

Fuel Economy Labeling of Advanced Technologies

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Agenda

- Label Fuel Economy Background & Requirements
- PHEV Example Modes of Operation
- Utility Factor
- Accounting for Electricity

Background

- Intent of fuel economy label is to provide consumers with easy to understand fuel economy estimates
- Fuel economy information is displayed on new car window sticker
- Also provided in:
 - Green Vehicle Guide
 - Available online at: www.epa.gov/greenvehicles
 - Fuel Economy Guide
 - Available at dealerships
 - Available online at: www.fueleconomy.gov
- New regulations in 2006 improved label format and made estimates more reflective of real world operation
 - 5-cycle adjustments now require either testing or a FE adjustment due to cold and hot ambient, high vehicle speed, and air conditioning loading
 - Widely supported and accepted by the public

Label Example

EPA Fuel Economy Estimates

These estimates reflect new EPA methods beginning with 2008 models.

CITY MPG

18

Expected range
for most drivers
15 to 21 MPG

HIGHWAY MPG

25

Expected range
for most drivers
21 to 29 MPG

**Estimated
Annual Fuel Cost**

\$2,039

based on 15,000 miles
at \$2.80 per gallon

Combined Fuel Economy

This Vehicle

21

10  31

All SUVs

**Your actual
mileage will vary**
depending on how you
drive and maintain
your vehicle.



See the **FREE Fuel Economy Guide** at doabrs or www.fueleconomy.gov



Statutory Label Requirements

1. The fuel economy, which is defined as the average number of miles traveled for each gallon of gasoline (or equivalent amount of other fuel)
2. The estimated annual fuel cost of operating the vehicle
3. The range of fuel economy of comparable vehicles of all manufacturers
 - Note that “other information” can be displayed in addition to the statutory requirements
 - Other regulatory requirements apply

Satisfying Statutory Label Requirements

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Example of Possibly Confusing PHEV FE Label

Confusing Fuel Economy Label Example		
Plug-in Hybrid Vehicle		
<p>All Electric Mode ALL ELECTRIC DRIVING RANGE CITY HIGHWAY 22 Miles 20 Miles</p> <p>CITY CONSUMPTION 40 kW-hr/100miles 83 MPGe</p> <p>HIGHWAY CONSUMPTION 44 kW-hr/100miles 77 MPGe</p> <p>Cost per charge: \$1.08 at 10¢ per kw-hr \$2.16 at 20¢ per kw-hr</p> <p>Estimated Annual Fuel Cost \$900 based on 15,000 miles at 15¢ per kw-hr</p>	<p>Annual Average Fuel Economy Using Average Drive Patterns and Daily Charging</p> <p>CITY FUEL ECONOMY 11 kw-hr/100miles Plus 60 MPG (39 MPGe)</p> <p>HIGHWAY FUEL ECONOMY 11 kw-hr/100miles Plus 58 MPG (40 MPGe)</p> <p>Estimated Annual Fuel Cost \$360 electricity at 15¢/kw-hr \$1,020 gasoline at \$4.00/gallon Total \$1,380 based on 15,000 miles at \$4.00 per gallon</p>	<p>Gasoline Operation Any Trip Starting with a Fully Discharged Battery</p> <p>CITY MPG 35 Expected range for most drivers: 29 to 41 MPG</p> <p>HIGHWAY MPG 35 Expected range for most drivers: 30 to 40 MPG</p> <p>Estimated Annual Fuel Cost \$1,700 based on 15,000 miles at \$4.00 per gallon</p>
<p>Your actual mileage will vary. Depending on how you drive and maintain your vehicle; particularly affected by ambient temperature, battery condition, and the use of heating and air conditioning.</p>		<p>Combined Fuel Economy This Vehicle 35</p> <p>11  47 All Midsize Cars</p>

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Advanced Tech FE Label Challenges

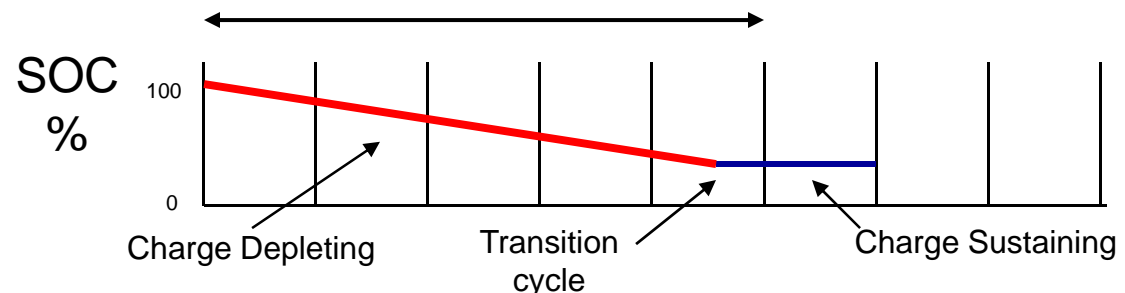
- How do label statutory requirements translate to vehicles such as Plug-In Hybrids?
- How can the Fuel Consumption be measured and labeled in an easily understandable and relevant way?
 - Specifically, how is the fuel consumption of 2 fuels displayed both by vehicle mode of operation and as an average?

PHEV Review: Modes of Operation

- **Charge Sustaining (CS)** The vehicle will operate like a conventional hybrid in charge sustaining mode. In this mode only gasoline is consumed.
- **Charge Depleting (CD)**, The vehicle is using “wall charge” energy. There are two possible CD modes.
 - **Blended** mode Vehicles can operate at lower speeds and/or loads on the electric motor without engine assist. However both battery and gasoline engine power are required to reach some operational speeds. In this mode both electricity and gas will be consumed
 - **All Electric** mode Vehicles operate at all speeds in electric mode until the battery reaches the state of charge where CS begins. A vehicle that can operate in All Electric mode may also have the ability to operate in blended mode. In all electric mode, only electricity is consumed.

Fuel Consumption Test

State of Charge (SOC)
(An “empty” battery is
not 0% SOC)



In this example, 5 test cycles are run until an entire cycle in charge sustain is reached on the 6th cycle

Statutory Label Requirements for Charge Deplete Mode

- All Electric Cd mode – same requirements as an electric vehicle, adjust the EV range and consumption via derived 5-cycle (real world)
 - Display FE in an adjusted miles per gallon equivalent
 - Consumption in “kw-hr/100 miles” is optional, but must be adjusted via 5-cycle
- Blended Cd mode – measure CO₂ and electrical consumption through entire SOC until Cs mode is reached
 - Display FE in an adjusted miles per gallon equivalent total, with 5-cycle adjustment based on total FE

EV Mode Fuel Economy, Example

1. Measured unadjusted electrical consumption

$$FC_{EV} = 27kwhr / 100miles$$

2. Convert to Fuel economy in miles per gallon equivalent of gasoline

$$FE_{MPGe} = \frac{33.7 \times 100}{FC_{EV}} \quad FE = 124mpg_e$$

3. Apply 5-cycle correction, result is label requirement

$$FE_{5cycle} = 78mpg_e$$

4. Apply 5-cycle correction ratio to consumption, result is additional label option

$$FC_{EV} = 27kwhr / 100miles \times \frac{124}{78}$$

$$FC_{EV} \cong 43kwhr / 100miles$$

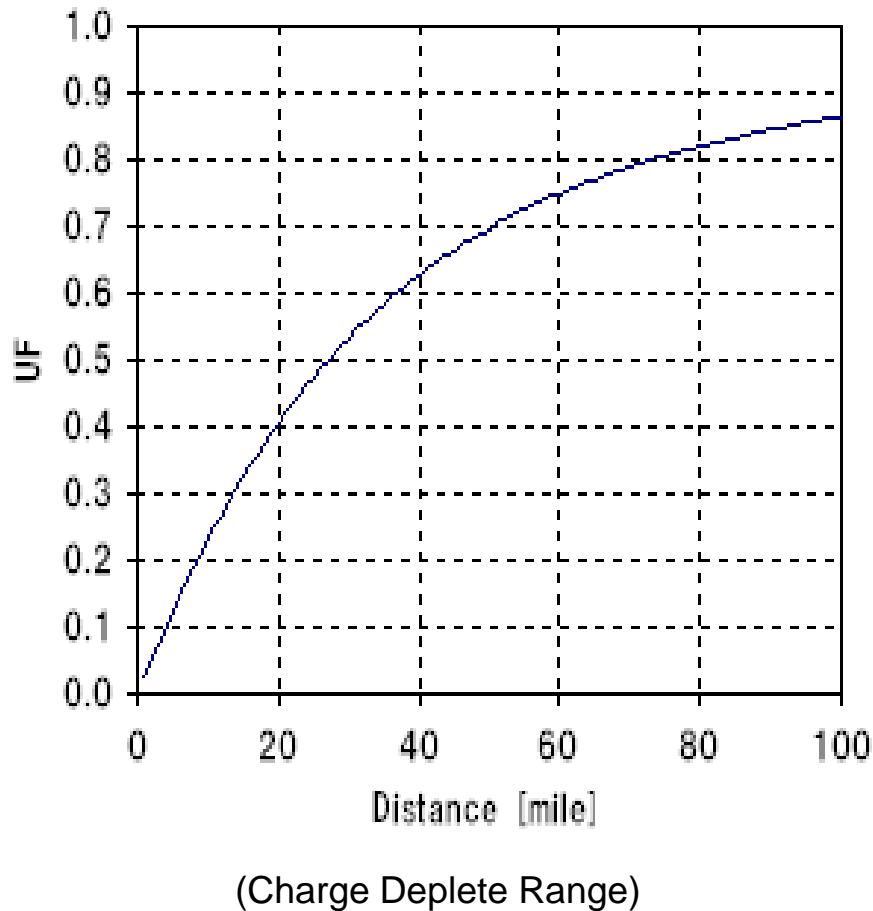
Combining Fuel Economy from Multiple Operational Modes

- Both CD and CS fuel consumption can be measured independently
- Q-How are CD and CS fuel economies combined to yield possibly CAFE, fleet CO2 standards, or a combined average annual gasoline fuel economy for the label?
- A- Utility Factors!

Utility Factor

- UF's provide a method for predicting the fractions of total distance driven in each mode of operation (Charge Deplete vs. Charge Sustain) ref. SAEJ1711
- UF is a way of accounting for charge depletion strategy and electrical storage capacity.

Utility Factor, Simple Form



- Uses Statistics based on transportation survey data
- Assume daily charge
- Using this graph, a PHEV with a charge deplete range of 20 miles would expect to spend 60% of the miles traveled in charge sustain mode and 40% in charge deplete mode
- Utility factors can be cycle specific
- UF and Electric Range calculations are still being refined by DOE, SAE, ARB, EPA, and others

UF- Simple, Binary

$$FE_{gasoline} = \frac{1}{\frac{UF}{MPG_{CD}} + \frac{1-UF}{MPG_{CS}}}$$

- This works fine for gasoline only FE, but what about the electricity or other fuel?

Accounting for Electricity

- Can apply UF principle, just “in reverse”
- Miles per gallon equivalent (mpg_e) must be displayed on the label that includes all fuels (**fuel economy is not gasoline only economy**)
 - Conversion is 33700 watt hours /gal
- In addition to mpg_e , fuel economy could be split into its constituent parts (display the way you pay)

UF Option

105mpg

Plus

12kwhr / 100miles

(76 miles per gallon of gasoline equivalent)

Summary

- Statutory requirements for Both Cd and Cs Fuel economies in mpg or mpge
- FE must be adjusted via 5-cycle
- Additional information on the label could include some average FE that incorporates both Cd and Cs FE
 - This FE would utilize utility factors and could be displayed in the manner in which the fuel is purchased
- Challenge to provide an easy to understand, relevant, label
- In-use, real world, advanced vehicle FE data lacking
- Continue to work with stakeholders on label concerns

Comments/ Questions

- ComplianceInfo@epamail.epa.gov

Appendix

FE Label Values - Background

- Test Cycles
 - **FTP (City)** – 11 miles long; 20 mph avg. speed; cold start, warm operation, & hot restart
 - **Highway** – 10 mile long; 48 mph avg. speed
- Label FE Values
 - City, Highway, Combined
 - Combined = $1/((0.55/\text{city FE})+(0.45/\text{hwy FE}))$
 - City and Hwy FE values are adjusted to reflect real world operation (2008 MY)
 - 5-cycle (Added 20F FTP, US06, SC03)
 - Derived 5-cycle (Applies correction to ftp/hwy FEs)

Blended Mode Fuel Economy, Example

1. Measure unadjusted electrical and gasoline consumption

$$FC_{Cd} = 10kwhr / 100miles$$

$$FE_{Cd} = 95mpg$$

2. Convert electrical consumption to fuel economy in miles per gallon equivalent of gasoline and add harmonically to measured gasoline consumption

$$FE_{MPGe} = \frac{1}{\frac{FC_{Cd}}{33.7 \times 100} + \frac{1}{FE_{Cd}}}$$

3. Apply 5-cycle correction, result is label requirement

$$FE_{5cycle} = 52mpg_e$$

4. Apply 5-cycle correction ratio to each fuel

$$FC_{Cd} = 10kwhr / 100miles \times \frac{74}{52}$$

$$FE_{Cd} = 95mpg \times \frac{52}{74}$$

Blended Mode Fuel Economy, Example

5. List Electrical Consumption and Gasoline Fuel Economy together but Separately. This would be the additional label information

67mpg

Plus

14kwhr / 100miles