"MPG Equivalent Economy Labels for New Electric Vehicles,"

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Outline

1. Fuel economy ratings for 2011 Nissan Leaf (electric) and Chevy Volt (hybrid)

2. Assumptions and calculation of MPGe on EPA stickers

3. Example EPA charging routines for 5 Chevy Volt trips:
   Cost per mile and MPGe comparisons

4. EV investment returns when compared to other hybrid and gasoline powered cars

5. Suggested physics student classroom presentations and/or laboratory activities

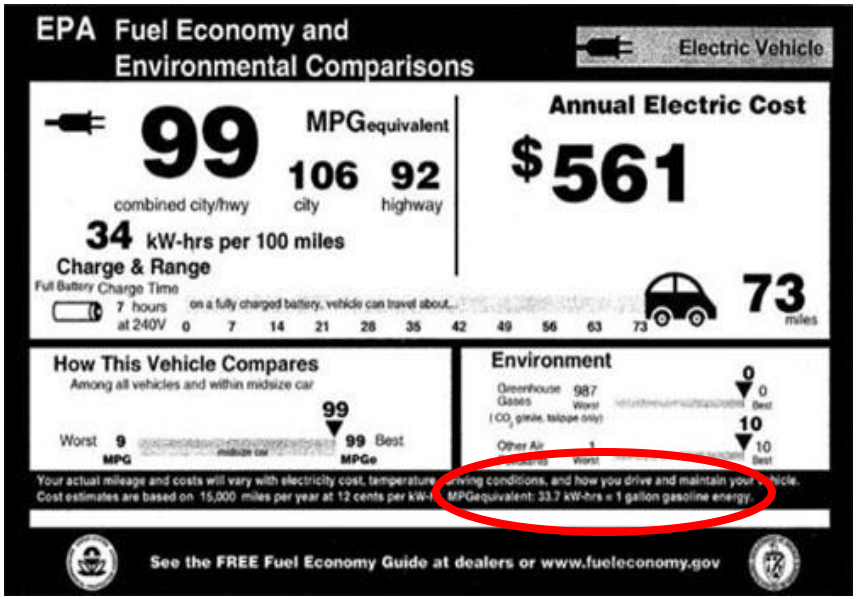
Manufacturer's mpg ratings released on August 11, 2009

GM Announces that Chevy Volt to get 230 mpg rating

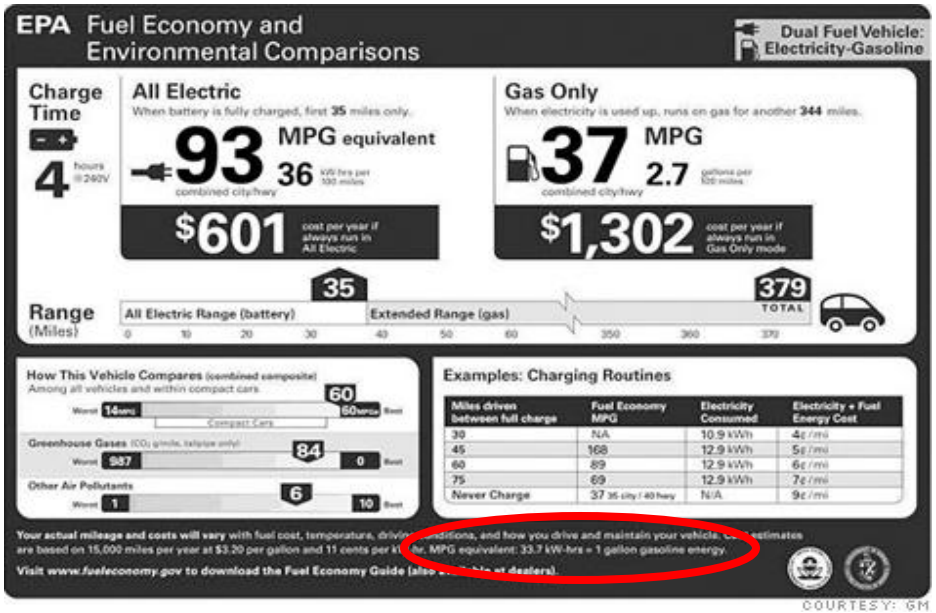
Nissan's Leaf Claims 367 mpg and Pokes Fun at Chevy Volt

EPA ratings and stickers released in November of 2010

Nissan Leaf First EV to Get EPA Rating



Two Days Later Chevy Volt Label Released and Explained



COURTESY: GM

EPA's **Assumption** for Calculation of MPGe:

"33.7 kW-hrs **Equivalent** to One Gallon of Gasoline Energy"

(or 115,000 Btu = 115,000 Btu)

Charge and Range for Nissan Leaf
34 kW-hrs per 100 miles

Charge and Range for Chevy Volt
36.4 kW-hrs per 100 miles

EPA Formula for Nissan Leaf

$$\frac{100 \text{ miles}}{34.0 \text{ kWh}} \times \frac{33.7 \text{ kWh}}{1 \text{ gallon gas}}$$

= 99 MPGe

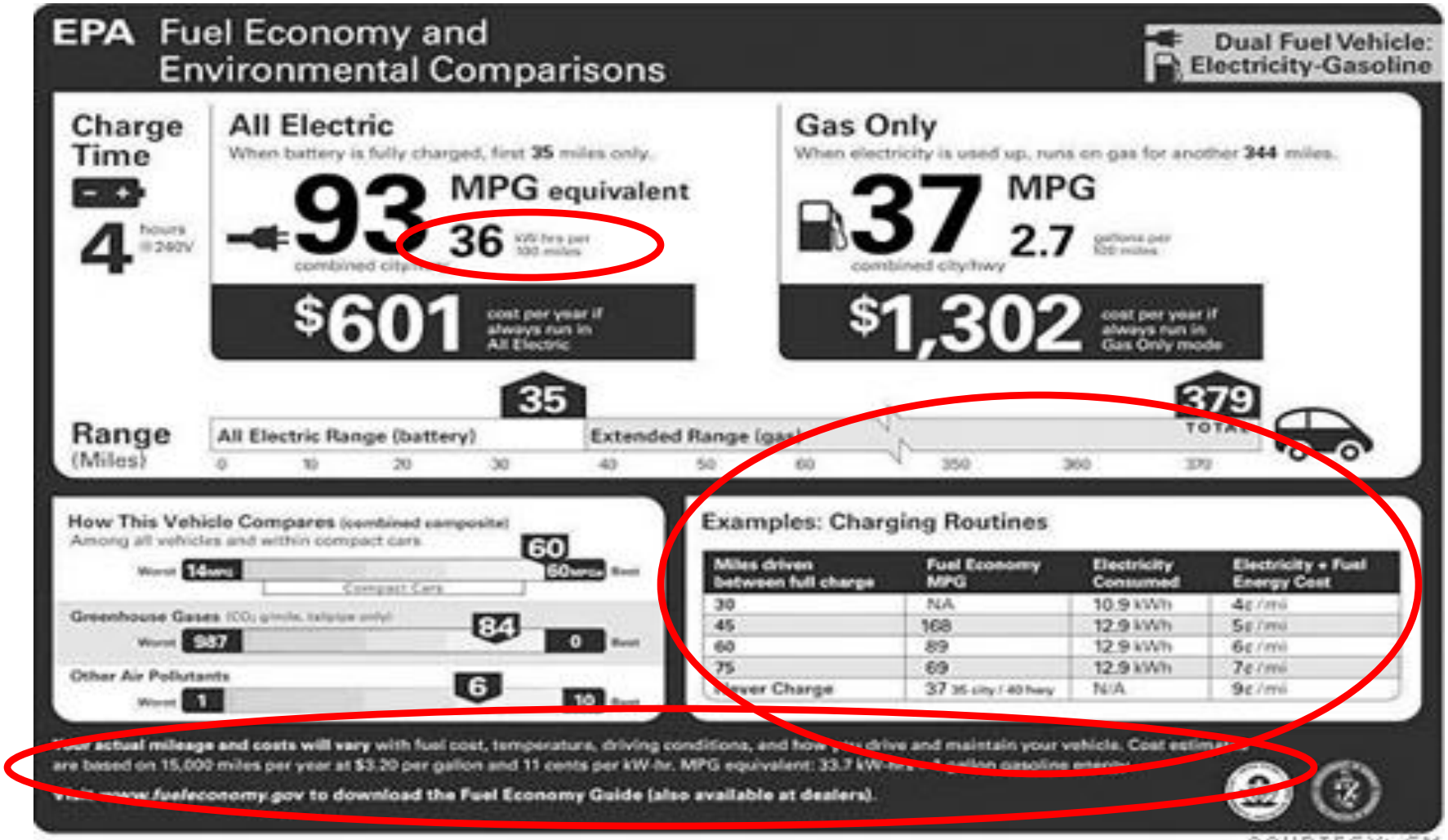
EPA Formula (Chevy Volt)

$$\frac{100 \text{ miles}}{36.4 \text{ kWh}} \times \frac{33.7 \text{ kWh}}{1 \text{ gallon gas}}$$

= 93 MPGe

….and now the fine print details….

First, a 36-kWh charge is required for 100 miles for Chevy Volt



COURTESY: GM

The Fine Print and Five Charging Routine Examples

Cost estimates are based on $3.20 per gallon gasoline and 11 cents per kW-hr.

<u>Let's compute the easy miles driven, MPG, and costs per mile</u>:

Electric case: 30 mi x **36.4** kWh/100 mi = 10.9 kWh
Cost becomes 10.9 kWh x $0.11/kWh = $1.20 per 30 mi (or 4 ¢ / mi)

Miles driven between full charge	Fuel Economy MPG	Electricity Consumed	Electricity + Fuel Energy Cost
30	NA	10.9 kWh	4 ¢ / mi
45			
60			
75			
Never Charge	37 35 city/40 hwy	NA	9 ¢ / mi

(Never Charge is $3.20/gallon gasoline case; $3.20/37 mi = 9 ¢ / mi case.)

How does one obtain 69 MPG on a **75-mile** trip?

Assume regular "**on board**" gas mileage method: MPG = miles driven/gallons used

First compute electric battery miles driven:

12.9 kWh x 100 mi/36.4 kWh ⟶ 35.4 mi driven on battery (and 39.6 mi on gas)

39.6 mi driven @ 37 MPG implies ⟶ 39.6mi/37 MPG = 1.07 gallon gas used

1.07 gallon used for 75-mi trip ⟶ MPG = 75 mi/1.07 gallon ≈ 69 MPG

Miles driven between full charge	Fuel Economy MPG	Electricity Consumed	Electricity + Fuel Energy Cost
75	69	12.9 kWh	7 ¢ / mi
Never Charge	37 35 city/40 hwy	NA	9 ¢ / mi

Electricity + Fuel Energy Cost:

(1.07 gallon x $3.20/gallon + 11 ¢/kWh x 12.9 kWh)/75 mi =($3.42 + $1.42)/75 mi ≈ 7 ¢ / mi

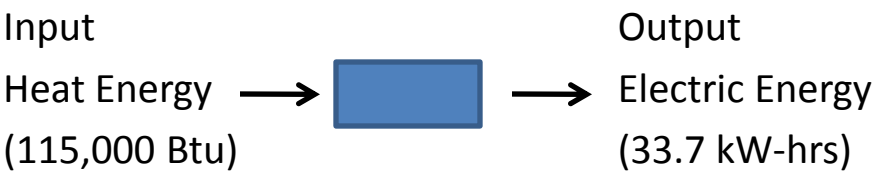
Similar MPG calculations for trips of 60 and 45 mi (and even 44, 43, 42, 41,and 40 mi)

Miles driven between full charge	Fuel Economy MPG	Electricity Consumed	Electricity + Fuel Energy Cost
60	**89**	12.9 kWh	6 ¢ / mi
45	**168**	12.9 kWh	5 ¢ / mi
44	**190**	12.9 kWh	**4.9 ¢ / mi**
43	**210**	12.9 kWh	**4.8 ¢ / mi**
42	**237**	12.9 kWh	**4.7 ¢ / mi**
41	**273**	12.9 kWh	**4.6 ¢ / mi**
40	**325**	12.9 kWh	**4.5 ¢ / mi**
30	**(really BIG!)**	10.9 kWh	4 ¢ / mi

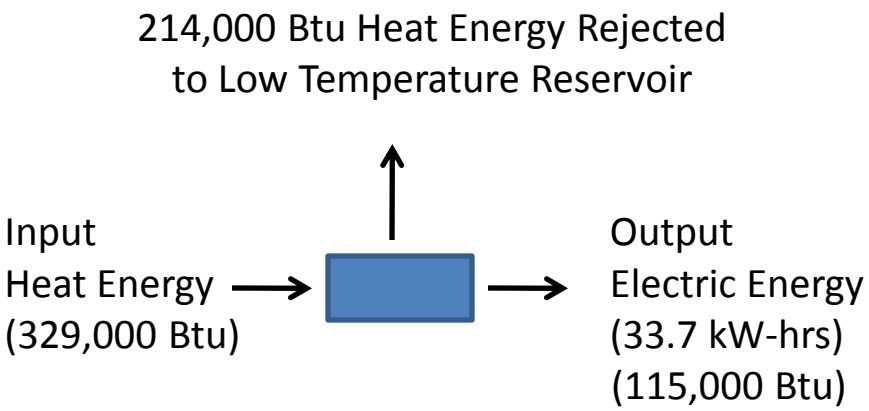
Power Plant Implications in the Assumption used in EPA's Formula

2010 EPA Power Plant for Electric Vehicles

33.7 kW-hrs **Equivalent** to One Gallon of Gasoline



US Power Plant in 2010 for Electric Vehicles at 35% Efficiency



Revised MPGe for **35%** Efficient Electric Power Plant:

"33.7 kW-hrs **Equivalent** to One Gallon of Gasoline Energy"
however, 329,000 Btu thermal required for 115,000 Btu electrical

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34 kW-hrs per 100 miles

Charge and Range for Chevy Volt
36.4 kW-hrs per 100 miles

EPA Formula for Nissan Leaf

$$\frac{100 \text{ miles}}{34.0 \text{ kWh}} \times \frac{33.7 \text{ kWh}}{2.7 \text{ gallon gas}}$$

= 35 MPGe

EPA Formula (Chevy Volt)

$$\frac{100 \text{ miles}}{36.4 \text{ kWh}} \times \frac{33.7 \text{ kWh}}{2.7 \text{ gallon gas}}$$

= 33 MPGe

Investment return: Miles driven needed to recover difference in base cost of Chevy Volt – less $7,500 plug-in hybrid tax credit

Vehicle	Type	Base MSRP	Curb Wt	Combined MPG	Electricity + Fuel Cost	Miles driven to recover initial cost difference
Nissan Leaf	**Electric**	**$32,780**	**3366**	**99**	**3.7 ¢/mi**	**--**
Chevy Volt	**Electric**	**$40,280**	**3781**	**93**	**4.0 ¢/mi**	**--**
Toyota Prius	Hybrid	$23,050	3042	50	6.4 ¢/mi	405,000
Honda Civic	Hybrid	$23,950	2877	41	7.8 ¢/mi	232,000

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Chevy Volt	**Electric**	**$40,280**	**3781**	**93**	**4.0 ¢/mi**	**--**
Chevy Volt	**Gas**	**$40,280**	**3781**	**37**	**8.6 ¢/mi**	**NA**
Smart Car	Gas	$12,490	1808	36	8.9 ¢/mi	414,000
Hyundai Elantra	Gas	$14,945	2661	33	9.7 ¢/mi	313,000
MINI Cooper	Gas	$21,100	2789	31	10.3 ¢/mi	185,000
Chevy Cruze	Gas	$16,525	3102	30	10.7 ¢/mi	243,000
Ford Focus	Gas	$16,640	2623	29	11.0 ¢/mi	231,000
Volkswagen Jetta	Gas	$15,995	2881	28	11.4 ¢/mi	227,000
Honda Accord	Gas	$21,180	3217	27	11.9 ¢/mi	147,000

Suggested physics student classroom projects, presentations, and/or laboratory activities

1. Calculations of MPGe that include upstream factors:
    - Fossil and nuclear power plant efficiencies
    - Alternative energy power source costs
    - Wellhead-to-refinery-to-consumer costs
    - Oil-related defense costs
2. Exponential (energy) growth – Al Bartlett
3. US and world energy production/consumption
4. World energy resources by country
5. CO_2 emissions by sector and country
6. The future role of solar and wind energy in US economy
7. The role of government in changing societal behavior

Thank you

Question and Comments