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ACEEE'S GREEN BOOK®

Proposed Updates to the ACEEE's Green Book® Rating System for Model Year 2011

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For Model Year 2011, we are proposing major changes to the methodology, which will be reflected in the release of ACEEE's Green Book® at greenercars.org early next year. The proposed updates to the methodology fall primarily in three areas:

- Use of emissions certification values to rate vehicles
- Incorporation of results from Argonne National Laboratory's GREET 2.7 in the vehicle life cycle analysis
- Treatment of plug-in electric vehicles

This memo discusses these three issues as well as emissions factors for electricity generation. Aspects of the methodology not discussed in this memo will remain as described in our technical report, "Rating the Environmental Impacts of Motor Vehicles: *ACEEE's Green Book*® Methodology, 2004 Edition" (Kliesch 2004) and subsequent model year 2005 - 2010 supplemental methodology memoranda.

Emissions Factors

With EPA's transition away from the MOBILE model, generating emissions factors from MOBILE is no longer a good option. EPA's replacement model, MOVES, does not directly permit the reporting out of emissions of vehicles meeting a given certification level (Tier 2 or LEV II bin), which is required for Green Book's vehicle ratings. ACEEE has not identified any other source of information regarding real-world emissions performance by certification level that is sufficiently complete to serve as a source for updating those emissions factors in a satisfactory way. Consequently, for the 2011 model year, the in-use criteria pollutant component of vehicles' damage cost (EDX) will be based directly on full useful life standards. This is a major departure from earlier Green Book methodology.

Several issues deserve mention in connection with this proposed change to the methodology, including: evidence that average real-world emissions may still substantially exceed the full useful life standard; emissions variations by class and fuel among vehicles in the same bin; and the effects of using certification values on vehicle ratings.

We may revisit the use of certification values in the future to consider whether this remains the best option in view of the data available.

Real-world emissions vs. certification values

Green Book emissions factors in prior years have been largely based on runs of EPA's MOBILE model, which showed average emissions over the life of a vehicle substantially in excess of the full useful life standards defining the vehicle's Tier 2 or LEV II bin. This is in part because the certification values pertain to performance over the Federal Test Procedure (FTP) cycle, which does not fully replicate real-world operation. In particular, operation at high speed, at low temperature, and using the air conditioner are not reflected in the bin certification levels. Some of these "off-cycle" emissions are captured by the Supplemental Federal Test Procedure (SFTP); but the corresponding supplemental standards are far above the standards defining the emissions bins and presumably also typically far above vehicle average emissions.

Another reason lifetime average emissions may exceed full useful life standards is that emissions deteriorate with time and mileage, and vehicles are driven further on average than the assumed full useful life of 120,000 miles. Furthermore high emitters (i.e. vehicles emitting far in excess of permitted levels) were among the vehicles captured in the MOBILE model. Because high emitters may have emissions orders of magnitude higher than certified levels, a relatively small number of such vehicles can have a large impact on average emissions levels.

Unlike MOBILE, MOVES does not directly produce a projection of how vehicles certified to a given emissions bin will perform over time. Instead, the emissions profile of the population of new vehicles of a given type in a given year is synthesized for MOVES using the expected sales breakdown by bin. This synthesis occurs outside the model (EPA 2009a). The emissions profile of the population of new vehicles of a given type in a given year thus reflects the bin distribution of sales in that year, so it is still possible to compare a MOVES estimate of fleet emissions with the average of the full life standards to which the vehicles in the fleet are certified.[1]

For example, a supplementary EPA analysis for the 2012-2016 greenhouse gas emissions rule for light-duty vehicles (EPA 2009) used MOVES to show grams per mile emissions of post-2010 vehicles as a function of age. We computed lifetime average grams per mile emissions from cars using those emissions rates weighted by the expected miles driven per year over the lives of the vehicles. We compared these emissions rates to weighted full-life standards using EPA's projected distribution of car sales by Tier 2 bin for 2010 and beyond (approximately one percent bin 2, 37 percent bin 3, three

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[1] It may also be possible to reconstruct bin-by-bin emissions projections from average emissions rates together with the annual breakdown by bin, but we have not yet succeeded in generating a consistent set of bin-specific emissions projections in this way.

percent bin 4, and 59 percent bin 5) (EPA 2009a). Figure 1 shows average lifetime emissions for gasoline cars as calculated in these two ways.

Figure 1 Lifetime Average Grams per Mile for the Average New Car in 2010+: MOVES and Full-Life Standard

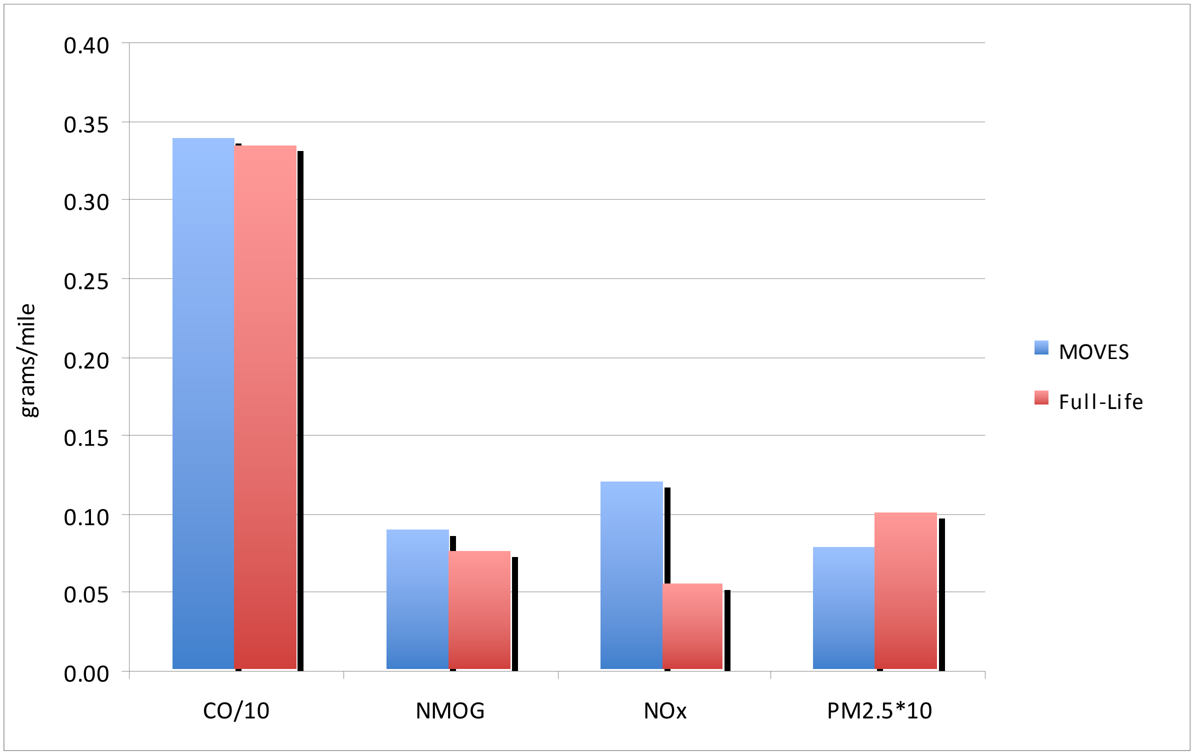


Figure 1 shows a reasonably good correspondence between the two sets of emissions rates for the given mix of emissions bins. In the case of NOx, however, average emissions as projected by MOVES are over twice as high as the average full-life standard to which the vehicles are certified. Hence using full-life certification values as lifetime emissions rates for gasoline cars may substantially understate NOx. The current Green Book NOx emissions factor for this combination of bins is much higher still; but we have no basis for reverting to those MOBILE-based numbers, since MOVES supercedes MOBILE.

A hallmark of Tier 2 standards, with the completion of their phase-in by MY 2009, is that requirements are the same for all vehicles in a given bin, regardless of class or fuel type. For a variety of reasons including those mentioned above, real-world emissions for vehicles within a bin may nonetheless vary with vehicle class and fuel.

Real-world emissions data for U.S. light–duty diesels have been hard to come by for many years, due in part to the small number of such vehicle sold. The same set of MOVES model outputs referenced above show NOx emissions for diesels in excess of those for gasoline vehicles, well into the future. However, that analysis is based on extrapolation from the performance of diesels certified to bin 10 and in particular does not reflect any emissions data for today's bin 5 "clean diesels" nor the characteristics of these vehicles' emissions control systems.

We propose to use certification values not only for gasoline and diesel vehicles, but also for CNG vehicles. As a result, impacts attributed to CNG vehicles will increase relative to those of other vehicles, because their emissions rates under the current methodology are below those of gasoline vehicles in the same bin and in some cases well below the certification values. In particular, PM emissions in the current methodology are negligible for a CNG vehicle meeting any LEV II standard or

Tier 2 standard of bin 2 or lower. Both hydrocarbon and NOx emissions are also estimated at an order of magnitude lower than gasoline emissions.

Current Green Book emissions factors also vary with vehicle class. In general, larger vehicles have higher emissions factors at a given certification level, although there are exceptions. As a result, larger vehicles may tend to benefit more from moving to certification emissions than would a smaller vehicle of the same certification level. At the same time, larger vehicles are certified on average to dirtier emissions levels, and the ratio of Green Book emissions rates to standards is generally lower for higher-emitting vehicles. Hence, how the net effect of moving to certification values varies by class is not obvious.

For the MOVES model, EPA computes real-world emissions using a characterization of operating modes based on vehicle-specific power (VSP). Truck driving patterns and other factors result in higher VSP values, and hence higher emissions, for high speed and high acceleration driving modes (EPA 2010, Kahan 2010). Hence a truck having the same emissions as a car over the FTP test cycle can have much higher real-world emissions at high speeds, which would be reflected in emissions as calculated by MOVES.

Using the MOVES outputs referenced previously, we generated lifetime factors for light trucks. These were higher than car values by a factor of 1.7-1.8, with the exception of NOx, which was higher than the car value by a factor of 2.9. These factors may overstate light truck emissions by virtue of their inclusion of emissions of light heavy-duty trucks of Classes 2b-3 (Kahan 2010). Although these are far less numerous than light trucks under 8,500 lbs GVW, their emissions could appreciably raise average truck emissions. Thus, while MOVES provides evidence that light truck emissions will be substantially higher than car emissions at a given standard, we do not at this time have class- and bin-specific estimates of how much higher they are, and will assume for the present that emissions are determined by certification level.

Given the various unresolved issues, we will consider in the future returning to emissions rates that differentiate among vehicles meeting a given bin. Rates that distinguish among cars and the various truck classes in particular may be warranted.

Implications of emissions rate changes for vehicle environmental damage costs

We reevaluated all 2010 vehicles replacing the emissions rates in the current methodology with certification values. This resulted in lower EDXs for almost all vehicles, and an average reduction of 12 percent, because the current real-world emissions factors by and large exceed certification values, often several-fold. In this section, we consider the implications of the proposed change in emissions rates across these vehicle features.

Percent change in EDX under the proposed change to using certification values is plotted by fuel in Figure 2. Diesel vehicles do better relative to gasoline vehicles because current Green Book emissions rates for NOx at a given certification are significantly higher than those for gasoline vehicles at the same standard. The only CNG vehicle model sold in recent years showed almost no change in EDX and therefore fares worse, as anticipated, in relative terms. Hybrids are shown separately as well, but are affected no differently from other high-efficiency gasoline vehicles by the proposed use of certification values.

Figure 2 Percent change in EDX technology/fuel type

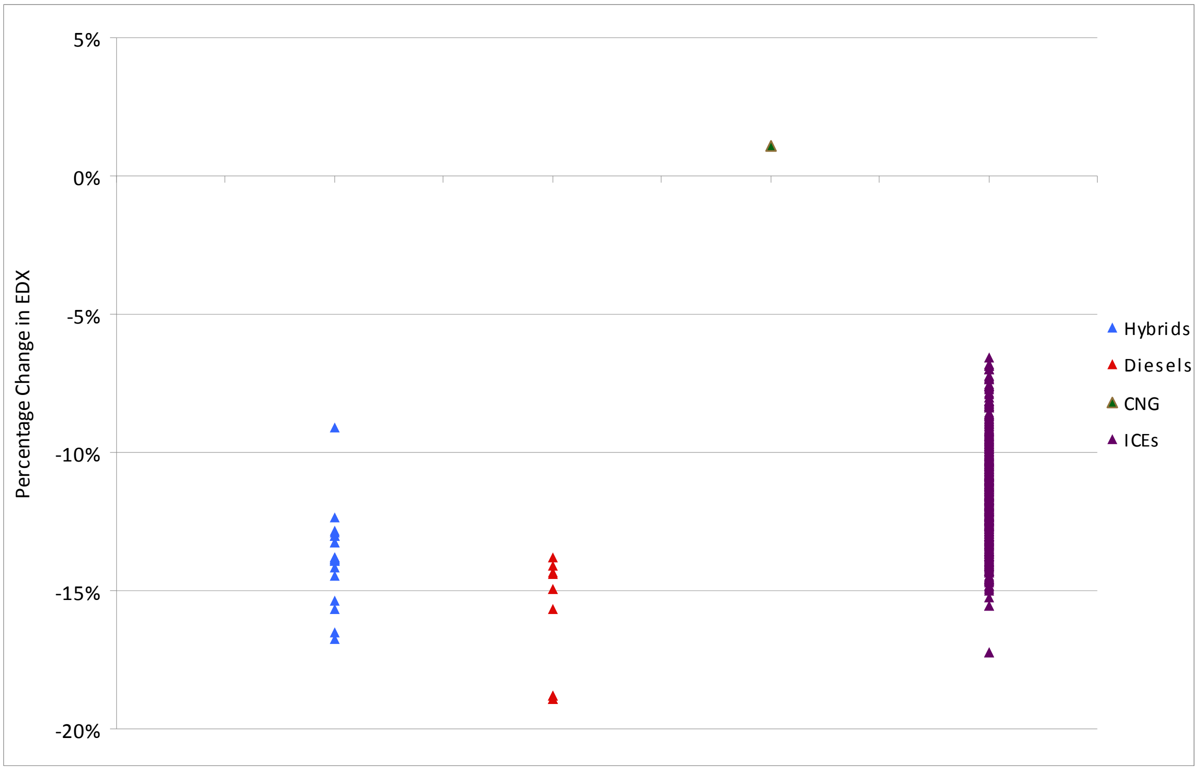
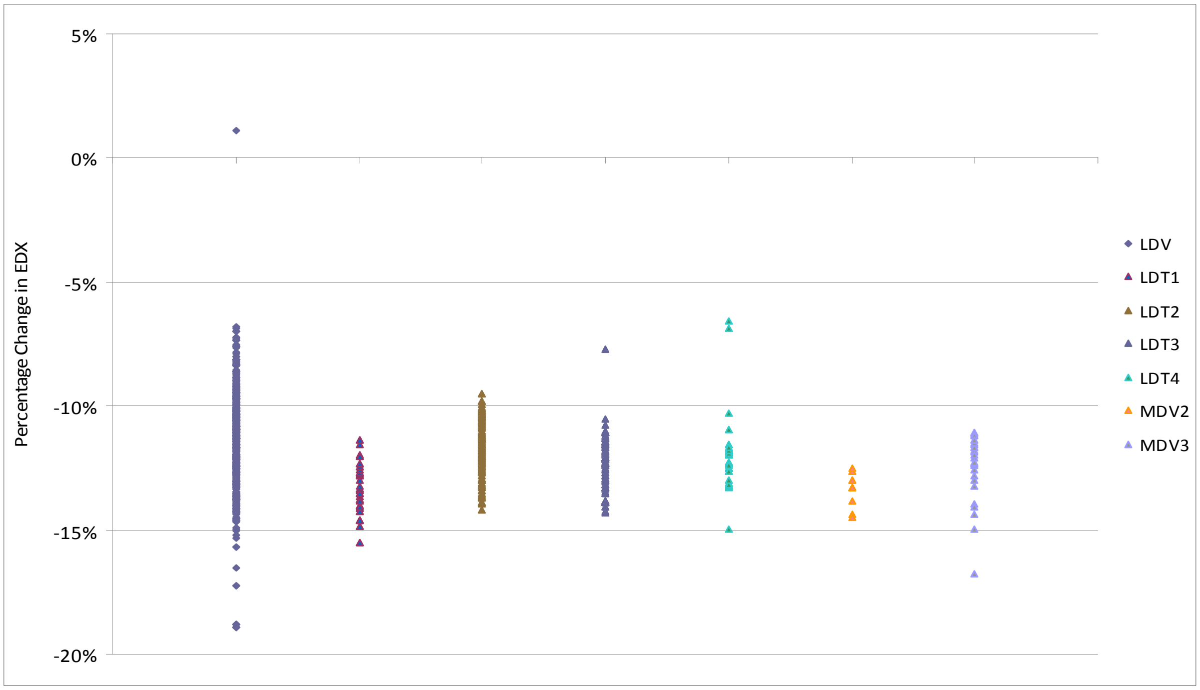


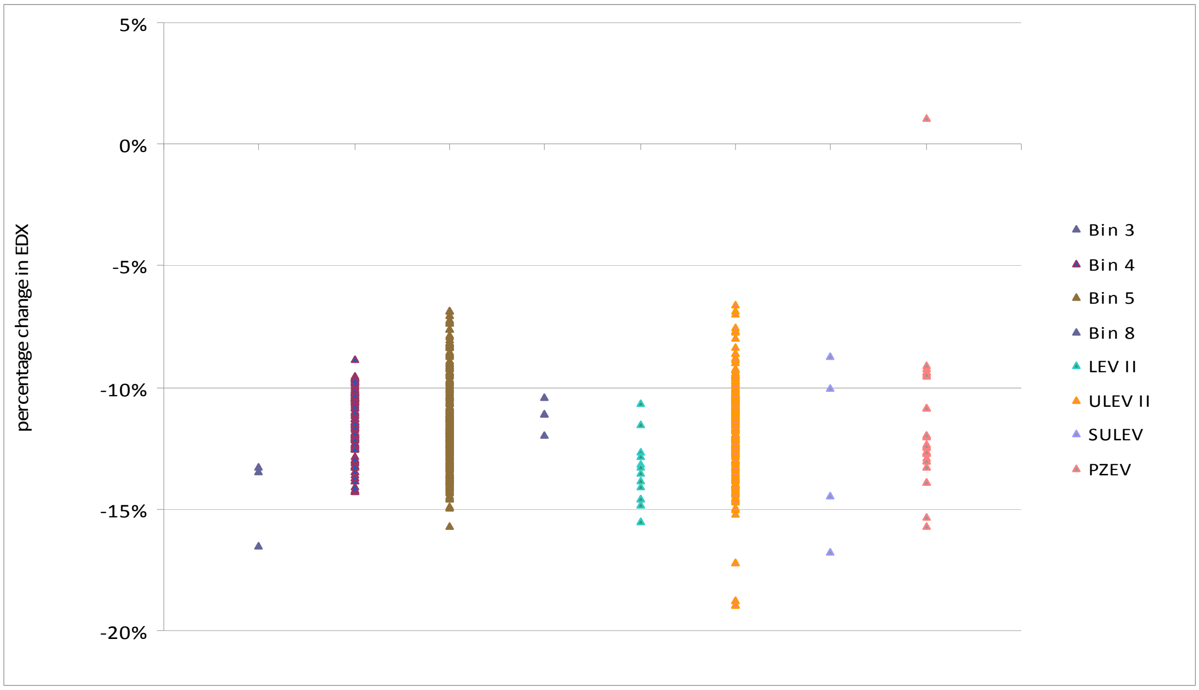
Figure 3 shows the vehicle class-related impacts of moving from current Green Book factors to certification factors.

Figure 3 Percent change in EDX by vehicle regulatory class



Another consideration in moving to emissions rates based on certification values is that the ratios of real-world emissions rates to the certification levels under the current methodology generally increase with the stringency of the certification level. Figure 4 shows the change in EDX across bins.

Figure 4 Percent change in EDX by emissions certification



The fraction of a typical vehicle's EDX accounted for by criteria pollutant emissions has declined over the years of Green Book publication.[2] In 1999, GHG emissions and criteria pollutant emissions contributed equally to the EDX of the average vehicle, by assumption. We have held the damage costs of air pollutants and of CO_2 constant over time. Due to the decline in criteria pollutant emissions over time, the contributions of GHG emissions and criteria pollutant emissions to the average vehicle's EDX were 64 percent and 36 percent respectively in 2010. As a result, the use of certification values rather than the in-use values previously generated for Green Book ratings will affect relative scores less than they would have previously. The switch to the use of full life standards still has a substantial effect on EDX, however.

Vehicle-Cycle Emissions Estimates

To date, Green Book methodology has estimated emissions associated with the materials production and manufacturing phases of vehicle life using only vehicle weight (including battery replacements) as a proxy. Thus far the methodology has not included emissions from vehicle recycling and disposal processes.

We propose to update calculation of vehicle life-cycle emissions in the Green Book methodology using Argonne National Laboratory's GREET 2.7 model. GREET 2.7 includes recycling and disposal impacts and permits the incorporation of greater detail on key components, such as batteries, that differentiate the vehicle cycle impacts of more advanced vehicles from those of conventional vehicles. GREET 2.7

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[2] However, as new vehicle fuel economy rises to meet standards recently adopted for the 2012 model year and beyond, this trend could be reversed in future model years.

provides emissions and energy estimates for internal combustion engine (ICE), hybrid-electric, and fuel cell cars and SUVs. Results for pickup trucks are forthcoming (Burnham 2010).

Internal Combustion Engine Vehicles (ICEVs)

GREET 2.7 calculates vehicle life-cycle energy and emissions based on a large number of vehicle-specific inputs. Most of these inputs are not available on a model-by-model basis, so we use GREET default values for most inputs, varying only vehicle weight and class for ICEVs. This approach results in linear formulae describing the relationship between vehicle mass and emissions of greenhouse gases and various criteria pollutants. The respective formulae are outlined in Table 1 below.

Table 1 Weight-based Formulae for Vehicle-Cycle Emissions in ICEs

Cars	**Pollutant**	**Intercept (grams per vehicle per lifetime)**	**Weight Co-efficient (grams per lb of vehicle per lifetime)**
	GHGs	2,734,754	1,527
	CO2	2,616,661	1,443
	PM10	3,582	2.85
	NOx	6,343	1.65
	CO	1,973	11.39
	SOx	8,736	3.86
SUVs	GHGs	3,391,114	1,493
	CO2	3,246,590	1,410
	PM10	4,468	2.82
	NOx	7,834	1.60
	CO	1,680	11.54
	SOx	11,069	3.47

The GHG formula, for example, will replace the value of 2,541 grams of CO2-equivalent emissions per pound of vehicle in the current methodology. For criteria pollutants, the GREET-based emissions are lower than Green Book methodology emissions for a vehicle of average weight, with the exception of PM emissions, which are substantially higher in GREET. On the other hand, GREET does not include emissions of toxics, which the current methodology does include, based on data from EPA's Toxics Release Inventory (TRI). Green Book estimates of embodied TRI impacts are equivalent to 1.1 grams per pound of vehicle; these are assigned the same damage cost as PM in the calculation of EDX. The GREET-based relationships are compared in graphical form to the current Green Book methodology relationships in Appendix 1 Figures A1-A2.

Hybrid Electric Vehicles

The use of GREET 2.7 permits an analysis of hybrid vehicle life-cycle impacts that reflects the size and composition of the battery. Almost all hybrids available today in the United States run on nickel metal hydride (Ni-MH) batteries, so we used this battery composition as a default for the present discussion. We varied vehicle weight and battery weight in GREET 2.7 to arrive at a linear regression model to integrate into the proposed Green Book methodology. Table 2 below highlights the y-intercepts and vehicle weight and battery weight coefficients for each vehicle-cycle pollutant.

It should be noted that the negative coefficient for CO shown in the Battery Weight column is a consequence of the fact that the vehicle weight (preceding column) includes the battery weight, so an increase in battery weight at fixed vehicle weight implies a decrease in the weight of other vehicle components.

Table 2 Weight- and Battery Weight-based Formulae for Vehicle Cycle Emissions in HEV Cars

Cars	Pollutant	Intercept	Weight Co-efficient	Battery Weight Co-efficient
	GHGs	2,575,594	1,626	12,206.20
	CO2	2,544,047	1,523	11,185.23
	PM10	3,431	2.86	15.21
	NOx	6,134	1.74	12.94
	CO	2,267	12.02	-0.08
	SOx	12,538	5.07	104.55
SUVs	**Pollutant**	**Intercept**	**Weight Co-efficient**	**Battery Weight Co-efficient**
	GHGs	3,180,884	1,598	12,233.45
	CO2	3,043,306	1,511	11,780.53
	PM10	4,275	2.86	15.21
	NOx	7,552	1.70	12.98
	CO	2,093	12.17	-0.23
	SOx	10,179	5.73	126.96

Electric Vehicles

Since GREET 2.7 does not yet evaluate EVs, we propose to use GREET's existing fuel cell vehicle methodology to estimate vehicle-cycle emissions estimates for battery-electric vehicles and the hybrid methodology for plug-in hybrids. Based on discussions with Argonne National Laboratory, we believe that increasing the battery weight input and removing the fuel stack and associated auxiliaries (storage tank, piping, etc) from the FCV analysis altogether will provide reasonable estimates of emissions and energy use for electric vehicles (Burnham 2010). Similarly, increasing the battery weight and removing the transmission component from the HEV analysis will provide emissions estimates for plug-in hybrid vehicles Tables 3 and 4 shows the associated intercepts and coefficients for the relationship between emissions, total vehicle weight and battery weight battery electric and plug-in hybrid electric vehicles.

Table 3 Weight- and Battery Weight-based Formulae for Vehicle Cycle Emissions for EVs

Pollutant	Intercept	Weight Co-efficient	Battery Weight Co-efficient
GHGs	2,068,368	1,600	5,445.65
CO2	1,974,119	1,515	5,247.32
PM10	3,153	2.62	7.03
NOx	5,280	1.68	6.43
CO	2,256	12.47	-10.51
SOx	7,158	5.17	45.90

Table 4 Weight- and Battery Weight-based Formulae for Vehicle Cycle Emissions in PHEVs

Pollutant	Intercept	Weight Co-efficient	Battery Weight Co-efficient
GHGs	2,575,594	1,626	5,422.61
CO2	2,462,845	1,539	5,225.71
PM10	3,431	2.86	6.79
NOx	6,781	1.61	6.12
CO	1,620	12.14	-9.80
SOx	8,073	6.15	44.94

As there are no electric SUVs and trucks on the market yet, we show the emissions rates for cars only.

For all three vehicle types, the intercepts shown are sizeable. This is largely due to the use of default inputs to GREET 2.7 for battery, tires, fluids and assembly, disposal and recycling; these do not vary with vehicle weight. Approximately 75% of the intercept is comprised of emissions associated with the manufacturing and use of tires, battery and fluids. Some scaling of these components with vehicle weight would be appropriate. Of the emissions from the assembly, disposal and recycling (ADR) component of the vehicle-cycle analysis, over half is associated with the assembly process, which may in fact be largely independent of vehicle weight. We believe the remaining emissions, associated with the disposal and recycling of a vehicle, should be scaled by total weight but have not done that here. We welcome comments on this approach.

Impact on EDX

We determined the impact of adopting GREET 2.7 vehicle-cycle emissions results as described above on the EDX of conventional, hybrid and electric vehicles. For this purpose we used current Green Book emissions rates, so this analysis was to explore the impact of the proposed change to the calculation of embodied emissions alone. It should be noted that, for this analysis, we applied the GREET-based formulae for cars to all vehicles. Application of the SUV formulae to SUVs would have a small but negative effect on SUV ratings. MY2011 ratings will apply the proper formulae to SUVs and, if available, to pickup trucks.

The average EDX for MY 2010 conventional ICE vehicles declined (improved) from 2.85 cents per mile to 2.78 cents per mile. Due to the difficulties in finding hybrid battery weight and peak power data, we ran only 4 MY 2010 hybrids using the GREET-based emissions results. Hybrids experienced an increase in the average EDX of 0.142 cents per mile. We evaluated a compact electric vehicle with a 600-lb. lithium ion battery using the current and proposed methodologies. The vehicle's EDX increased by 0.17 cents per mile using GREET's emission results. We also evaluated a plug-in hybrid with a 440-lb. battery using the HEV-based GREET formulae, which resulted in an EDX 8 cents per mile higher than under the current methodology.

Emissions Factors for PHEVs and EVs

The proposed methodology updates a number of factors necessary to evaluate all-electric vehicles (EVs) and plug-in hybrid vehicles (PHEVs).

Consumption of Electricity from the Grid

Grams per mile emissions from a vehicle running on electricity generated off-board are calculated as the product of the vehicle's average kilowatt hours (kWh) per mile and grams per kWh from power generation. For these vehicles, EPA listings include kWh per mile over the city and highway test cycles, i.e. the FTP and Highway Fuel Economy Test (HWFET) Cycles, respectively.

Just as for gasoline vehicles, however, these test values need to be adjusted to better represent typical energy usage, because there are major differences between real-world driving and the driving patterns reflected in the test cycles (EPA 2006). Current Green Book methodology for gasoline and diesel vehicles reflects EPA's 2006 rule adjusting the calculation of real-world fuel economy for labeling purposes. This rule directs car manufacturers to test their vehicles in model year 2008 and beyond using a "five-cycle" test, comprising: the FTP Cycle, the HWFET Cycle, the US 06 Supplemental FTP Cycle to represent high speed aggressive driving, the SC 03 Supplemental FTP Cycle to represent the impact of air conditioner operation at high temperature, and a cold FTP Cycle to reflect the impact of cold temperatures.

For alternative fuel vehicles, including PHEVs and EVs, manufacturers have the option of using a "Derived 5-cycle" test (which was also an option for testing any vehicle through model year 2010), in which the new label city and highway fuel economy values are calculated from the original two-cycle test values alone, as shown in Equations 1 and 2 below (EPA 2006).

$$\text{Derived 5-Cycle City FE} = 1/\,(0.003259 + 1.1805/\,\text{FE}_{\text{FTP}}) \qquad \text{Equation 1}$$

Derived 5-Cycle Highway FE = 1/ (0.001376 + 1.3466/ FE_{HWFET}) Equation 2

For high fuel economy vehicles, Equations 1 and 2 yield severe corrections, as shown in Figure 5 and Figure 6.

Figure 5 Laboratory Fuel Economy vs. Derived 5-Cycle Fuel Economy

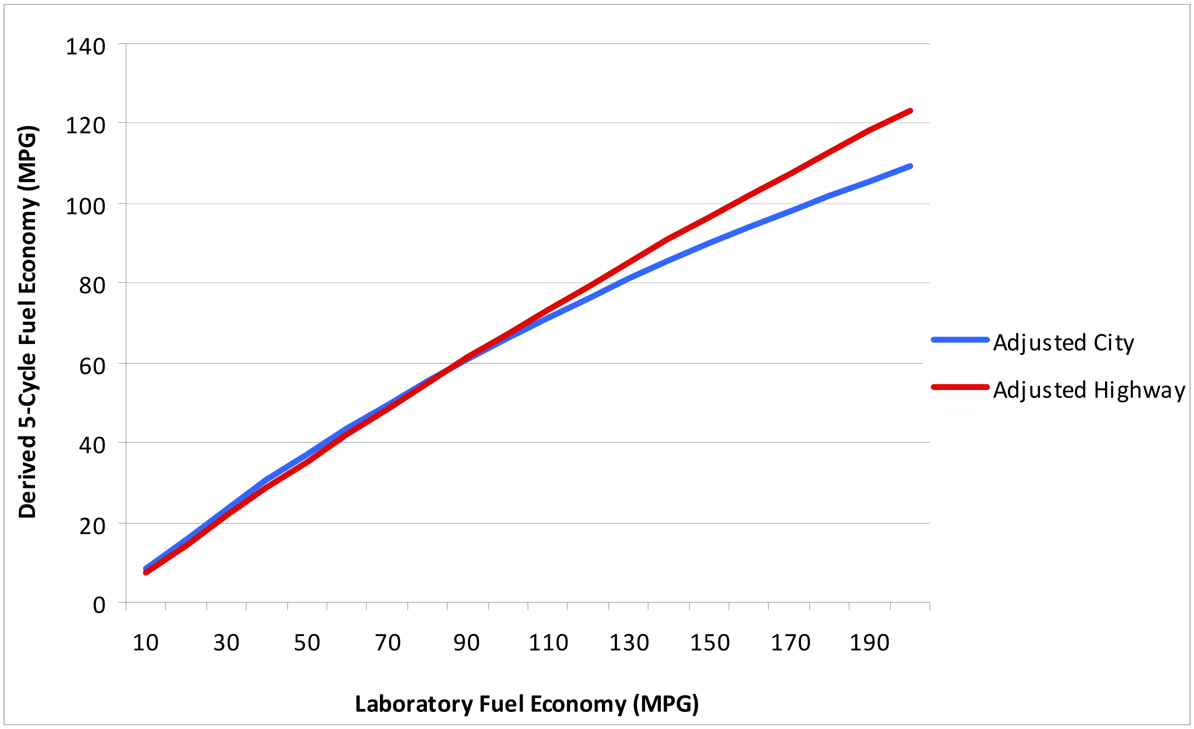
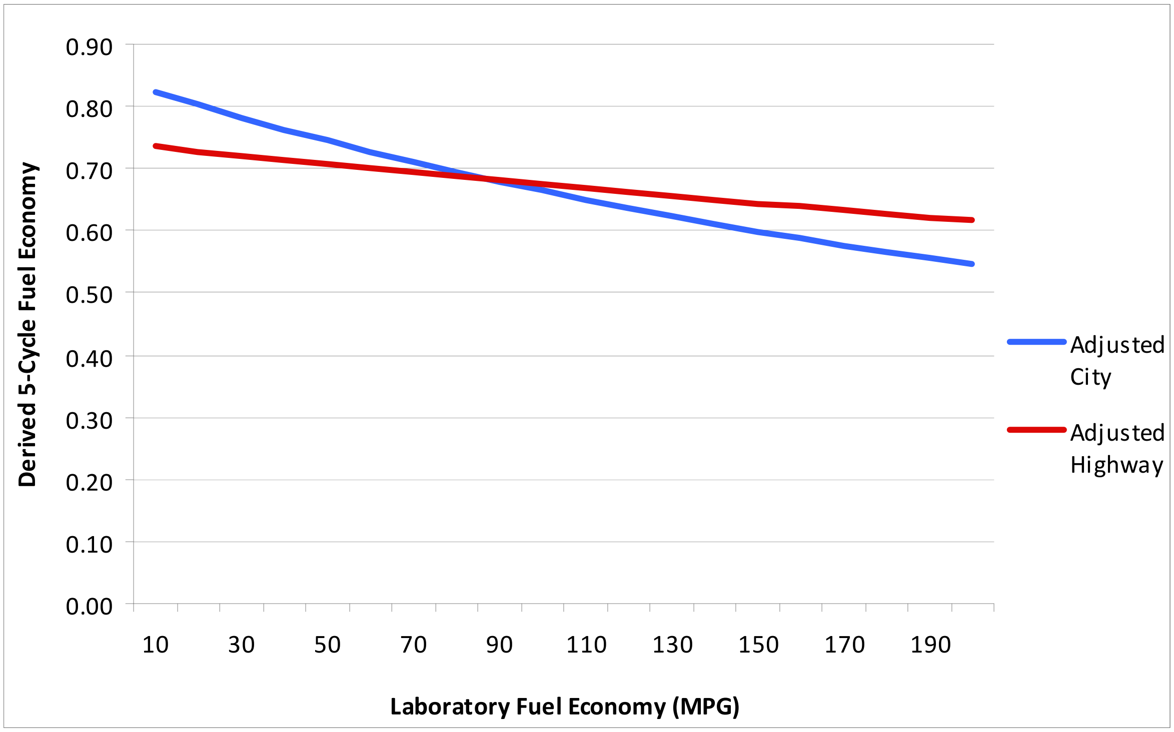


Figure 6 Derived 5-Cycle Adjustment Factor to Laboratory Fuel Economy



Manufacturers of plug-in vehicles are likely to report fuel economies using the derived 5-cycle approach, assuming the results are favorable to these vehicles. Converting kWh per mile values to miles per gallon using the EPA energy conversion of 33,705 kWh per gallon (EPA and DOT 2010) yields fuel economies of well over 100 miles per gallon. A 4 mile-per-kWh EV, for example, would achieve 135 miles per gallon, resulting in downward corrections of 38 percent and 35 percent for city and highway fuel economies, respectively.

We propose to cap the derived 5-cycle adjustments of Equations 1 and 2 at 30 percent, as was done in the 2010 EPA/DOT proposed fuel economy labeling rule (EPA and DOT 2010). The agencies declined to apply the full correction factor for these vehicles because the data used to generate the derived 5-cycle equations do not include results from any EVs or other high-mpg vehicles, so these corrections are not empirically based. The 30 percent cap on the downward adjustment also has been used by researchers at Argonne National Laboratory (Elgowainy et al.).[3] We note however the comments of the ICCT (German 2010) that loads not captured over the test cycle (e.g. aerodynamic drag at high speed or initial cooling for air conditioning) are largely independent of a vehicle's fuel economy and hence constitute a higher percentage of fuel consumption for high fuel economy vehicles. This implies that placing a cap on the correction factor is not warranted. Thus our treatment of plug-in vehicles may be generous in this regard and should be revisited once data are available.

As in the case of non-plug-in vehicles, we calculate the combined energy consumption for plug-ins by using a 43%/57% city/highway weighting.

Treatment of PHEVs

Emissions from PHEV operation are the emissions associated with the operation of the ICE together with the emissions associated with the grid electricity used to power the vehicle. Thus we will calculate PHEV emissions as the weighted sum of emissions associated with operation on the two power sources, where the weighting corresponds to the percentage of operation using each power source. The weighting for grid electricity is percentage of miles the vehicle is operated on electricity, or the utility factor (UF).

For PHEVs, city and highway fuel economy values (miles per gallon of gasoline equivalent) for electric-only operation and for conventional fuel operation will be available, as will a combined gasoline/electric fuel economy. From this information, it is possible to compute a UF for the vehicle, which provides the weighting from which we will calculate GHG and criteria pollutant emissions as described above.

U.S. Power Generation Characteristics

The U.S. power generation mix has changed significantly over the past decade. Coal generated power has decreased from 56 percent in 2001 to 45 percent in 2009 (EIA 2001, EIA 2009). On the other hand, power generation from natural gas has doubled from approximately 10 percent in 2001 to little more than 23 percent in 2009. A comparative power generation mix is illustrated in Figure 74. Power generation from renewable energy sources, not shown in this figure, increased from approximately 8 percent in 2001 to 10.5 percent in 2009. These changes will be reflected in Green Book's analysis of plug-in vehicles' upstream emissions.

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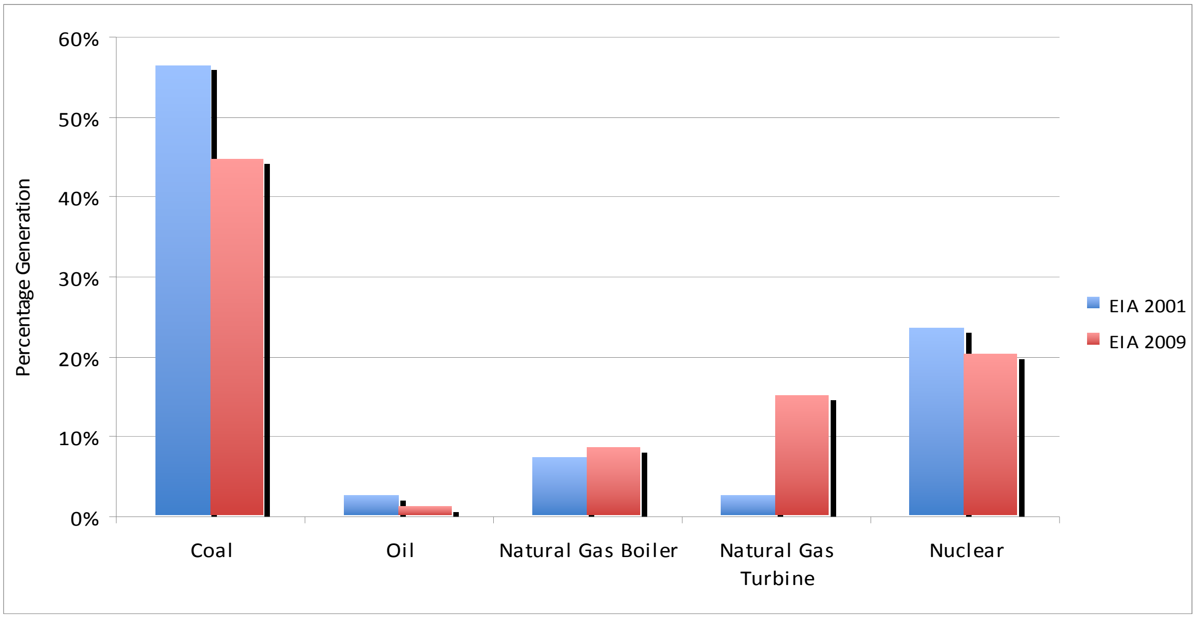
[3] Elgowainy et al. (2010) suggests an exception for the fuel economy of a parallel PHEV, where the adjustment may vary depending on the size of the battery. This source did not specify the size threshold at which this variable adjustment might become relevant, however, so we propose the same adjustment for parallel PHEVs until there is adequate data to support an alternative treatment for these vehicles.

Figure 7 U.S. Power Generation Mix

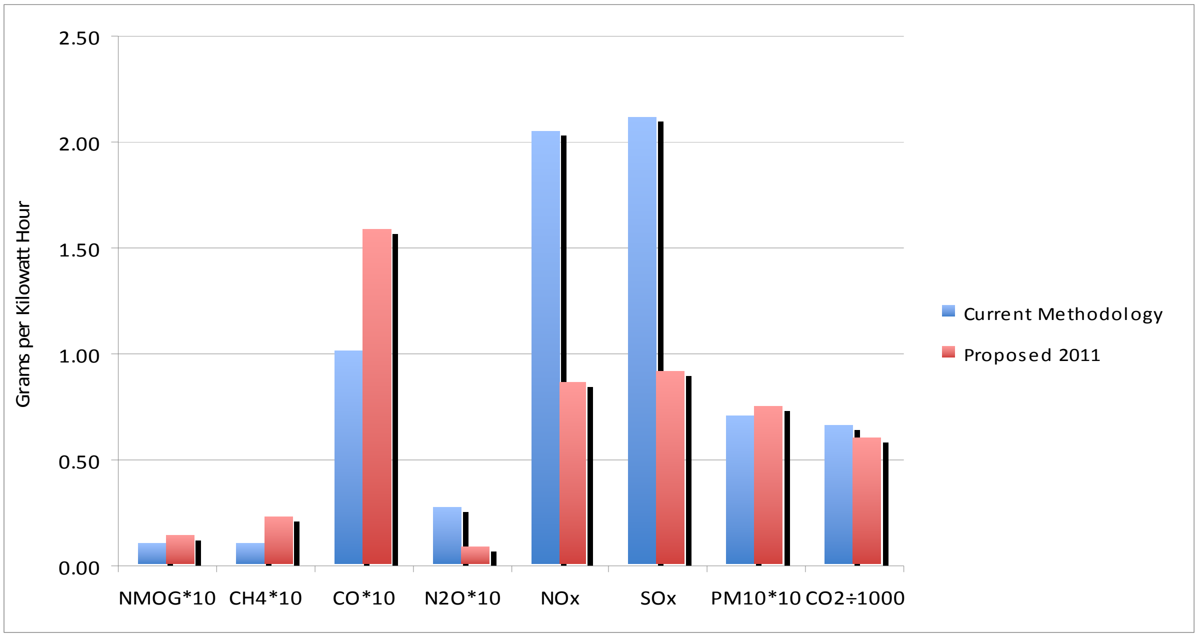


Distribution efficiency increased from 2001 to 2009 while generation efficiency of coal- and oil-based power plants decreased. These two effects together leave the average net efficiency of generation and distribution almost unchanged.

Emissions Factors and Damage Costs for Power Generation

We propose to update electricity generation emissions factors for NMOG, CH_4, CO, N_2O, NOx, SOx, PM_{10}, and CO_2 using the latest version of the DeLucchi Life-cycle Emissions Model (2005). We compiled pollutant emissions, in grams/MBtu, for different modes of power generation from the model. We then multiplied by generation and distribution efficiency as reported by EIA to calculate emissions per unit of delivered power (g/MBtu). Figure 8 highlights the difference in fuel-cycle emissions from electricity generation between the current methodology and the proposed update.

Figure 8 Comparison of fuel cycle emissions from electricity generation in grams per kilowatt-hour (g/kWh)



Note that emissions of NMOG, CH_4, CO, and PM_{10} have increased, while N_2O, NOx, SOx, and CO_2 have decreased in 2010.

Damage costs for these pollutants will be left unchanged (in real dollars) for the 2011 Green Book methodology. The resultant damage cost for non-nuclear electricity in constant cents per kWh has declined by 17 percent. For nuclear power, we propose to continue using damage costs from Ottinger et al. (1991). We explored a number of studies to find updated nuclear damage cost information, including a European Commission study and ORNL/RFF (1995), but they did not include environmental externalities.

The resultant overall damage cost for electricity is 0.61 cents per kilowatt-hour, a 14 percent decline from the damage cost in the current methodology. These changes are shown in detail in Table A1.

Combined Impact of Methodology Changes

To determine the overall impact of the use of emission certifications and updated emissions results from GREET 2.7 on vehicle ratings, we applied those changes to the model year 2010 data set.

On average, EDX values declined by 0.4 cents. For gasoline and diesel vehicles, EDX declined by up to 21 percent, with over 98 percent of all models declining between 10 and 20 percent. The use of emissions certifications to replace the current methodology's emissions factors has the greatest impact on the average EDX.

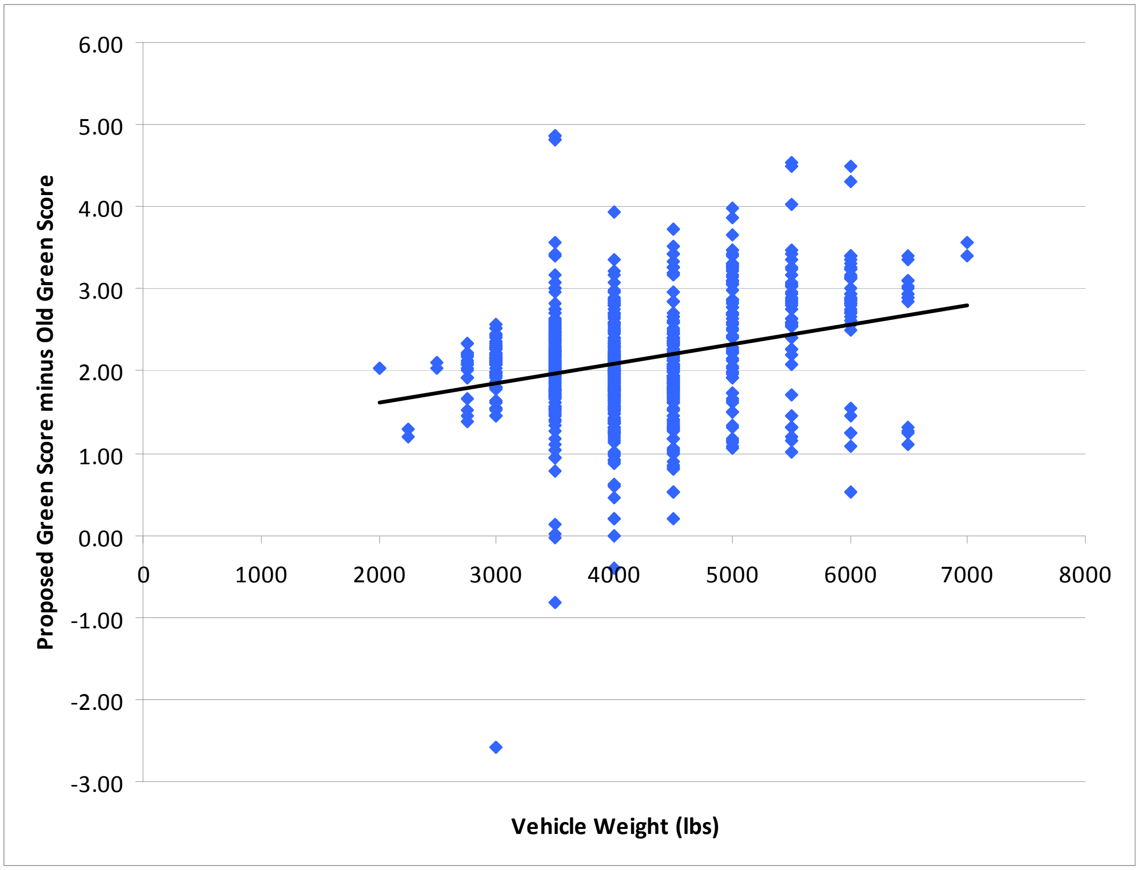
The transformation from EDX to Green Score was adjusted, per usual Green Book practice, to ensure to the extent possible the comparability of Green Scores across years. For changes to the methodology that affect EDX but do not reflect any real change in the environmental impacts of vehicles, we shift this transformation to preserve average Green Score. With regard to the methodology changes proposed here, we assume that the use of emissions results from GREET is purely a methodological change and does not represent an actual greening of the fleet, while the use of certification values as emissions rates reflects some improvement in real-world performance. Accordingly, we have adjusted the transformation from EDX to Green Score to take into account approximately half the impact of the use of emissions certification values.

The average Green Score for 2010 vehicles increased from 32.4 to 34.5 when incorporating GREET emissions results and emissions certification values.

The list of 2010 "Greenest" Vehicles would remain largely unchanged, comprised of a number of hybrid and small conventional vehicles in addition to the new electric vehicles. The CNG Honda Civic GX remains at the top of the list, scoring 54 points with the new methodology. The Nissan Leaf and Toyota Prius follow closely behind, tied for second place with 52 points. We were unable to score a number of hybrid vehicles that typically make it onto the "Greenest" list due to lack of data of battery size but we anticipate their rankings will be affected only slightly. The proposed changes to scoring will likely allow the Tier 2 Bin 5 "clean" diesels to make an appearance on the "Greenest" list

As a consequence of the proposed changes, the "Meanest" vehicles of 2010 list would be populated by an even larger number of European sports cars. This is due to the fact that the heavier light-duty vehicles that typically make the list see larger positive changes to their Green Scores from the proposed methodology. Figure 9 below shows that the average increase in Green Scores for these vehicles is roughly one point greater than for the smallest vehicles.

Figure 9 Difference in Current and Proposed Green Scores for MY2010 Dataset



Appendix 1: Application of GREET 2.7 to Green Book Embodied Emissions

Figure A1. ICE Vehicle-Cycle GHG and CO2 Emissions

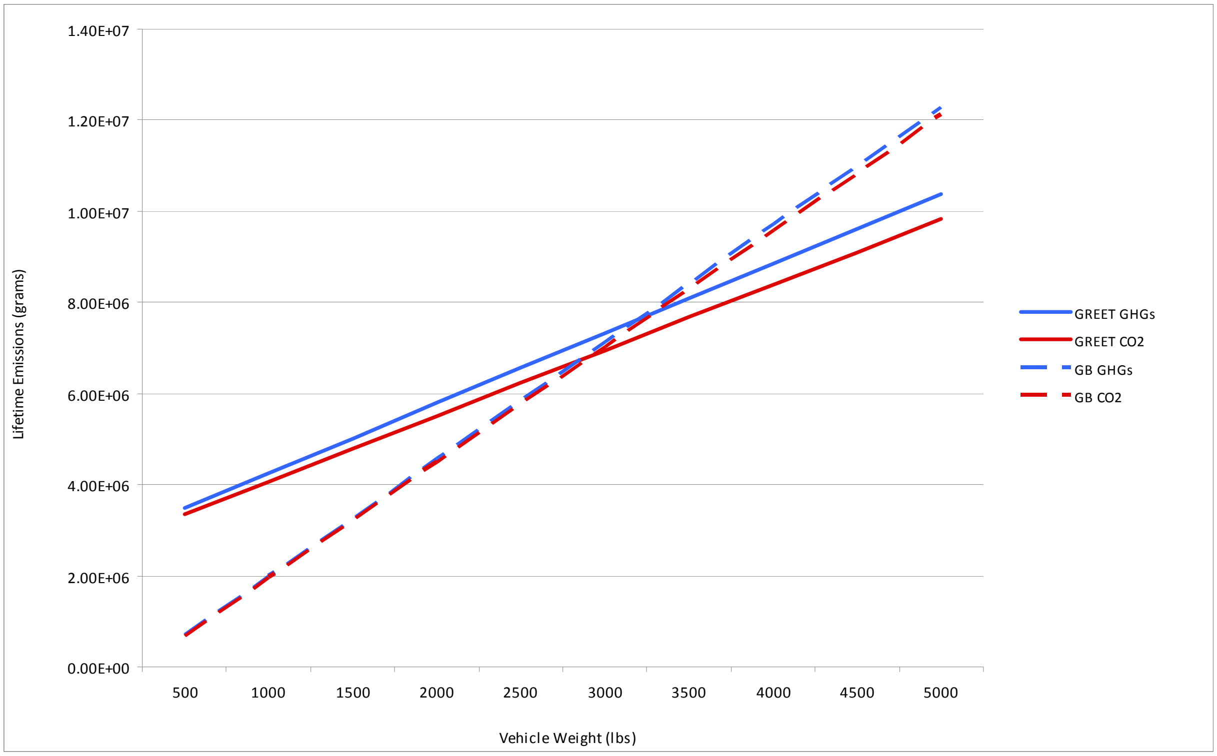
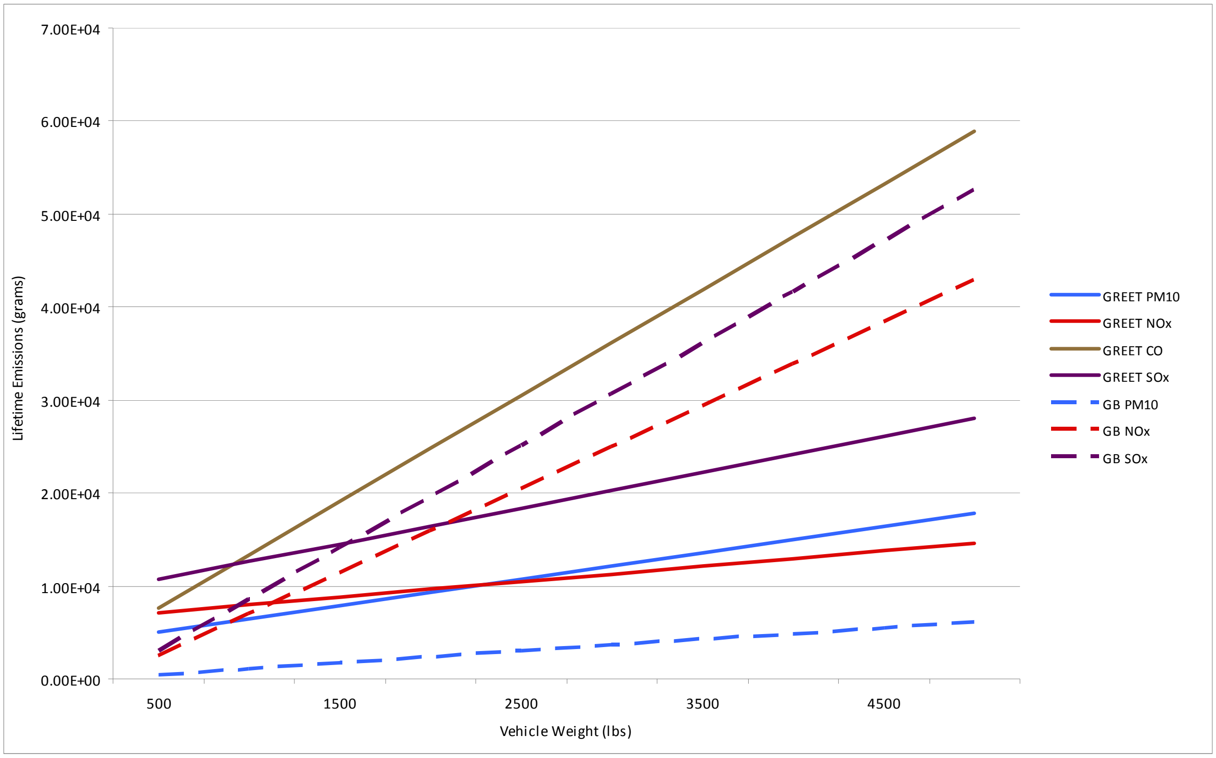


Figure A2. ICE Vehicle-Cycle Criteria Pollutant Emissions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6.00E+04
5.00E+04
4.00E+04
3.00E+04
2.00E+04
1.00E+04
0.00E+00
Lifetime Emissions (grams)
500
1500
2500
3500
4500
Vehicle Weight (lbs)
GREET PM10
GREET NOx
GREET CO
GREET SOx
GB PM10
GB NOx
GB SOx

Appendix 2: Proposed Emission Factors or Electric Vehicle Recharging

Table A1. Emissions Factors for Electric Vehicle Charging

Fossil Fuel Resource and Technology

	Coal	Oil	Natural Gas Boiler	Natural Gas Turbine	Nuclear	Renewable (d)	Others (e)	
Generation Mix (a)	44.64%	0.98%	8.36%	14.92%	20.21%	10.45%	0.44%	Average Net Efficiency
Generation Efficiency (b)	33.66%	30.33%	34.53%	34.53%	32.64%			31.10%
Distribution Efficiency (c)	93.85%	93.85%	93.85%	93.85%	93.85%	93.85%	93.85%	

Emission Rates (f) in grams per million BTU (g/Mbtu Input)				
NMOG	1.47	2.43	3.87	1.92
CH4	0.95	0.85	1.02	10.89
CO	11.86	15.15	24.01	49.90
N_2O	0.95	0.33	0.63	2.00
NO_X	153.73	42.53	23.90	59.60
SO_X	185.76	149.90	0.16	0.16
PM_{10}	8.40	11.71	3.38	19.01
CO_2 (kg/Mbtu)	95.14	75.00	53.33	53.22

Resulting Estimates:

Emissions per unit of delivered power (g/Mbtu)	Coal	Oil	Natural Gas Boiler	Natural Gas Turbine	National Average	Average g/kWh	Damage Cost 2004 $/kg	Damage Cost 2004 ¢/g	Damage Cost ¢/kWh
NMOG	4.65	8.54	11.94	5.92	4.04	0.014	0.06	0.01	0.000
CH4	3.00	2.98	3.16	33.59	6.65	0.023			
CO	37.55	53.23	74.10	153.97	46.45	0.158	0.01	0.00	0.000
N_2O	3.00	1.17	1.95	6.17	2.44	0.008			
NO_X	486.64	149.41	73.76	183.91	252.31	0.861	0.85	0.08	0.073
SO_X	588.02	526.60	0.49	0.49	267.77	0.914	4.02	0.40	0.367
PM_{10}	26.58	41.14	10.43	58.65	21.89	0.075	6.81	0.68	0.051
CO_2 (kg/Mbtu)	301.16	263.50	164.56	164.23	175.28	598.056			
Total									0.491

Nuclear Power Externality Cost	
Damage Cost (¢/kWh)	0.61
Generation Share	20.21%
Cost (¢/kWh)	0.12
Non-Nuclear electricity cost (¢/kWh)	0.49
Overall external electricity cost (¢/kWh)	0.61

a. ACEEE calculations based on information at http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html for 2009 calendar year
b. ACEEE calculations based on information from the EIA at <http://www.eia.doe.gov/cneaf/electricity/epa/epat5p4.html>

c. c. ACEEE calculations based on information from <http://www.eia.doe.gov/cneaf/electricity/epa/epates2.html>
d. d. Includes power generated from hydro, geo-thermal, solar, wind, woods, bio-mass, and photovoltaics. Hydropower was almost 66% while windpower was 17% of the total renewable power.
e. e. Others include power generated from municipal solid waste, tire derived fuels, purchased steam, hydro-electric pumped storage etc.
f. Updated from 2005 Delucchi Greenhouse Gas emissions data

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