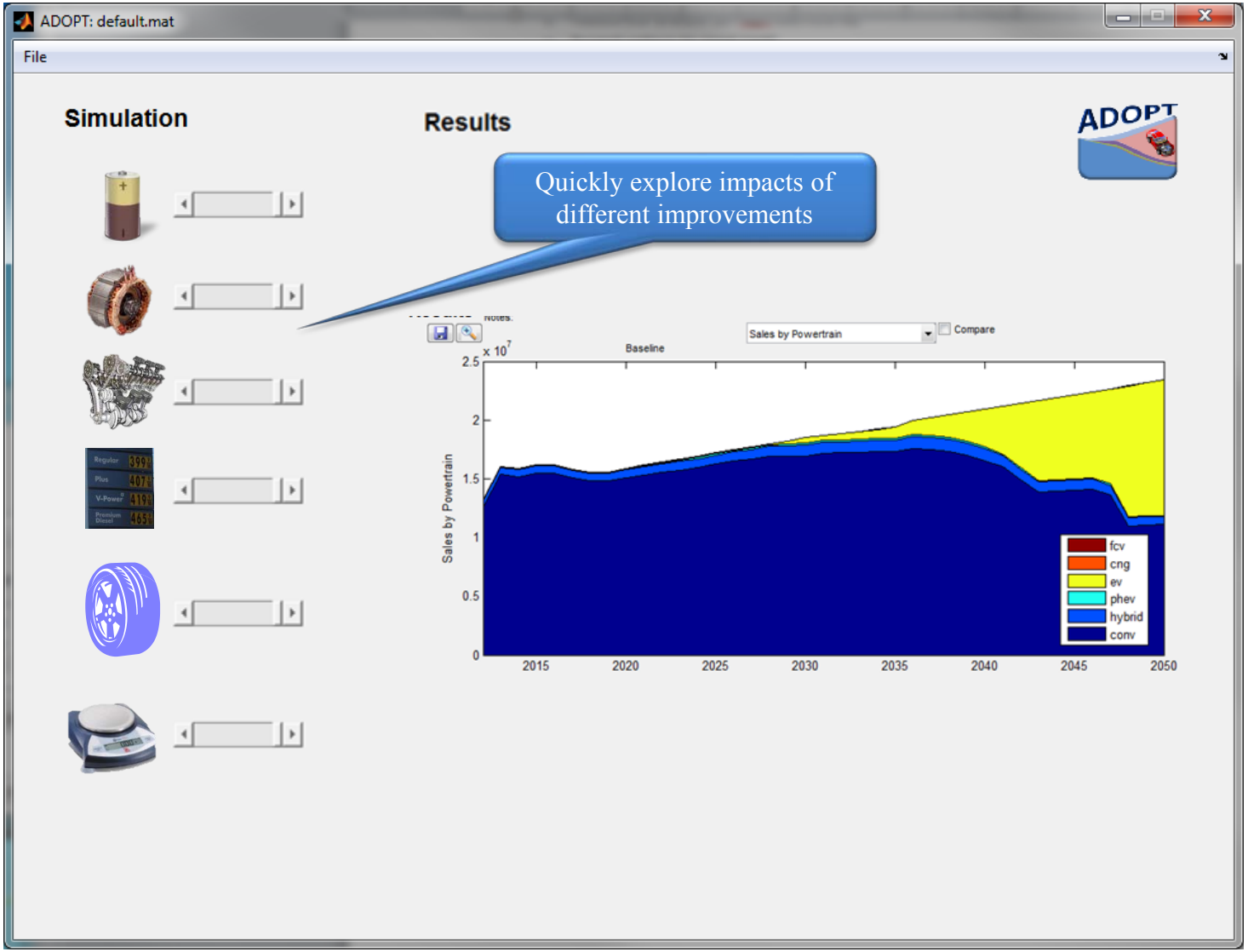


  - Evaluate and add the neighbor effect to determine the impact on petroleum use and GHGs
    - Review the literature
    - Use sales by zip code and ADOPT to explore further
    - Implement and validate

  - Stretch mixing distribution and look for tipping points

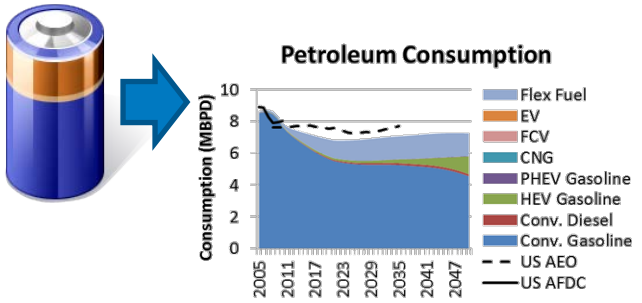
Proposed Future Work

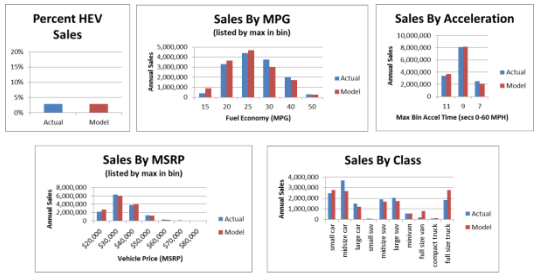
VTO Mission: Plan, execute, and communicate (slider & knob interface)

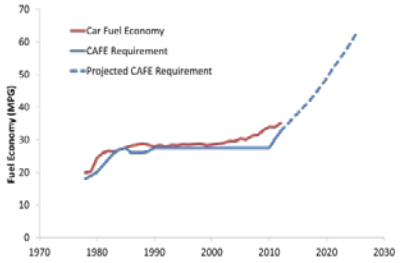


Summary

- **Estimating the impact of technology R&D on petroleum and GHG goals is key to**
  - Estimate current pathway effectiveness
  - Understanding how to adjust R&D targets to meet goals
- **The FASTSim/ADOPT tool provides an extensively validated approach**
- **It still needs an improved approach to CAFE**
- **Other potential improvements should be explored (neighbor effect)**







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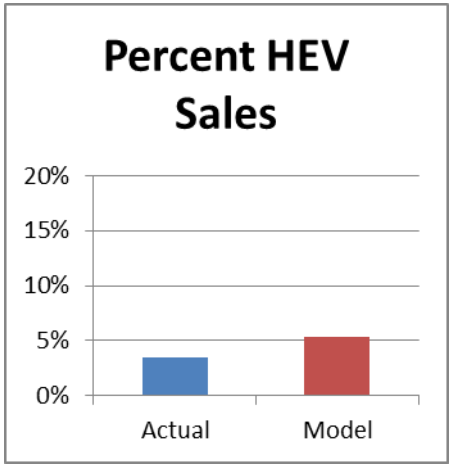
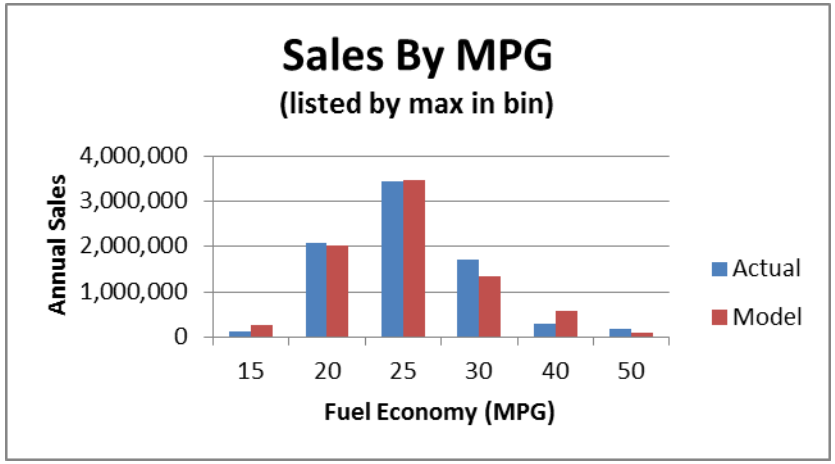
Technical Back-Up Slides

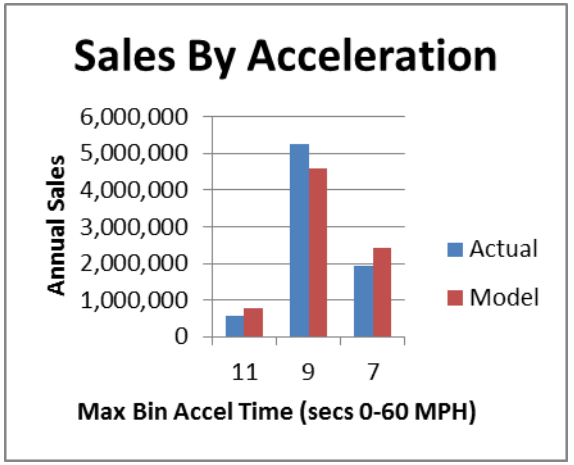
(Note: please include this “separator” slide if you are including back-up technical slides (maximum of five). These back-up technical slides will be available for your presentation and will be included in the DVD and Web PDF files released to the public.)

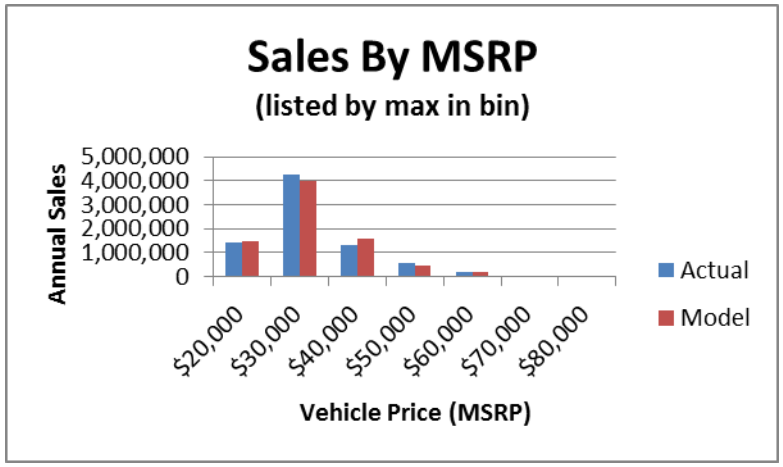
Choice Model: Validation

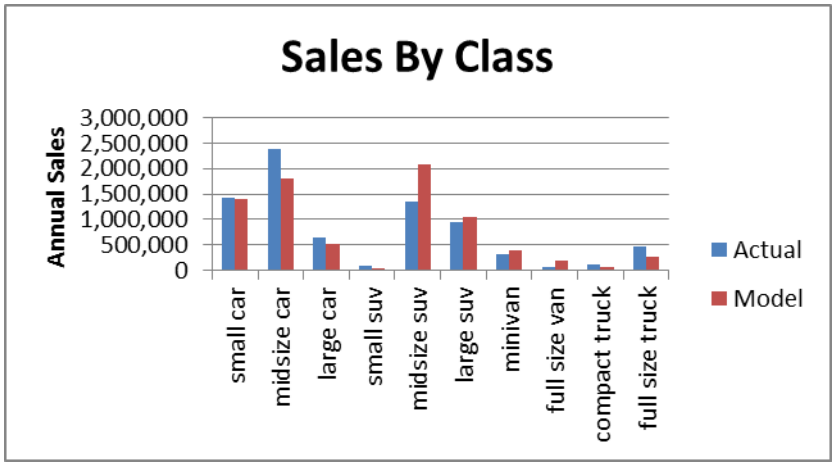
2008 U.S. Sales





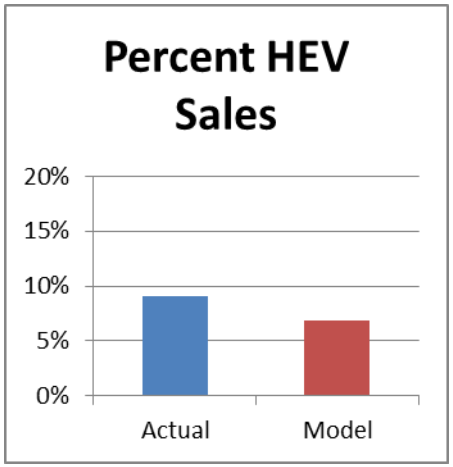


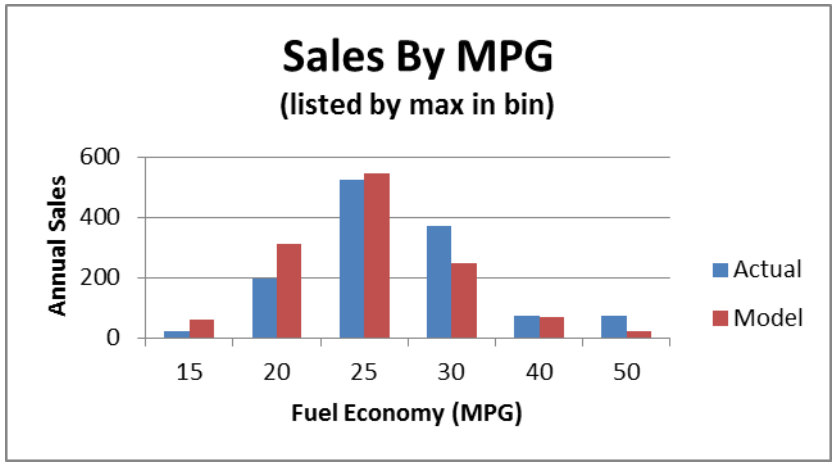


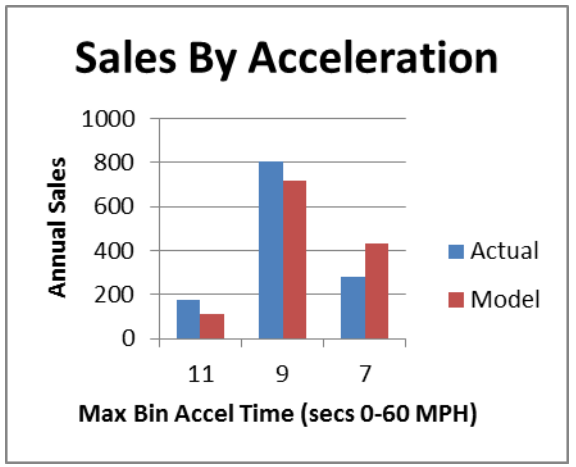


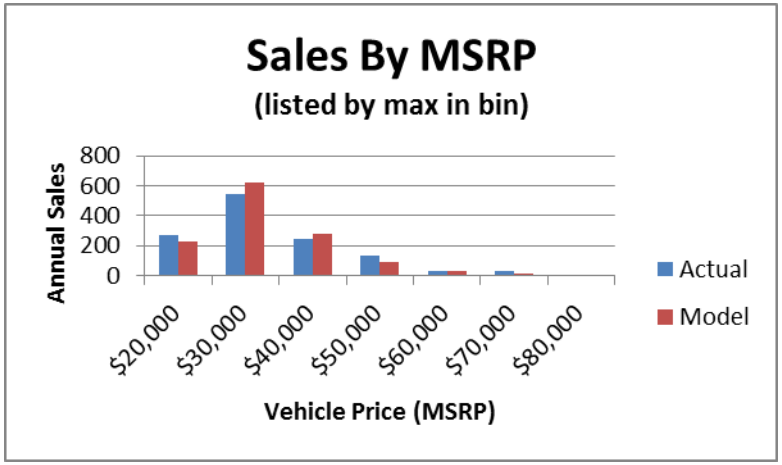
Choice Model: Validation

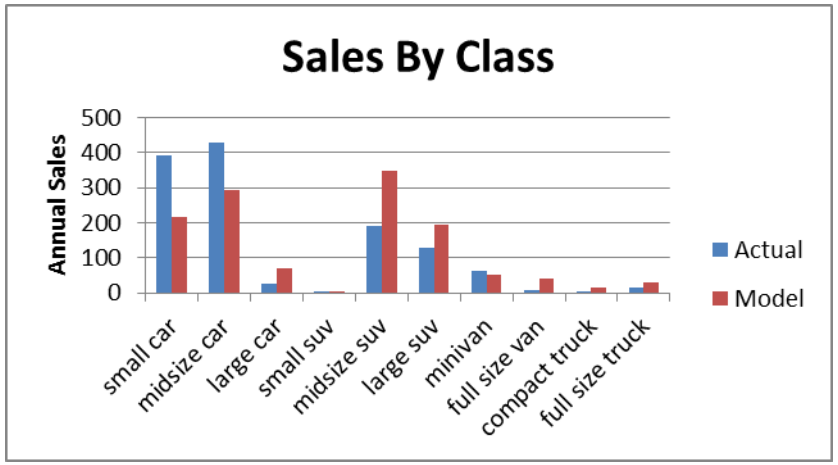
2008: 90004 (Los Angeles, CA)





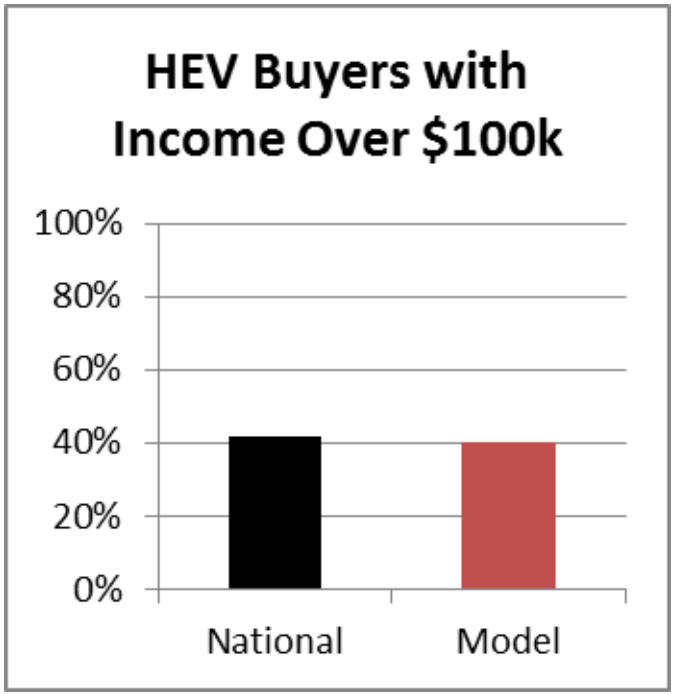


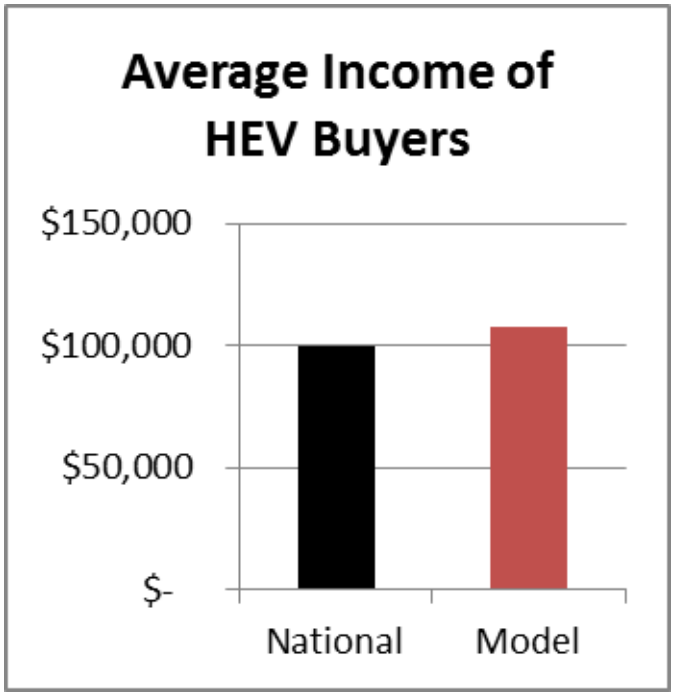




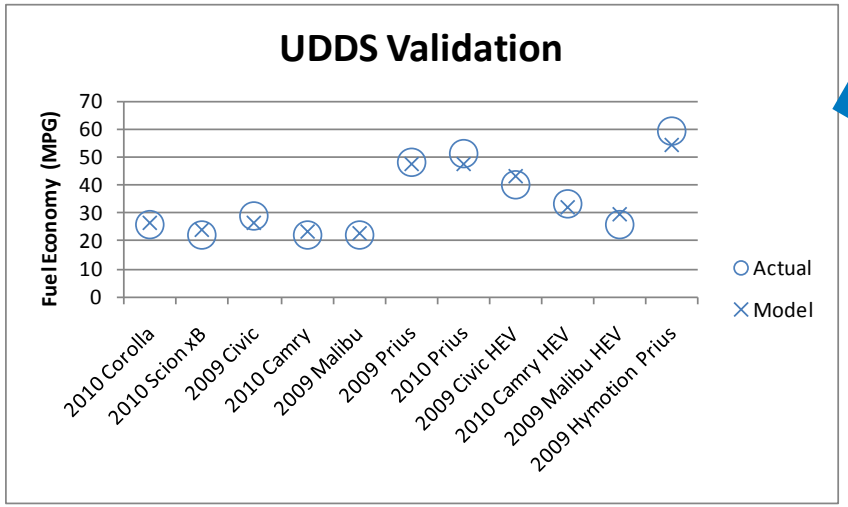
Choice Model: Validation

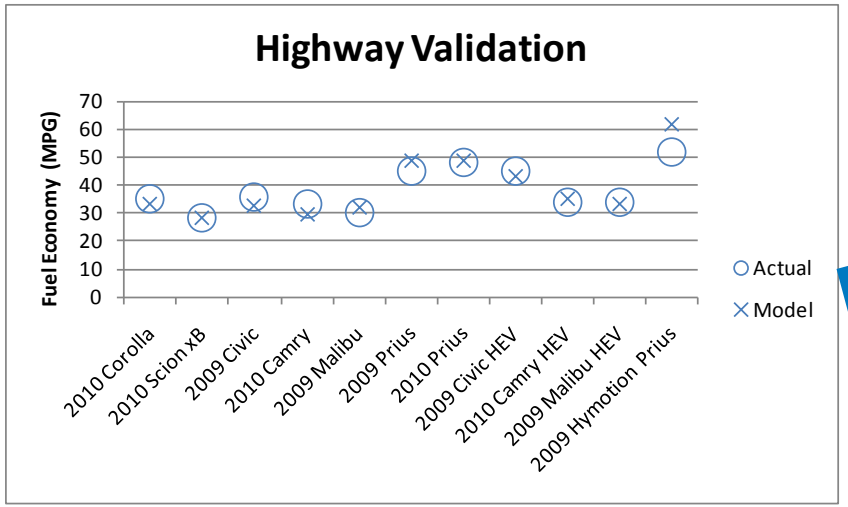
2012 U.S. Sales
Model matches *who* is purchasing hybrids

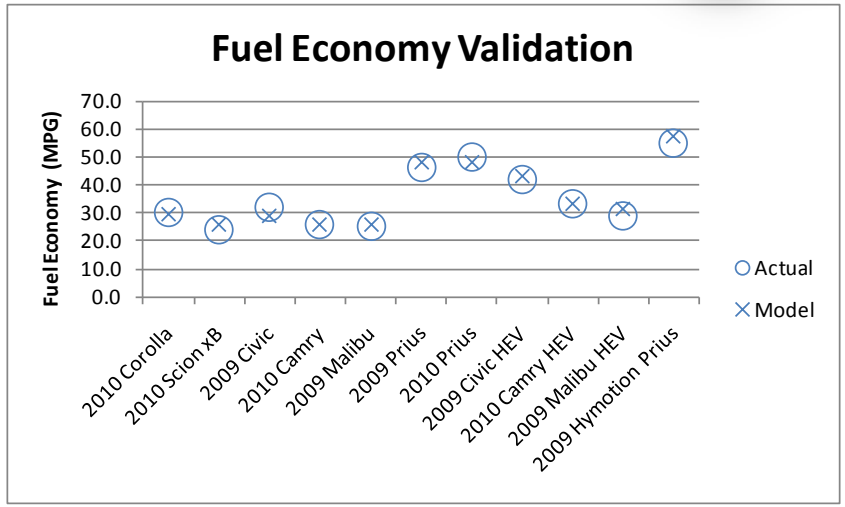




FASTSim Fuel Economy Validation







FASTSim EV Efficiency Validation