Fuel Economy Numbers for Electric Vehicles

Prepared by: MIT Electric Vehicle Team, March 2008

Energy efficiency of electric vehicles is generally expressed as Watt-hours per mile (Wh/mi). miles per gallon of gasoline equivalent (mpgge)

Battery-to-wheel Fuel Economy: Converting Wh/mi energy use into the equivalent battery-to-wheel fuel economy, expressed in mpgge, depends on only the energy density of gasoline:

$$mpgge_{battery-to-wheel} = \frac{1}{[Wh/mi]} * U_{gasoline} \quad (1)$$

where, the energy density of gasoline by volume, $U_{gasoline,}$ is 115,000 Btu/gal or 33,705 Wh/gal[DOE 2000]. EPA sticker fuel economy labels are based on only this battery-to-wheel mpgge value, adjusted down to account for differences between real-world vehicle use and dynamometer testing.

Full Cycle Fuel Economy: The "full cycle" fuel economy equivalent value for an electric vehicle must inlclude the efficiencies for electricity generation and transmission:

$$mpgge_{fuel-to-wheel} = \frac{1}{[Wh/mi]} * U_{gasoline} * e_{electricity} \quad (2)$$

where $e_{electricity}$ is a lumped efficiency value of 0.303 that includes both average electricity generation efficiency (32.8 %) and average transmission efficiency (92.4 %). In the case of on-board charging (such as in a series hybrid), $e_{electricity}$ should reflect the efficiency of the on-board fuel converter only.

Likewise, the full cycle fuel economy of a conventional vehicle can be expressed as:

$$mpgge_{fuel-to-wheel} = mpgge_{\tan k-to-wheel} * e_{gasoline} \quad (3)$$

where, $e_{gasoline}$ is a lumped efficiency value of 0.830 that includes both refining and distribution efficiencies.

CAFE Fuel Economy: When counting electric vehicles toward an automaker's Corporate Average Fuel Economy (CAFE) value, the value used to measure compliance with fuel economy standards, the full cycle fuel economy value is further adjusted. The electric vehicle's full cycle mpgge value is normalized by the well-to-tank efficiency for gasoline, $e_{gasoline}$, and then further adjusted by a fuel-efficiency incentive factor of 6.667:

$$mpgge_{CAFE} = \frac{1}{[Wh/mi]} * U_{gasoline} * \left(\frac{e_{electricity}}{e_{gasoline}} \right) * 6.667 \quad (4)$$

MIT Porsche 914 BEV: The MIT Electric Vehicle Team (EVT) has converted a Porsche 914 into a battery electric vehicle (BEV) that uses roughly 185 Wh/mi (model results) over the EPA combined (city and highway) drive cycle. Consequently, the Porsche 914 BEV has a battery-to-wheel gasoline equivalent fuel economy of:

$$\frac{1}{185 \cdot Wh/mi} * \frac{33{,}705 \cdot Wh}{gallon\_gasoline} = 182 \cdot mpgge \quad (5)$$

The full cycle fuel economy value of the Porsche 914 BEV is:

$$\frac{1}{185 \cdot Wh/mi} * \frac{33{,}705 \cdot Wh}{gallon\_gasoline} * 0.303 = 67 \cdot mpgge \quad (6)$$

Finally, were EVT to go into business producing automobiles, the Porsche 914 BEV would have a CAFE credit value of:

$$\frac{1}{185 \cdot Wh/mi} * \frac{33{,}705 \cdot Wh}{gallon\_gasoline} * \left(\frac{0.303}{0.830}\right) * 6.667 = 444 \cdot mpgge \quad (7)$$

Table 1 below lists the equivalent fuel economy values for a range of electric vehicles, including the MIT vehicle, for comparison.

Table 1: Fuel economy values in miles per gallon gasoline equivalent for several production electric vehicles along with the MIT Porsche 914 BEV.

Vehicle	Energy Use (Wh/mi)	Battery-to-wheel fuel economy (mpgge)	Full cycle equivalent fuel economy (mpgge)
GM EV1	179	188	69
Tesla Roadster	240	140	51
MIT Porsche 914 BEV	185	182	67
Toyota RAV4 EV	235	143	52
Ford Ranger EV	315	107	39

Sources:

U.S. Department of Energy (DOE) (2000 June 12). "*Federal Register Vol. 64 No. 113.*" U.S. GPO.

Idaho National Laboratory (INL). (2006 May 30), "Test Reports for Vehicles by Manufacturer and Model," http://avt.inl.gov/vehicles.shtml