Fuel Economy Information Project: Research, Data Validation, and Technical Assistance Related to Collecting, Analyzing, and Disseminating Accurate Fuel Economy Information

Brian West, Bo Saulsbury (PI), John Thomas, Shean Huff, Tim LaClair
*Oak Ridge National Laboratory*

David Greene, *University of Tennessee*

DOE Management Team:
Dennis Smith, Linda Bluestein
*Vehicle Technologies Office*
*U.S. Department of Energy*


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

Timeline

• Annual, fiscal year project
• Ongoing research to support Fuel Economy Guide and fueleconomy.gov

Budget

• FY14: $1000k
• FY15: $975k
  o $600k for research to develop and validate fuel efficient driving and maintenance tips and provide technical assistance
  o $375k for research on market for fuel economy, official MPG vs. real world MPG, and "Personalized MPG"

Barriers Addressed

• Consumer reluctance to purchase new technologies
• Lack of technical experience with new fuels and vehicle technologies
• Consumers lack confidence in official MPG estimates and tend to undervalue the potential savings associated with fuel efficient vehicles
• Misinformation about fuel economy is widely disseminated
• “Conventional wisdom” about fuel economy changes as vehicle technologies evolve

Partners

• DOE Clean Cities
• ORNL (Project Lead)
• The University of Tennessee
• The University of California, Davis
• NREL and ANL
• Transportation Research, Inc.
PROJECT RELEVANCE

• Fuel Economy Guide and fueleconomy.gov fulfill DOE’s statutory responsibility to provide fuel economy information to the public in collaboration with EPA (49 USC 32908, 2006).

• Objectives (from FY15 Annual Operating Plan):
  • Promote consumer interest in fuel economy and advanced vehicle technologies in order to reduce dependence on petroleum and promote the use of clean energy alternatives.
  • Conduct research to support those functions and to improve understanding of the market for automotive fuel economy and advanced technology vehicles; conduct engineering research to validate and update fuel efficient driving and maintenance tips for fueleconomy.gov.
PROJECT RELEVANCE

Addresses specific barriers identified in VTO’s Multi-Year Program Plan 2011–2015:

• Research to validate existing and develop new fuel efficient driving and maintenance tips; to understand how consumers use and value fuel economy information; and to analyze the relationship between official MPG estimates and real world MPG.

• Leads to new information and tools on fueleconomy.gov to address barriers:
  • consumer reluctance to purchase new technologies
  • consumers’ lack of technical experience with new fuels and vehicle technologies

And other barriers:

• consumers lack confidence in official MPG estimates and tend to undervalue the potential savings associated with fuel efficient vehicles
• misinformation about fuel economy is widely disseminated
• “conventional wisdom” about fuel economy changes as vehicle technologies evolve
PROJECT APPROACH: FY14 MILESTONES

FY14

✓ Completed “Where the Energy Goes” charts for advanced technology gasoline and hybrid vehicles and deployed charts on fueleconomy.gov.

✓ Completed publication on fuel economy effects of vehicle alterations (low tire pressure, open windows, rooftop and hitch-mounted cargo, and trailer) and added information to fueleconomy.gov.

✓ Completed feasibility report on results of “Personalized MPG” research.

✓ Developed new fuel economy vs. speed curves for emerging vehicle technologies and deployed “Speed Penalty” tool on fueleconomy.gov.

✓ Completed assessment of hybrid vehicle sensitivity to driving style (“regenerative braking study”).
PROJECT APPROACH: FY15 MILESTONES

FY15

✓ Published results quantifying light-duty vehicle powertrain efficiencies for standard EPA cycles, and documenting recent improvements in vehicle powertrains and tractive power requirements.

✓ Developed a consumer-oriented page on fuel octane and deployed page on fueleconomy.gov.

• Organize meeting of the fueleconomy.gov government/industry discussion group for continued discussion of future research activities (on track)

• Progress report on FY15 Personalized MPG estimates research (on track).

• Progress report on FY15 update to “Fuel Economy vs. Speed” analysis with emerging vehicles (on track).
PROJECT APPROACH

• Conduct research to validate existing and develop new fuel efficient driving and maintenance tips for fueleconomy.gov:
  ▪ Conduct literature reviews, mine available data (EPA, OEMs, ANL, INL)
  ▪ Design and execute on-road and laboratory vehicle experiments
  ▪ Consult with FE discussion group and industry and lab peers
  ▪ Publish research results and update fueleconomy.gov

• Conduct research to develop personalized MPG estimates to address consumers’ lack of confidence in official MPG estimates.

• Conduct research using “My MPG” data to analyze the relationship between official MPG estimates and real world MPG.

• Conduct on-road and survey research to understand how consumers use and value fuel economy information.

• Provide direct consumer outreach and technical assistance; respond to questions from fueleconomy.gov users and the automotive and consumer media.

• Support Clean Cities Program with “on call” technical assistance.
ACCOMPLISHMENTS AND PROGRESS

- FE.gov hosted >49.7 million user sessions in MY14
  - >350 million users sessions since 1999.
- FE.gov cited in >2,500 media articles and blog posts since 2013.
  - Continue to be important resource for media stories about gasoline prices, fuel economy, AFVs, and electric drive vehicles.
ACCOMPLISHMENTS AND PROGRESS

• Continued to validate existing and add new fuel efficient tips, especially for hybrids, PHEVs, and EVs
• Driving more efficiently
• Keeping your car in shape
• Planning and combining trips
• Choosing a more efficient vehicle
• Tips for hybrids, PHEVs, and EVs
• Tips for cold and hot weather (Backup Slide)
ACCOMPLISHMENTS AND PROGRESS

- Researched effects of intake air filter condition (backup slide)
  - Commonly held misconception that dirty air filter decreases fuel economy

- Published SAE Paper *Effect of Intake Air Filter Condition on Light-Duty Gasoline Vehicles*, and SAE Paper *Effect of Air Filter Condition on Diesel Vehicle Fuel Economy*

- Added new information on fueleconomy.gov
ACCOMPLISHMENTS AND PROGRESS

• Researched fuel economy effects of air conditioner use

• Published SAE Paper *Effects of Air Conditioner Use on Real-World Fuel Economy*

• Added new information on fueleconomy.gov
ACCOMPLISHMENTS AND PROGRESS

- Researched effects of vehicle speed on fuel economy (backup slide)
- Published SAE Paper *Predicting Light-Duty Vehicle Fuel Economy as a Function of Highway Speed.* (Effort included data mined from OEM partner as well as ORNL test data.)
- Developed new fuel economy vs. speed curves for emerging vehicle technologies and deployed “Speed Penalty” tool on fueleconomy.gov (milestone)
ACCOMPLISHMENTS AND PROGRESS

• Researched fuel economy effects of vehicle alterations (backup slide)

• Published SAE Paper Fuel Economy and Emissions Effects of Low Tire Pressure, Open Windows, Roof Top and Hitch-Mounted Cargo, and Trailer (milestone)

• Added new information on fueleconomy.gov
ACCOMPLISHMENTS AND PROGRESS

- Quantified light-duty vehicle powertrain efficiencies for standard EPA cycles and documented recent improvements in vehicle powertrains and tractive power requirements

- Published article “Drive Cycle Powertrain Efficiencies and Trends Derived from EPA Vehicle Dynamometer Results” in SAE International (milestone)
• Completed “Where the Energy Goes” analyses for advanced technology gasoline and hybrid vehicles (milestone)

• Updated/added new pages on fueleconomy.gov

Figure above shows significant improvement in light duty vehicle fuel economy since ~2005. Figure taken from “Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 – 2013,” EPA-420-R-13-11, U.S. EPA, Office of Transportation and Air Quality
• Analyzing the relationship between official MPG estimates and real world MPG (backup slide)

• Current “MY MPG” analysis show great variability in individuals’ own MPG estimates relative to official government estimates, but evidence of only modest bias relative to the sample average. Estimates are inaccurate for many individuals even though they may be unbiased for the population as a whole (preliminary, unpublished).

• Also, there is preliminary evidence that the shortfall between test cycle MPG numbers (used to measure compliance with regulations) has been increasing since 2005, which could affect the benefits realized by fuel economy and greenhouse gas emissions standards.
ACCOMPLISHMENTS AND PROGRESS

- Completed assessment of hybrid vehicle sensitivity to driving style ("regenerative braking study")
- Added information to fueleconomy.gov (milestone)

Summary of Analysis and Findings

A Tractive Power Model was exercised to compare tractive energy use for a vehicle with hybrid and conventional powertrain over cycles with various intensities.

Results show that for the most aggressive cycles, the **hybrid fuel economy is more significantly affected** due to the limitations of the regenerative brakes.

- While the hybrid vehicle will sometimes require higher total tractive power due to higher weight (from additional powertrain), the hybrid will use less fuel than the conventional vehicle on virtually any given cycle, and the percent change in fuel use from mild to aggressive driving is more significant.
Continued research on “Personalized MPG”

- Consumers lack confidence in official MPG estimates (“Your mileage will vary”); contributes to consumers undervaluing fuel economy.
- “Personalized” MPG estimates based on individual drive cycles (as recorded by OBD devices) could help reduce this lack of confidence.
- Current study: can we develop a reasonably accurate (within 5%) model of MPG based on individual drive cycle and publicly available vehicle characteristics?
- Goal: a tool on fueleconomy.gov that can generate a Personalized MPG estimate for any vehicle based on the user’s individual drive cycle data.
- Published feasibility report on results in 2014 (milestone)
ACCOMPLISHMENTS AND PROGRESS

• Developed consumer-oriented “Octane” page on fueleconomy.gov (2015 milestone)
ACCOMPLISHMENTS AND PROGRESS

• Completed research on “driver feedback devices”

• Energy feedback to drivers appears to produce measurable increases in on-road MPG.

• Feedback device can help average driver improve MPG by about 3%; driver who uses feedback device specifically to save fuel can improve MPG by about 10%.

• Variation in MPG improvements by screen design ranged from 1.6% to 2.9%.

• People know few effective actions to improve MPG; feedback can facilitate learning and new habits.
RESPONSES TO PREVIOUS YEAR REVIEWERS’ COMMENTS

This project was not reviewed in 2014.
• DOE Clean Cities provides funding and project guidance and oversight.
• ORNL conducts research and analysis to validate existing, and develop new fuel efficient driving and maintenance tips and to develop personalized MPG estimates to address consumers’ lack of confidence in official MPG estimates.
• The University of Tennessee uses “My MPG” data to analyze the relationship between official MPG estimates and real world MPG.
• The University of California, Davis conducts research to understand how consumers use and value FE information.
• NREL conducts research on alternative fuels and AFVs to support the AFDC website.
• ANL conducts research to support the GREET model and on idle reduction, and makes available advanced vehicle data from their vehicle research efforts (leverages other VTO programs).
• Transportation Research Center, Inc., provides contract vehicle test track services such as coast downs to establish vehicle dynamometer coefficients.
PROPOSED FUTURE ACTIVITIES

- Continue to provide technical assistance for fueleconomy.gov users, the automotive and consumer media, and the Clean Cities Program.

- Expand research (gather data from a larger vehicle sample) to develop personalized MPG model and calculator.

- Continue research using “My MPG” data to analyze relationship between official MPG estimates and real world MPG.

- Continue research to understand how consumers use and value fuel economy information.

- Research to validate existing/develop new fuel efficient driving and maintenance tips:
  - Evaluate emerging vehicles and “opportunity vehicles,” mine data from partners to expand fuel economy vs. speed database, refine models (e.g., model by vehicle type)
  - Re-assess air conditioning penalty as new technologies emerge
  - Quantify effect of pre-heating/pre-cooling cabin for plug-in vehicles in cold/hot weather
  - Assess fuel economy penalty associated with accessory loads (heated seats, defroster, headlights, electronics)
  - Assess effects of additional accessories/alterations/maintenance
    - Truck bed covers/caps, roof racks (possible OEM data mining)
    - Alternate tire/tire sizes (e.g., snow tires, low rolling resistance tires)
    - Wheel alignment
    - More tire pressure data recommended
Summary

RELEVANCE
- FE.gov fulfills DOE’s statutory responsibility to provide fuel economy information to the public; Research and Technical Assistance efforts ensure that information is accurate, up-to-date, and useful

APPROACH
- Gather relevant information through vehicle experiments, data mining from literature or national lab and industry partners

ACCOMPLISHMENTS
- Numerous accomplishments in transferring engineering data to consumer information on fe.gov

COLLABORATIONS
- Work closely with other NLs, Universities, industry partners and contractors

FUTURE WORK
- Continue to provide technical assistance to fe.gov users, media, Clean Cities
- Research improved driving tips, personal mpg
Technical Backup Slides
Backup Slide: **Air Filter Study Approach and Conclusions**

**Approach**
- 5 gasoline and 3 diesel vehicles evaluated with clean and clogged intake air filters
- Shop towels used to create a consistent clogged filter state
- Dynamometer drive cycle tests conducted for fuel economy and emissions. Full power acceleration tests conducted to assess vehicle performance

**Results Summary:**
- Clogged intake air filters had no measurable effect on modern gasoline or diesel vehicle fuel economy
- Carbureted vehicle fuel economy was affected by the dirty filter, consistent with the 1970s literature (due to “choking” effect and decrease in air:fuel ratio, increase in CO emissions)
- Full power acceleration is reduced by filter clogging for **all vehicles**
- No other significant powertrain behavior changes were noted
- **Website updated based on new publications**

**Carbureted 1972 Pontiac Grandville confirmed results from 1970s literature**
Backup Slide: **Effect of Cargo Carriers, Trailers, etc.**

- Conducted Lit review; Limited amount of published data
- Experimental campaign
  - Configure vehicles and perform coastdowns to determine road load force
    - Per SAE J2263 (Road Load Measurement Using Onboard Anemometry and Coastdown Techniques)
  - Duplicate road load force in vehicle laboratory and conduct repeatable experiments

**Results Summary**

- Tire Pressure and the hitch mounted Cargo Tray had small effects on the compact sedan (<5%) and minimal effects on the sport utility vehicle (<1%).
- Large box Trailer at the maximum allowable towing capacity doubled fuel consumption of the sport utility vehicle at speeds over 65 mph.
- Roof top Cargo Box with the compact sedan decreased the fuel economy by almost 27% at 80 mph.
- Hitch mounted Cargo Tray gave much better FE results, compared to the roof top Cargo Box, for both the SUV and compact sedan for all three test cycles examined.
- Emissions not significantly affected by vehicle configuration with the exception of the cargo Trailer case, which led to protective enrichment and significantly increased CO emissions at high speed.
**Backup Slide: Fuel Economy versus Highway Speed**

OEM proving ground data combined with ORNL experiments to assess over 70 vehicles

- 74 Vehicle database (ORNL, Chrysler)
- SS speeds of 50, 60, 70 & 80mph.
- Examine % mpg change for 10mph change
- Avg. mpg change: 12.4%, 14.0% and 15.4% for 60 vs. 50, 70 vs. 60, 80 vs. 70 mph respectively. Histogram also shows trend.
- Special cases: cyl. deactivation & protective enrichment revealed more extreme FE loss at higher speeds

- No strong trend by vehicle type observed
- Slight shift to greater % FE loss at higher speeds
Backup Slide: Quantifying effects of cold weather on fuel economy

- Cost prohibitive to conduct significant number of cold laboratory experiments
  - Mined available EPA “city cycle” data for 20°F and 77°F cold starts
    - Certification requires “city test” results at 77°F (FTP) and 20°F (“cold CO”)
      - Identical drive cycle, differ only in ambient temperature
  - Analysis of these two datasets provides direct comparison of 20°F and 77°F fuel economy, allows quantitative advice on cold weather
    - Comparing Bag 1 (20F vs 77F) yields “short trip” comparison
    - Comparing full city test yields “longer trip” comparison

City test conducted in 3 phases
Engine is “cold” for Bag 1

Largest FE difference for Bag 1 (short trip). Hybrids more severely impacted (34%) than conventional vehicles (22%)
Analyzing the relationship between official MPG estimates and real world MPG

Conducted analysis of 3,000 in-use MPG data (Greene et al. 2006) and 35,000 in-use MPG data (Lin and Greene 2011) from the fueleconomy.gov “My MPG” database.

Studies indicated that EPA combined city/highway MPG estimates, adjusted for shortfall between test procedure values and real world experience, were very nearly unbiased estimators of MPG estimates reported by individuals. However, the accuracy of the EPA adjusted MPG estimates for any particular vehicle was poor, with a 95% confidence interval of +/- 7 MPG.

Project is funding an update of 2011 study by The University of Tennessee. Current study analyzes 75,000 in-use MPG data from My MPG.