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

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Overview

Timeline

- Project start date: Oct. 2013
- Project end date: Sept. 2015
- Percent complete: 75%

Barriers

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

Budget

- Total project funding: $285K
  - DOE share: 100%
- Funding received in FY14: $150K
- Funding for FY15: $135K

Partners

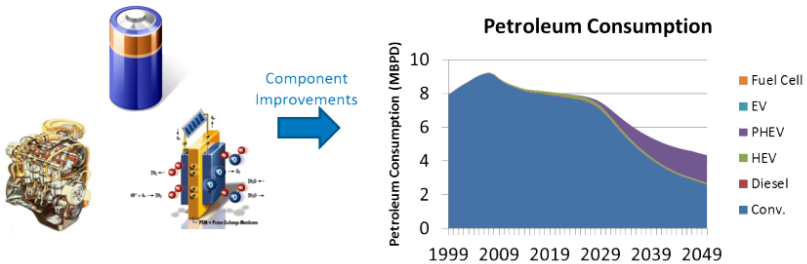
- Interactions/collaborations
  - GM, Ford, Chrysler
  - EIA, ORNL, ANL, SNL
  - SRA International, TA Engineering
  - UC – Davis
- Project lead: NREL

ANL: Argonne National Laboratory
GM: General Motors
EIA: U.S. Energy Information Administration
NREL: National Renewable Energy Laboratory
ORNL: Oak Ridge National Laboratory
SNL: Sandia National Laboratories
UC: University of California

Relevance\Objective

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 method for estimating how VTO R&D impacts overall VTO goals.



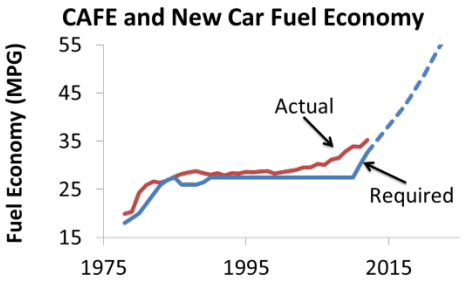
Objective: Improve comprehensiveness, accuracy, comprehension, and use

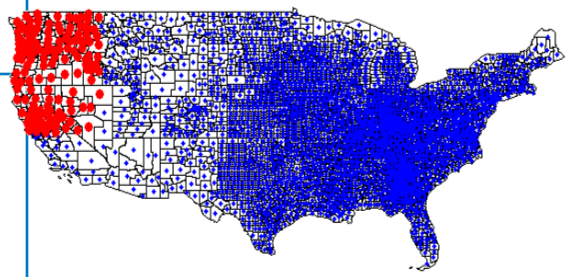
- Add all relevant VTO R&D targets to assess their impact on petroleum use and GHG emission
- Improve approach to creating new model options to find the most marketable configurations
- Expand consumer heterogeneity to improve realism and substitution patterns
- Add CAFE and GHG rule to capture large policy impacts
- Improve validation (validation over time) to provide confidence in the results
- Add results chart to review and understand results
- Complete VTO impact assessment
- Improve interface to expand use and better leverage the effort.

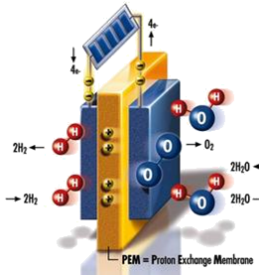
GHG: greenhouse gas
MBPD: million barrels per day
VTO: Vehicle Technologies Office

Milestones

Month / Year	Milestone or Go/No-Go Decision	Description	Status
Dec. 2014	Quarterly update	• Expanded to capture the CAFE/GHG ruling implications for alternative fuels • **Added region-based data for United States down to ZIP Code level** to more accurately capture fuel prices, income distributions, and incentives • Improved alignment with AEO assumptions for better comparisons • Published papers on ADOPT and FASTSim.	Complete
March 2015	Quarterly update	• **Added fuel cell vehicles** • Added remaining DOE research and development (R&D) technologies • **Added powertrain component size evolution** for all powertrains • Completed analysis estimating petroleum and GHG emission impacts of expected DOE R&D technology improvements.	Complete
June 2015	Quarterly update	• Complete CAFE and GHG ruling related enhancements • Complete region-based framework.	
Sept. 2015	Milestone and paper	• Complete and publish report on petroleum and GHG emission impacts.	

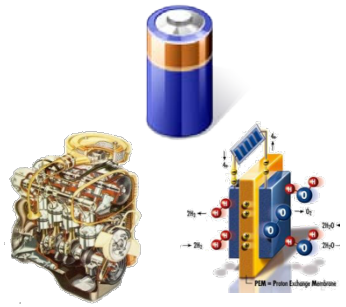






ADOPT: Automotive Deployment Options Projection Tool
AEO: Annual Energy Outlook
CAFE: Corporate Average Fuel Economy
FASTSim: Future Automotive Systems Technology Simulator

Approach: ADOPT Overview



Technology Improvements

Vehicle attributes

Fuel prices

Photo by Keith Wipke, NREL 15986

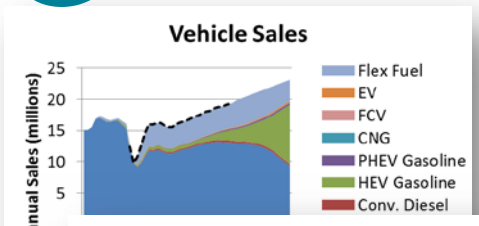
Policy (CAFE)

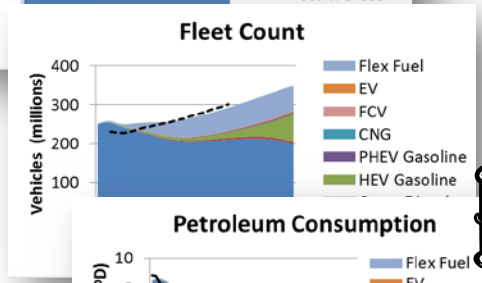
Income distribution

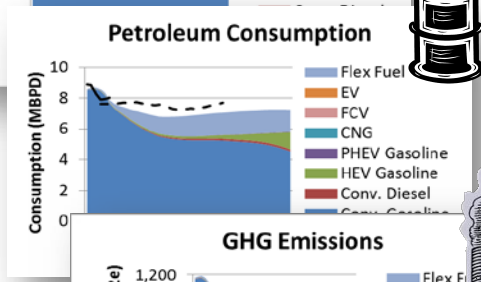
Fueling station availability

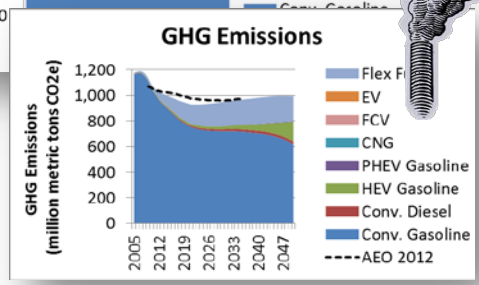
Photo by Michael Penev, NREL 19206

Weighting (logit) Function









Approach: Overview

Include all relevant VTO technologies

Capture key consumer choice aspects

Validate in relevant dimensions

Understand the results

Expand tool use

Attribute trade-offs

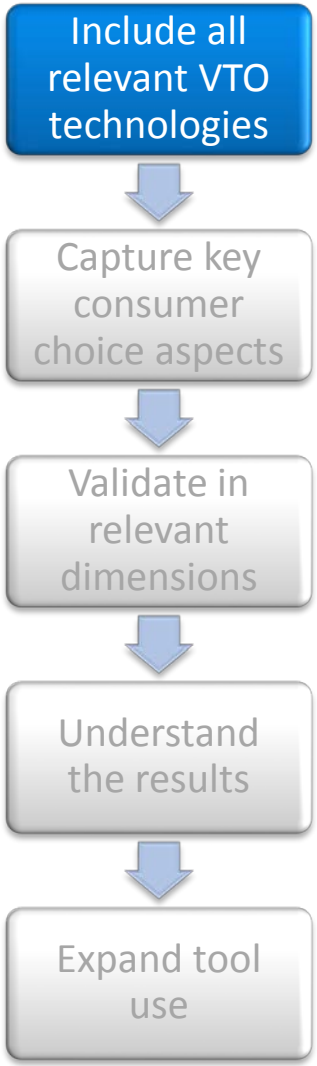
Vehicle options

Consumer heterogeneity

Policy implications

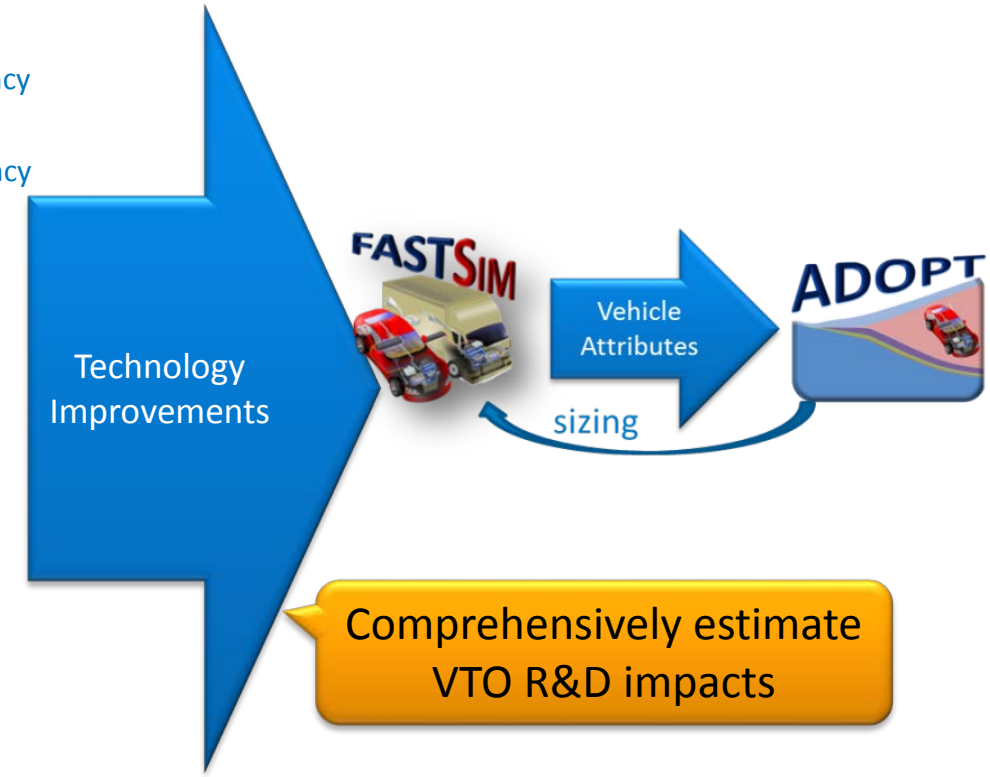
Accomplishments:
All areas were improved
(except attribute trade-offs, which work well)

Accomplishments: Added All VTO R&D Impacts



- **Added remaining relevant VTO R&D improvements over time**
  - Battery price
  - Motor price
  - Gasoline engine efficiency
  - Diesel engine efficiency
  - Atkinson engine efficiency
  - Lightweighting
  - Fuel cell price
  - Hydrogen storage price
  - Compressed natural gas (CNG) storage price
  - CNG engine efficiency
  - Fuel cell efficiency
  - Fuel cell size
  - Hydrogen storage size
  - CNG storage size
  - Battery mass
  - Hydrogen storage mass
  - CNG storage mass

New



Comprehensively estimate VTO R&D impacts

- **Benefit: Captures VTO R&D impacts on petroleum and GHG goals**

Approach: Capture Attribute Trade-Offs

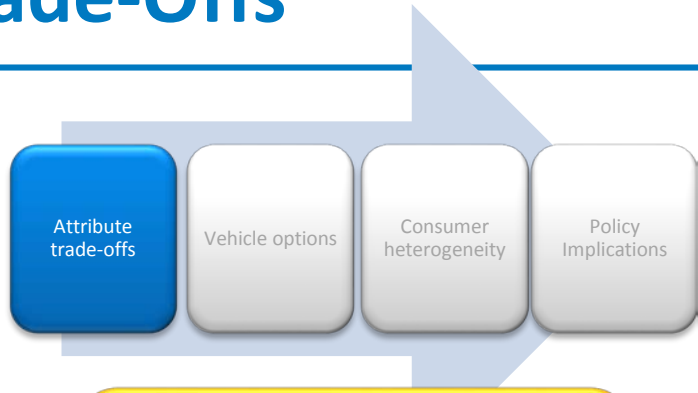
Include all relevant VTO technologies

Capture key consumer choice aspects

Validate in relevant dimensions

Understand the results

Expand tool use



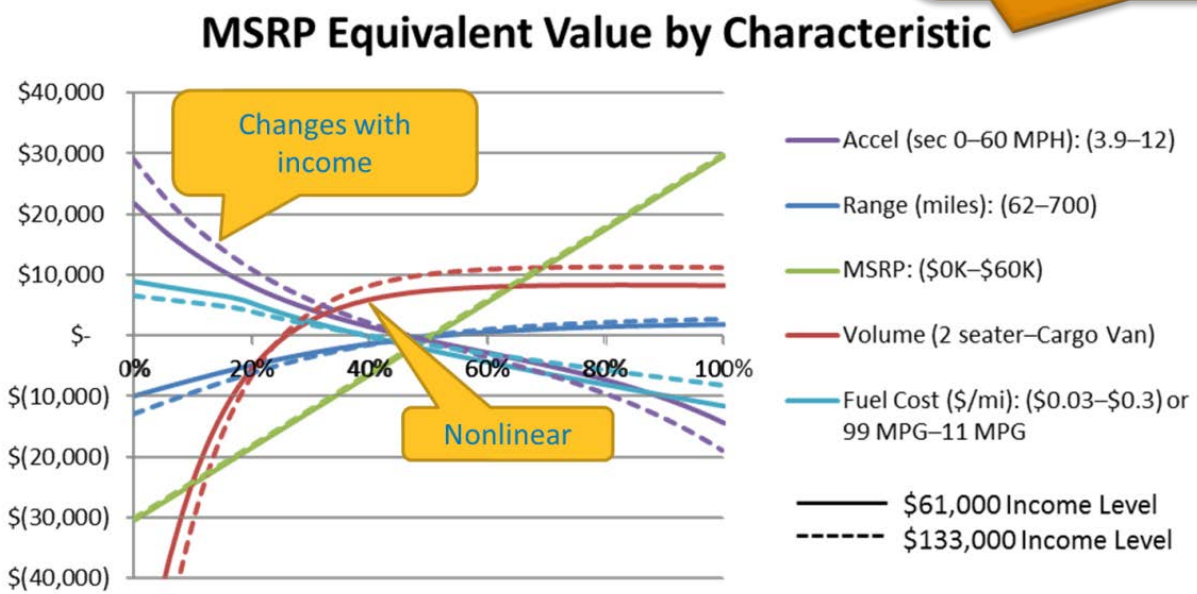
Nonlinear preferences

Going from a range of 100 to 200 miles is more important than going from a range of 500 to 600 miles

Preferences change with income

- Higher-income consumers are less influenced by cost and more influenced by performance (the MSRP equivalent value of acceleration changes more for higher income levels).
- Income, and thus preferences, change over time.

These nonlinear, income dependent trade-offs were required to match historical sales



MSRP: Manufacturer's Suggested Retail Price

Accomplishments: Improved the Introduction of New Vehicle Options

Include all relevant VTO technologies

Capture key consumer choice aspects

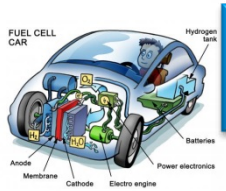
Validate in relevant dimensions

Understand the results

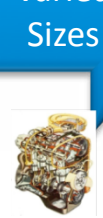
Expand tool use

Attribute trade-offs | Vehicle options | Consumer heterogeneity | Policy Implications

1. One new powertrain is specified



Varied Sizes



2. The powertrain is copied into best-selling vehicles

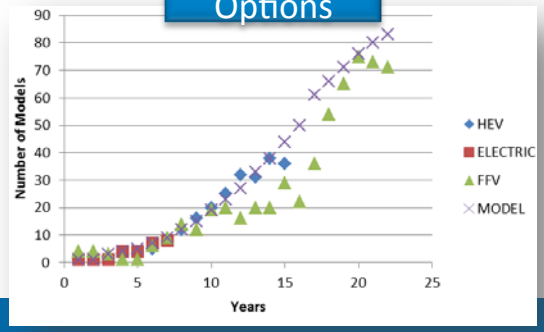
New Options

3. FASTSim estimates vehicle attributes

Attributes

4. New vehicles go into the choice model

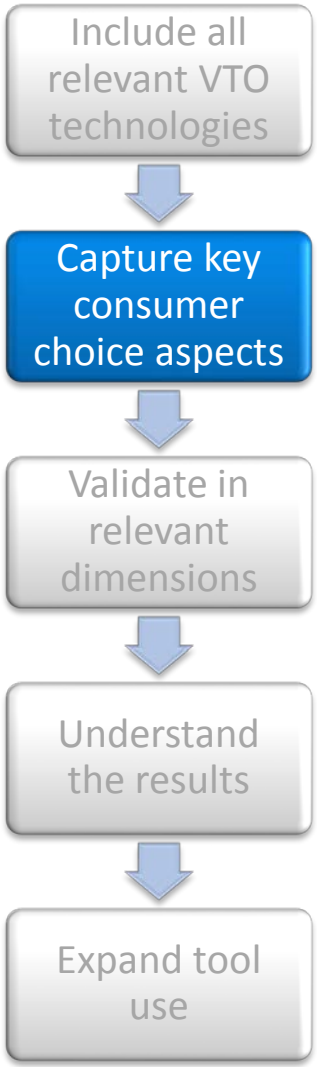
Number of Options



This process finds marketable new powertrain options (Prius, Leaf, Tesla)

FFV: flex fuel vehicle

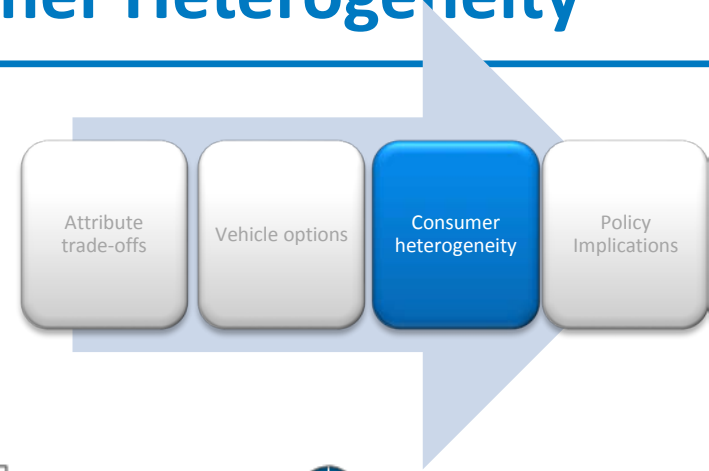
Accomplishments: Expanded Consumer Heterogeneity

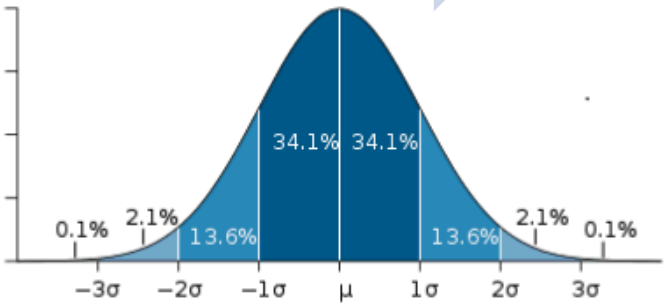


Increased consumer heterogeneity to improve substitution patterns

- Example: If a new truck option is introduced, other truck sales go down more than other car sales
- Added 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

Heterogeneity improves realism with variation in consumer tastes

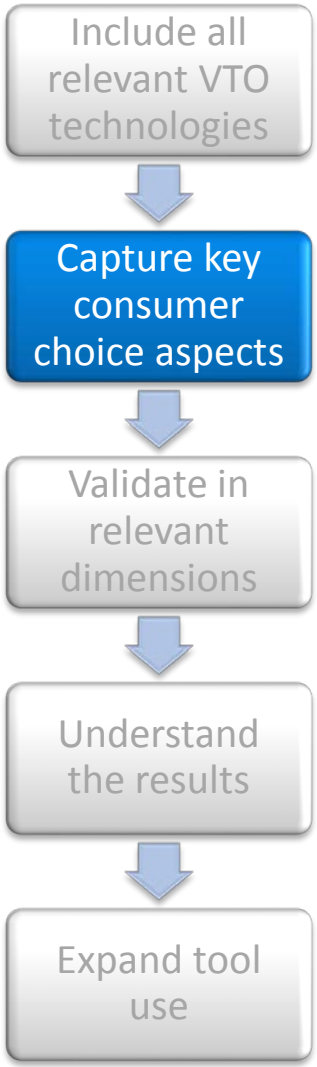




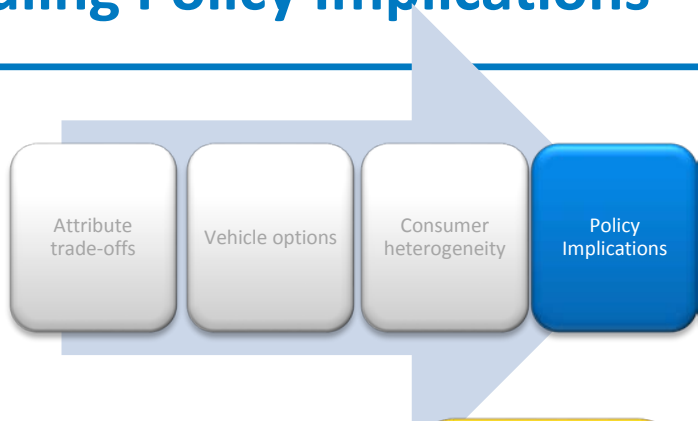
$$S_V = \frac{EXP(\sum_A (E_A \times V_A))^x}{\sum_V (EXP(\sum_A (E_A \times V_A))^x)}$$

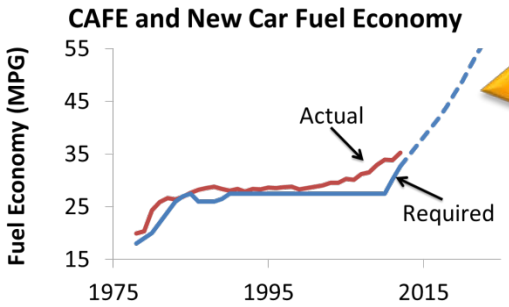
S_V: Market share for vehicle model V
E_A: Coefficient for attribute A
V_A: Value of attribute A for vehicle V
x: Sales distribution factor

Accomplishments: Added CAFE and GHG Ruling Policy Implications

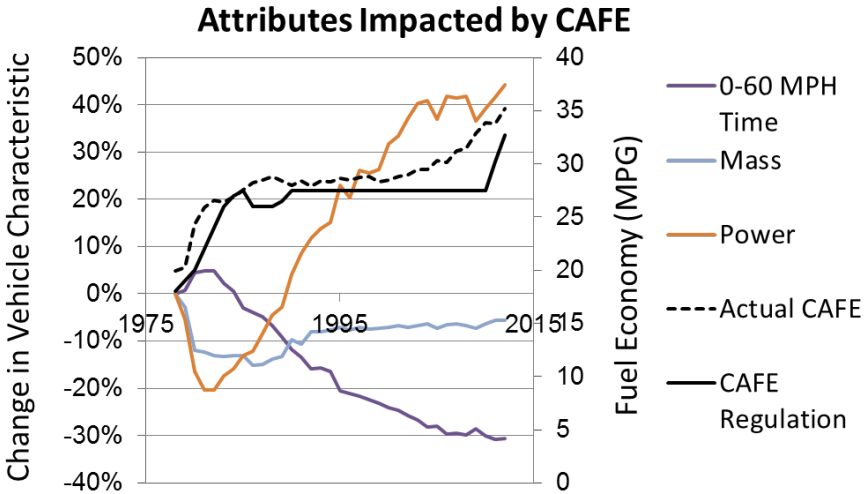


- **CAFE and GHG rule implications**
  - New vehicle fuel economy is driven by CAFE
  - CAFE is increasing sharply
  - Major impact on vehicle options and sales.
- **Added data for CAFE and GHG ruling**
  - CAFE is based on vehicle footprint—added data to all vehicles
  - Added regulation-based GHGs by fuel.
- **Added techniques to help meet the CAFE and GHG ruling based on current and past trends**
  - Technology improvements
  - Engine downsizing: Reduces fuel economy, cost, and acceleration
  - Incentives/penalties (iterates until the totals balance each year).





Important to capture because of the large increase



Approach: Validate in Relevant Dimensions

Include all relevant VTO technologies

Capture key consumer choice aspects

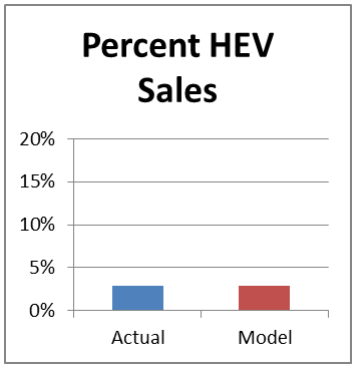
Validate in relevant dimensions

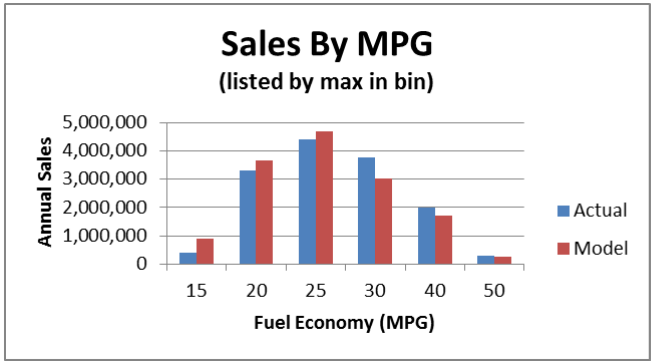
Understand the results

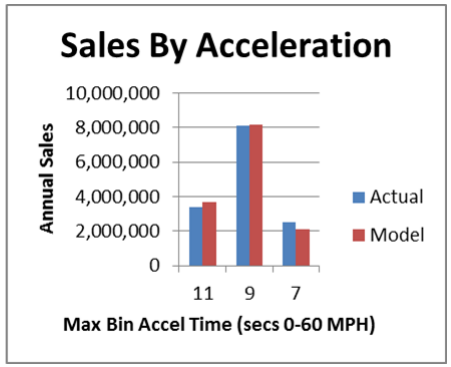
Expand tool use

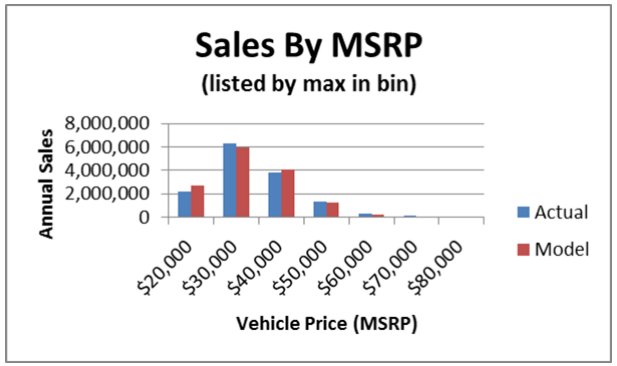
Validating for a given set of vehicles provides confidence in attribute trade-offs

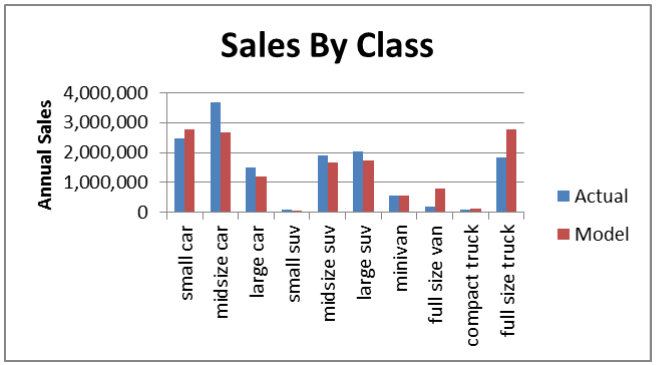
2012 U.S. Sales (matches similarly for 10 other years/regions)











Accomplishments: Improved Validation

Include all relevant VTO technologies

Capture key consumer choice aspects

Validate in relevant dimensions

Understand the results

Expand tool use

Expanded vehicle attributes to change by year

- Example: Volt MSRP drops from $40K to $35K (2011–2013)
- More accurate validation

Validating over time provides confidence in how the model changes the set of vehicles

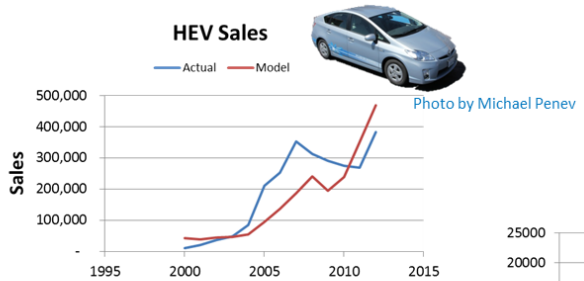


Photo by Michael Penev

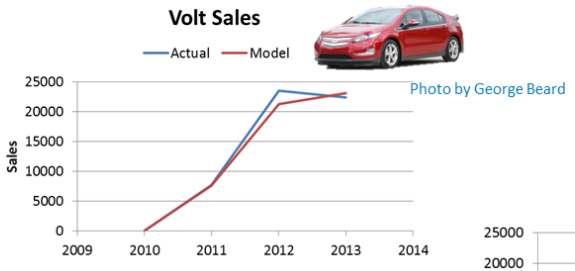
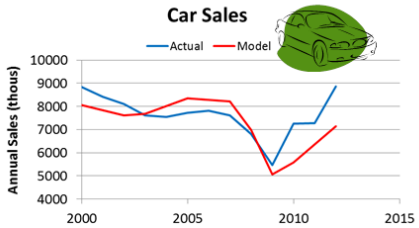
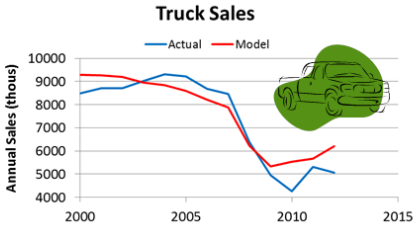


Photo by George Beard





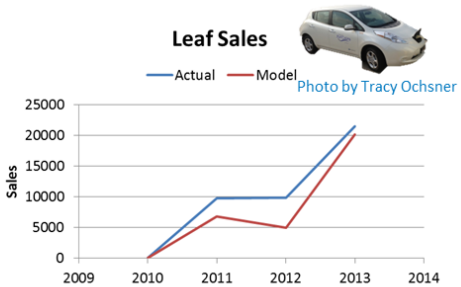


Photo by Tracy Ochsner

Accomplishments: Completed VTO Impact Analysis and Improved Interface for Understanding the Results

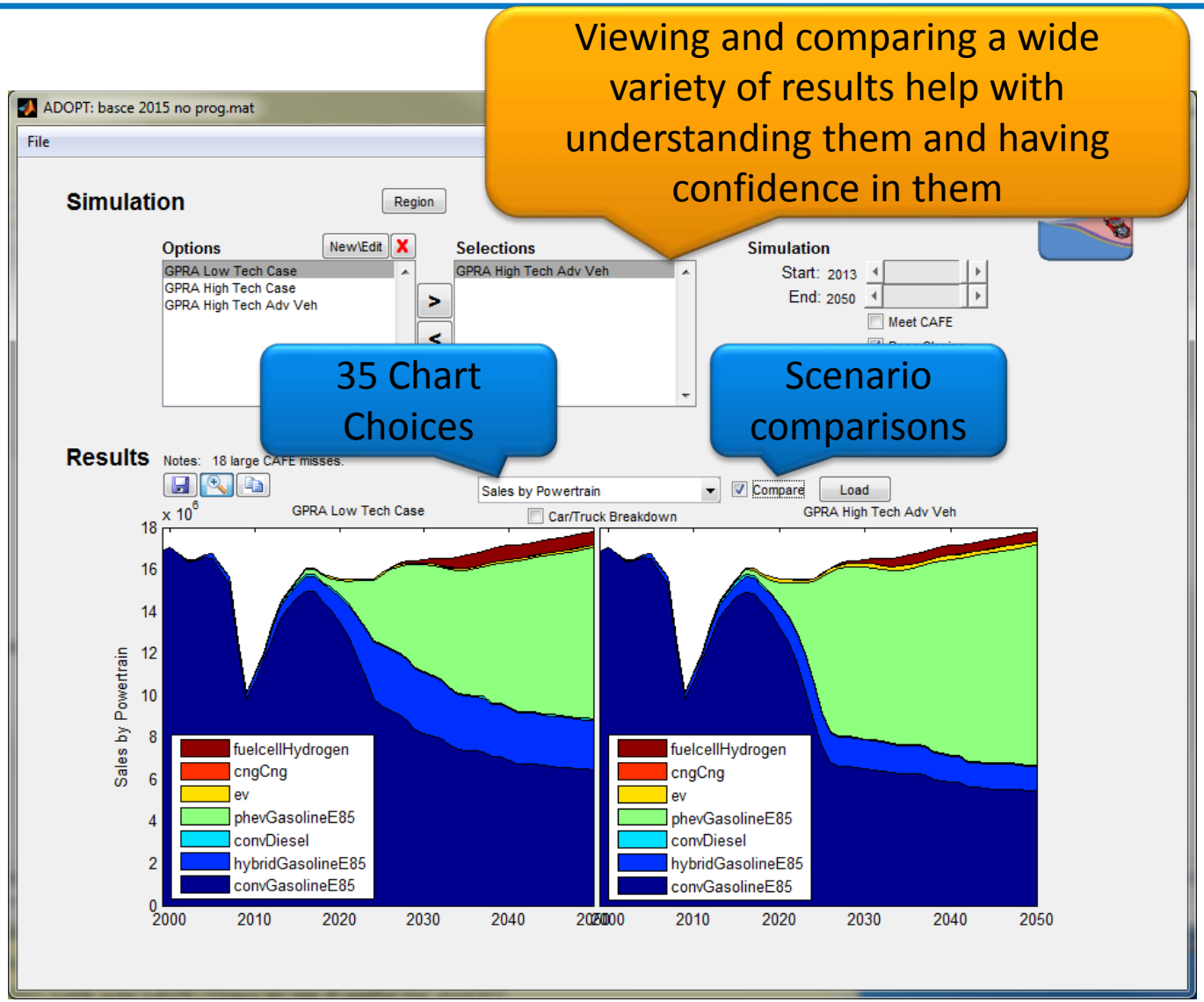
Include all relevant VTO technologies

Capture key consumer choice aspects

Validate in relevant dimensions

Understand the results

Expand tool use



Viewing and comparing a wide variety of results help with understanding them and having confidence in them

35 Chart Choices

Scenario comparisons

Accomplishments: Completed VTO Impact Analysis and Improved Interface for Understanding the Results

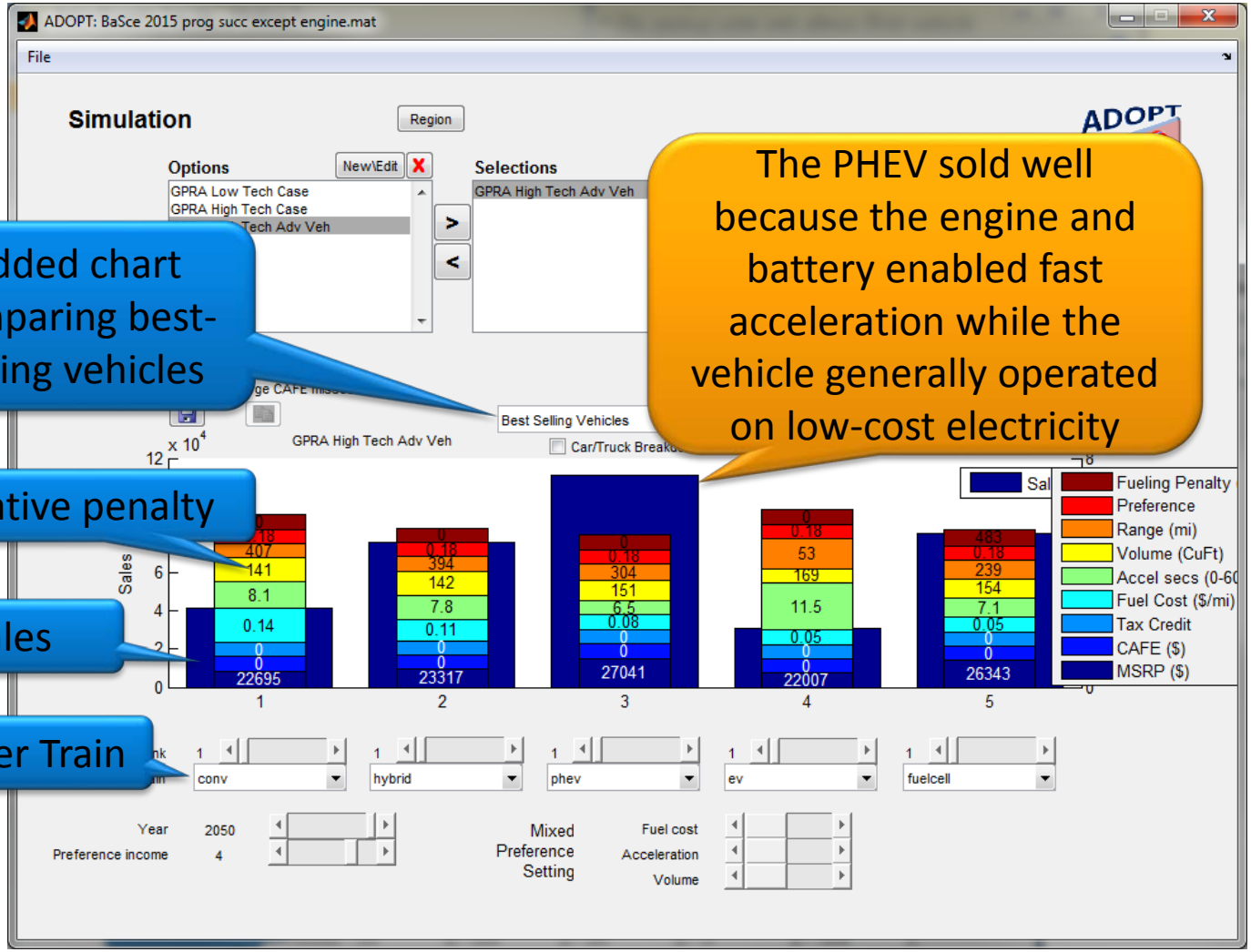
Include all relevant VTO technologies

Capture key consumer choice aspects

Validate in relevant dimensions

Understand the results

Expand tool use



Added chart comparing best-selling vehicles

The PHEV sold well because the engine and battery enabled fast acceleration while the vehicle generally operated on low-cost electricity

Relative penalty

Sales

Power Train

PHEV: plug-in hybrid electric vehicle

Accomplishments: Improved Interface to Expand Use

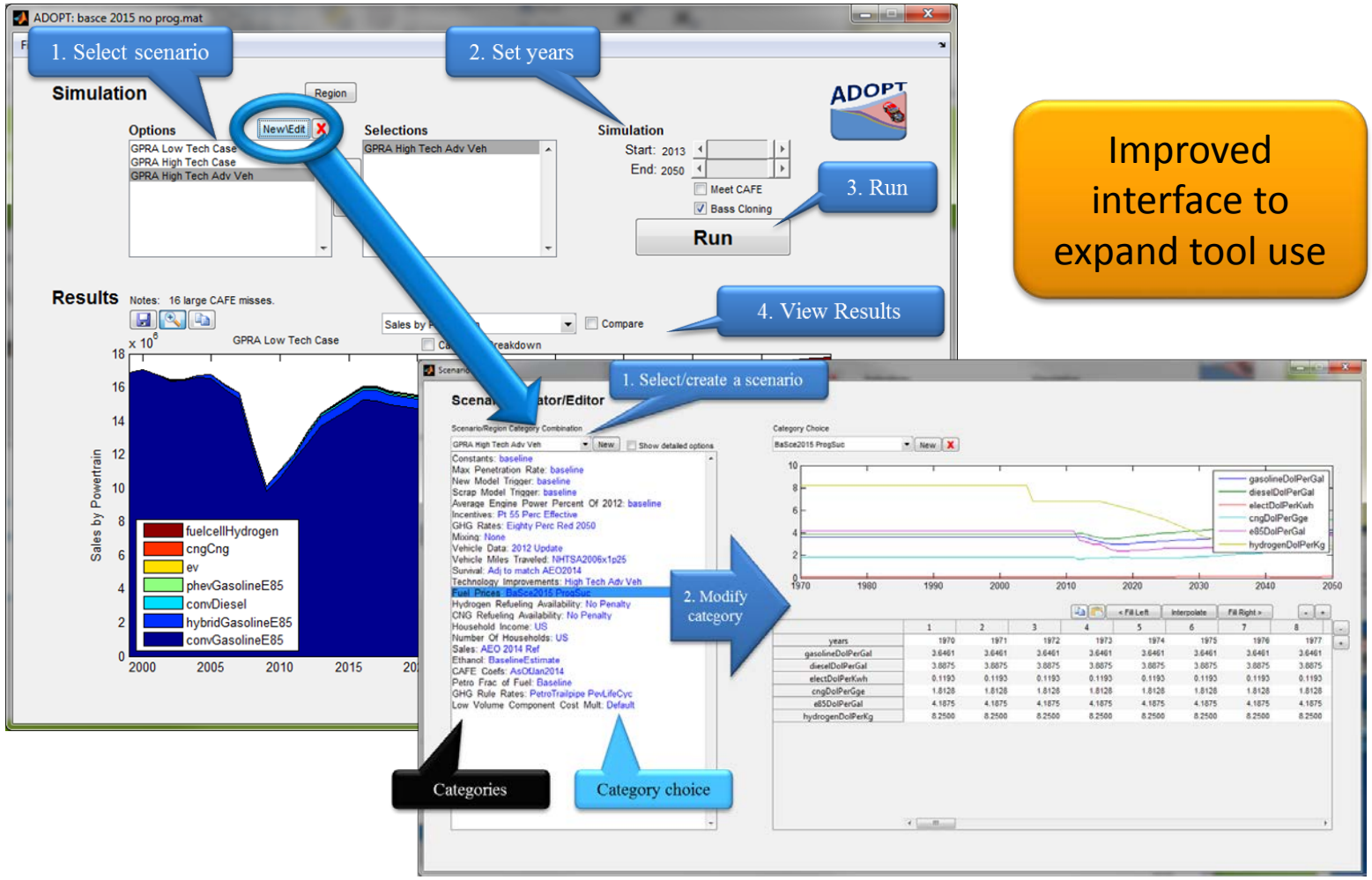
Include all relevant VTO technologies

Capture key consumer choice aspects

Validate in relevant dimensions

Understand the results

Expand tool use



Improved interface to expand tool use

Response to Previous Year Reviewers' Comments

- "The reviewer felt that the **effect of CAFE** will be important."
  - Response: This is a very good point. CAFE drives the increase in fuel economy, and is increasing sharply. The CAFE and GHG rule were implemented in ADOPT, footprint data were added for all vehicles, and techniques were developed to meet the regulations.

- "The reviewer stated that there was lots of progress, but that the project seems to be **assuming that existing data and validations can be extended to new technology types**."
  - Response: This is another good point. While some approaches to estimating consumer adoption focus on perceptions of new technologies, ADOPT assumes that when most people purchase a vehicle, they tend to focus primarily on what the vehicle does for them. Specifically, it assumes people choose based on price, fuel cost, acceleration, range, size, and refueling availability, which are characteristics of existing and new technology types.

- **"…it was not explained how new models are introduced."**
  - Response: This is also a very good point. The approach to introducing new models is critical. If the approach doesn't capture a variety of options that have different acceleration, price, efficiency, size, and range, it will likely miss the most popular advanced vehicles. For example, if a limited dataset is used that assumes a single HEV that has similar performance to an average conventional vehicle, it would miss the Toyota Prius with its relatively slow acceleration[1], and the Prius accounts for half of HEV sales[2]. Therefore, we improved how new models are introduced and added a slide describing the details.

1. "The Ten Slowest Cars We Tested in 2010," Motor Trend (online). 2010. http://wot.motortrend.com/ten-slowest-cars-tested-2010-20289.html
2. U.S. Department of Energy, Energy Efficiency and Renewable Energy, Alternative Fuels Data Center, http://www.afdc.energy.gov/data/search?q=hybrid+sales.

Collaboration and Coordination

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

Led to improvements in substitution patterns (expanded heterogeneity)

Improved confidence in the model from the positive feedback

- **Worked with ANL to compare approach and results with**
  - MA3T (ORNL)
  - LVChoice (Energetics)
  - LAVE_Trans (ORNL)

Improved understanding of results

Expanded error checking

- **Obtained data from:**
  - PA Consulting Group
  - Polk
  - SRA International (Sentech)

Expanded validation and confidence

Challenges/Proposed Future Work

- Doesn't capture the impacts that VTO R&D has on heavy-duty vehicles
  - Proposing to integrate an approach to capturing heavy-duty vehicles
- New CNG vehicle options are not being created
  - Fully integrate CNG vehicles
- Needs more flexibility to simulate different regions (incentives, fuel prices, income distributions
  - Completing in FY15
- Does not account for impacts of the ZEV mandate
  - Proposing for FY16
- Allows all consumers to benefit from tax incentives when actual incentives depend on income
  - Proposing for FY16
- Doesn't capture neighbor effects, connected and autonomous vehicles, or PEV charging infrastructure impacts
  - Proposing for FY16
- Model requires MATLAB license, which limits distribution and use
  - Modify to enable MATLAB compilation

Improve Comprehensiveness

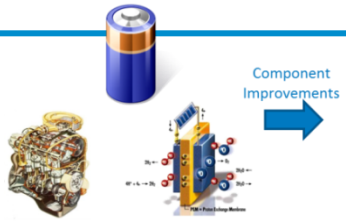
Improve Accuracy

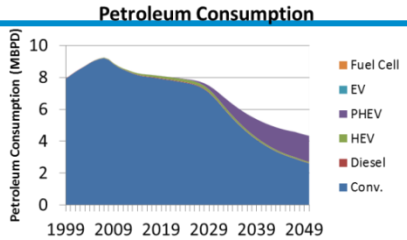
Expand use

Summary

Relevance: Estimate VTO R&D Impact

Objective: Improve the approach





Approach

Include all relevant VTO technologies → Capture key consumer choice aspects → Validate in relevant dimensions → Understand the results → Expand tool use

Accomplishments

- Added all relevant VTO R&D targets to assess their impact on petroleum use and GHG emission
- Improved the approach to creating new model options to find the most marketable configurations
- Expanded the consumer heterogeneity to improve realism and substitution patterns
- Added the CAFE and GHG rule to capture large policy impacts
- Improved the validation (validation over time) to provide confidence in the results
- Added results charts to review and understand results
- Completed VTO impact assessment
- Improved the interface to expand use and better leverage the effort.

Proposed future work

- Add heavy-duty vehicles to more comprehensively capture VTO R&D impacts
- Expand new vehicle powertrain options approach to CNG vehicles to more comprehensively capture VTO R&D impacts
- Improve the accuracy by adding the ZEV mandate and adding income impacts to the federal tax incentives
- Add neighbor effects, connected and autonomous vehicle impacts, and PEV charging infrastructure impacts
- Update model to enable compiling so users do not need a MATLAB license so more people can leverage the tool.

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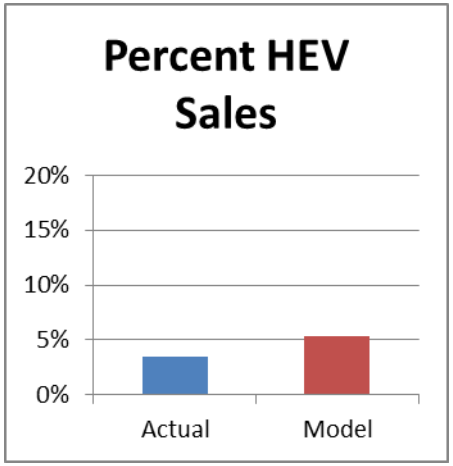
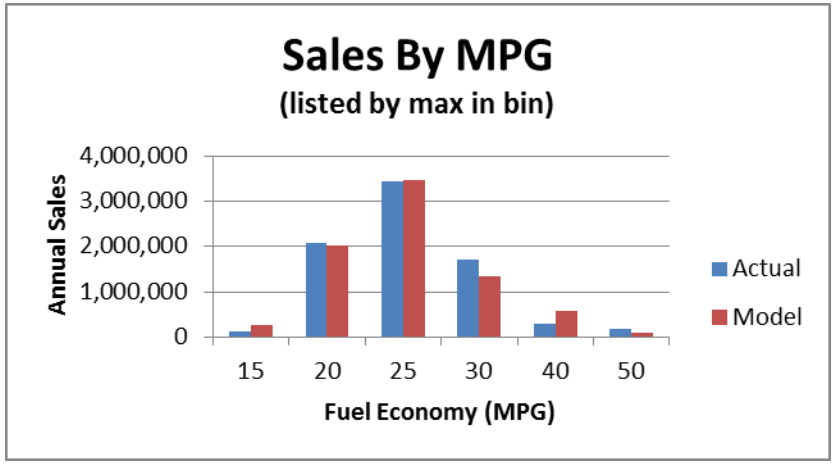
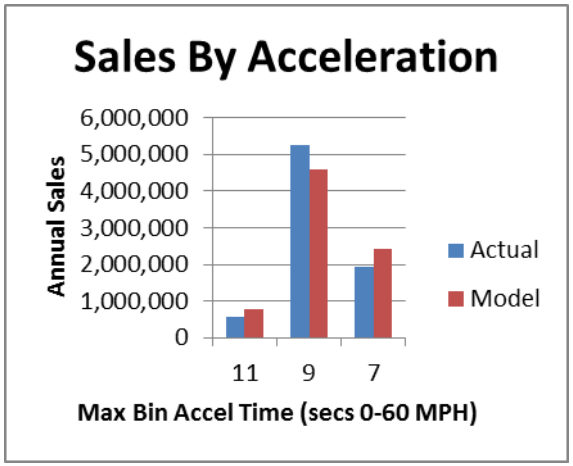
Technical Back-Up Slides

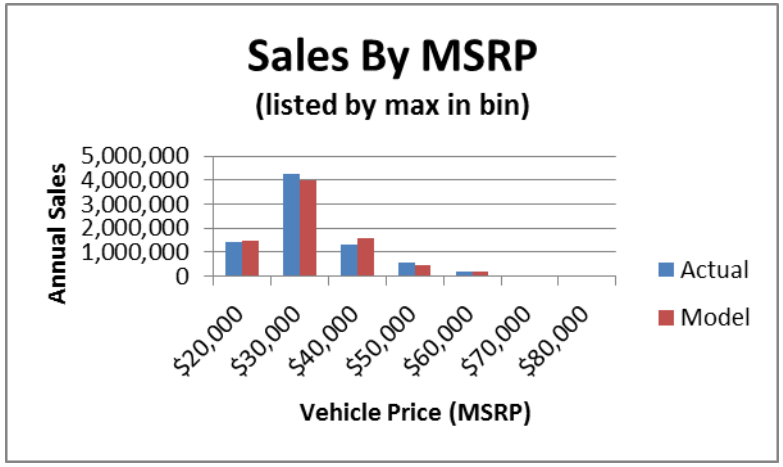
Choice Model: Validation

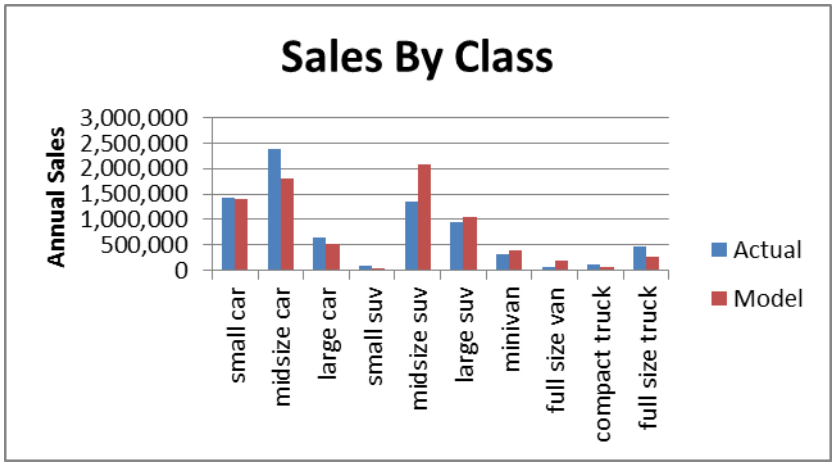
2008 U.S. Sales





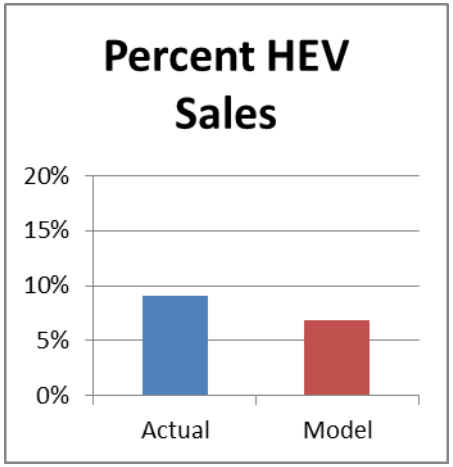


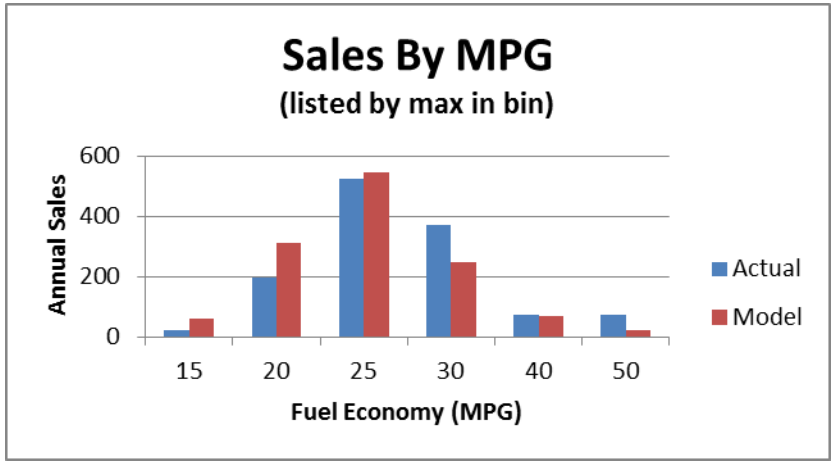


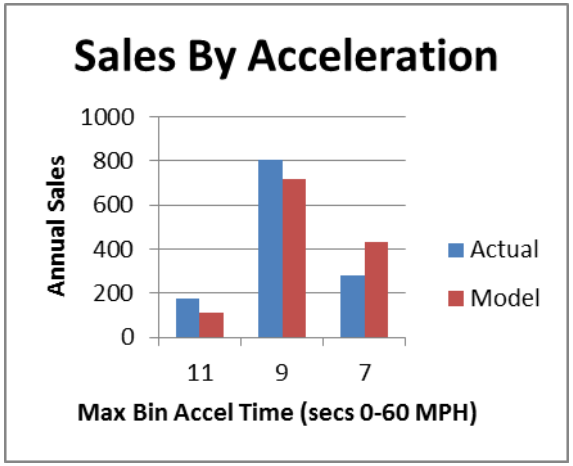


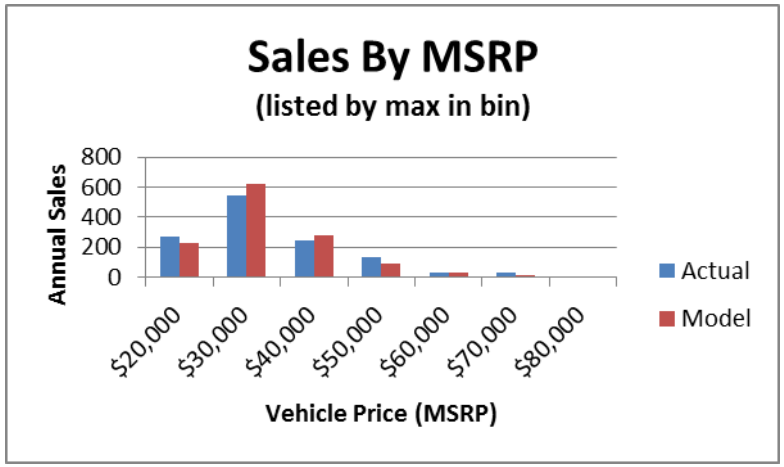
Choice Model: Validation

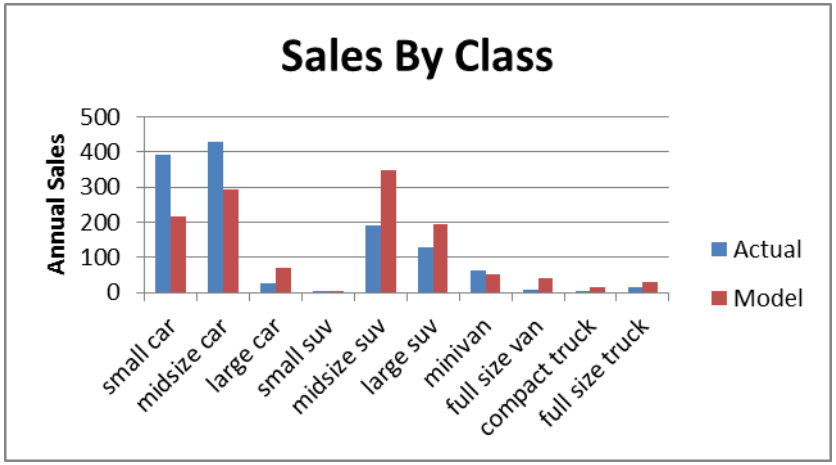
2008: 90004 (Los Angeles, CA)





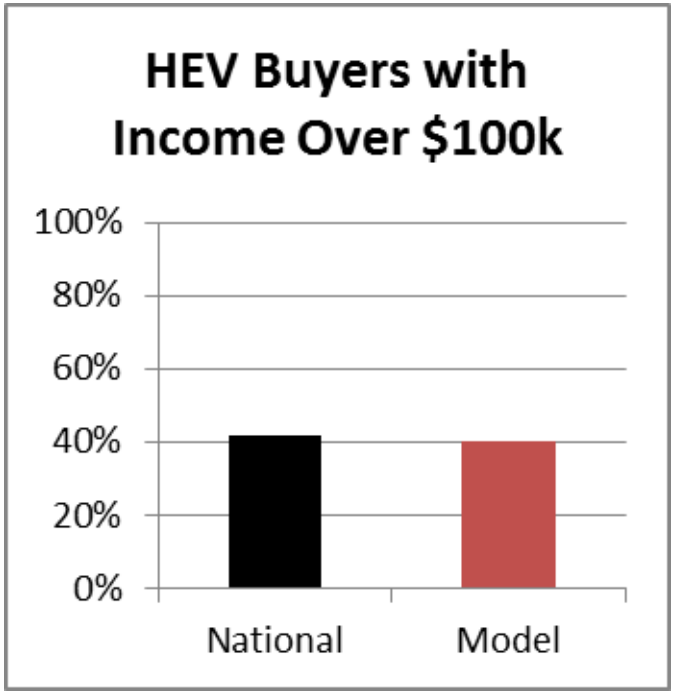


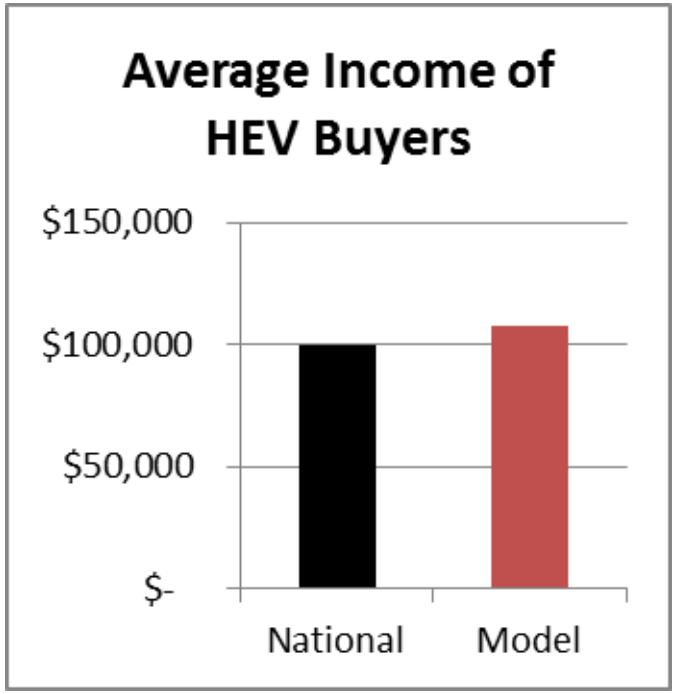




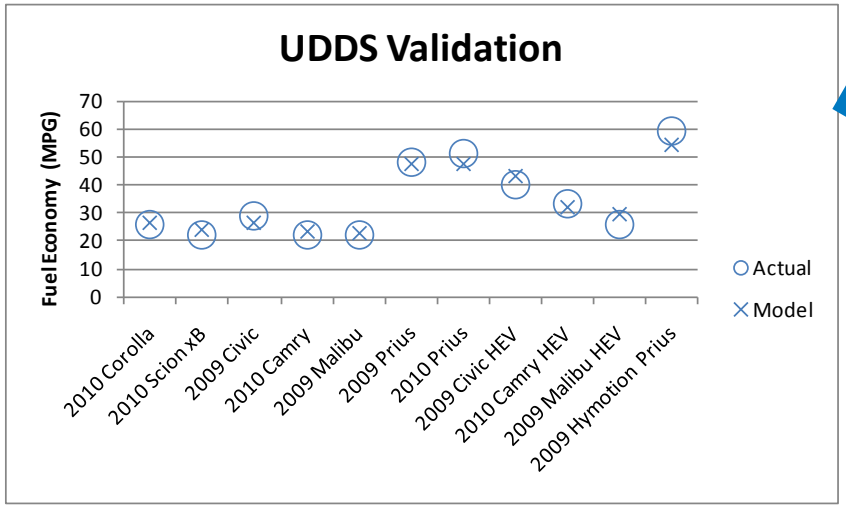
Choice Model: Validation

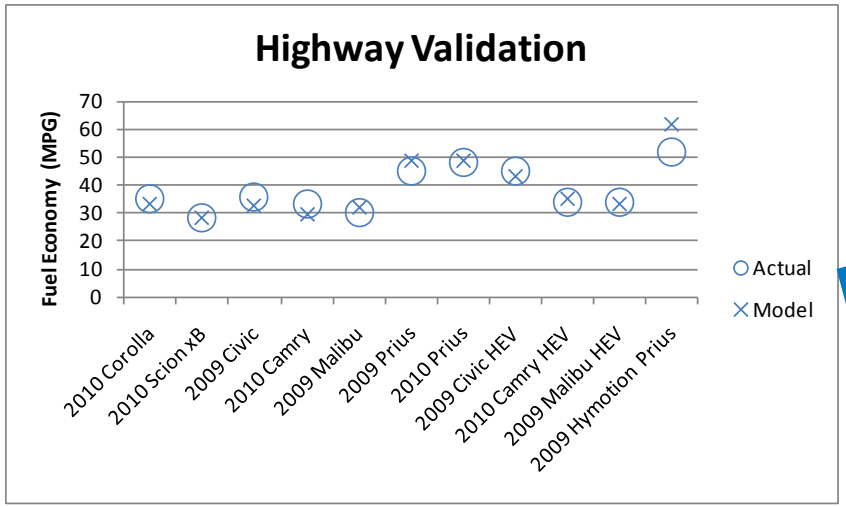
2012 U.S. Sales
Model matches *who* is purchasing hybrids

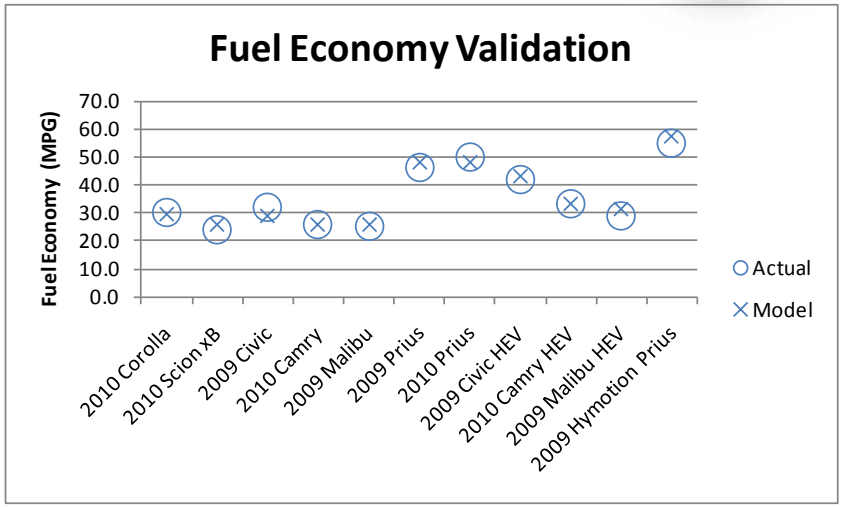


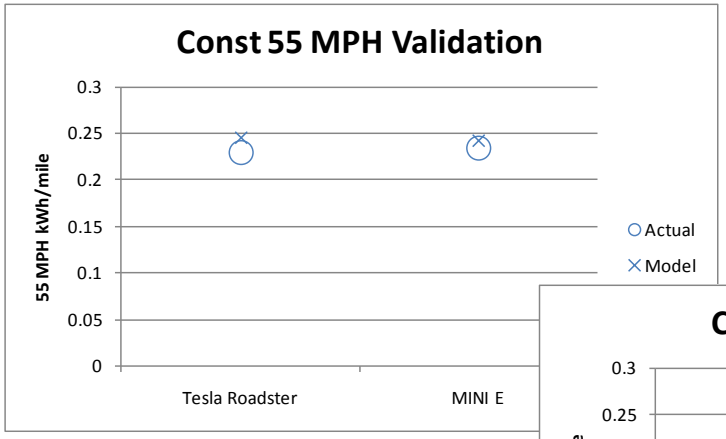
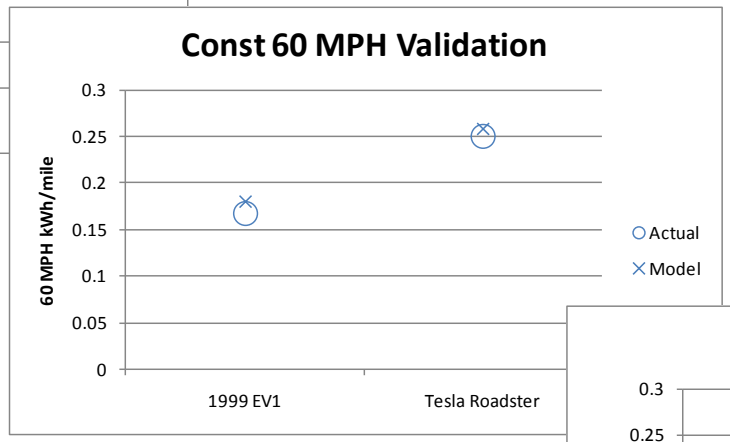
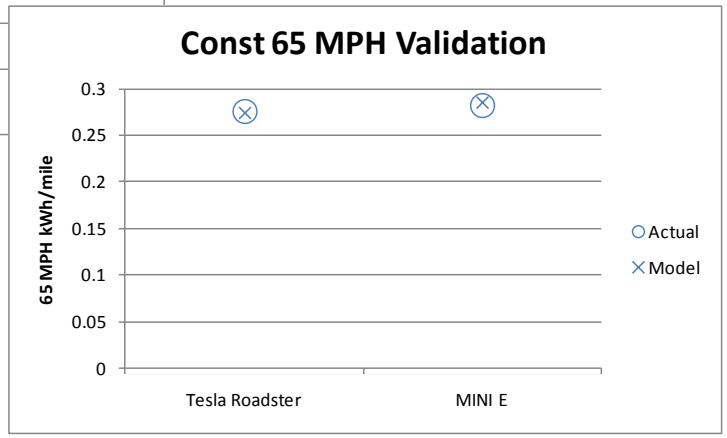


FASTSim Fuel Economy Validation







UDDS: Urban Dynamometer Driving Schedule

FASTSim EV Efficiency Validation