Updates to ACEEE's Greenercars Rating System for Model Year 2021
American Council for an Energy-Efficient Economy
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This document details our updates for the analysis of model year 2021 cars and light trucks, reflected in the release of ACEEE's Greenercars rankings available at Greenercars.org. Aspects of the methodology not discussed in this memo will remain as described in the report *Rating the Environmental Impacts of Motor Vehicles: ACEEE's Green Book Methodology, 2016 Edition* (Vaidyanathan, Slowik & Junga 2016) or in previous methodology updates.

Proposed changes from the model year 2021 methodology are:

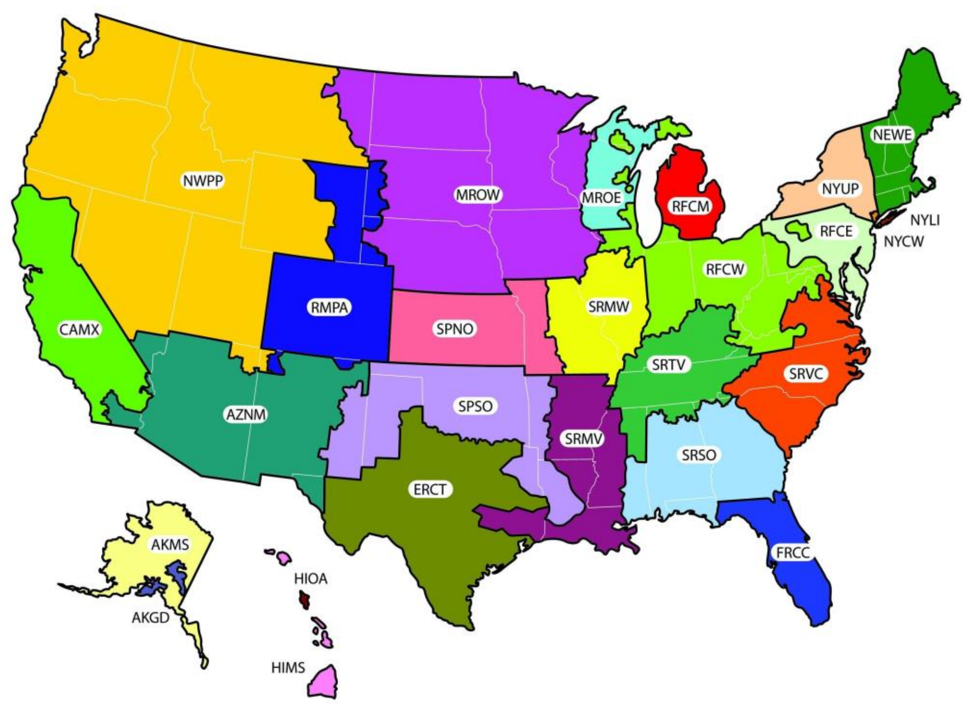
- State-based grid mix for the Greenercars EV calculator
- State sales-weighted upstream emissions

Proposed Changes

State-Based Grid Mix for EV Calculator

GreenerCars currently uses a national average electricity generation mix to estimate the greenhouse gas and criteria pollution from the electricity used by plug-in vehicles for its Green Scores. However, ACEEE also offers an EV calculator so that drivers can understand the impact of their local electricity grid when examining plug-in vehicle options. Currently, this calculator asks the user to input their zip code and this is used to determine the local grid mix as well as the local gasoline and electricity price to arrive at a location-specific EDX, Green Score, and fuel savings for electric vehicles. Zip codes are used to determine which EPA eGrid subregion the user lives in to identify the generation mix. These 26 regions were created by EPA and are smaller than NERC (North American Electric Reliability Corporation) regions but are larger than balancing authorities, a portion of the grid controlled by a single dispatcher that maintains supply and demand balance on the grid. They can contain multiple, whole states but many states are also split into multiple subregions. Zip code is also used to determine which PADD (Petroleum Administration for Defense District) the user resides in to determine gasoline prices while electricity prices are determined by a representative state or an average of states in each eGrid subregion (EIA 2012; EPA 2020). Figure 1 shows these eGrid subregions.

Figure 1. EPA eGrid Subregions



This Is a representational map; many of the boundaries shown on this map are approximate because they are based on companies, not on strictly geographical boundaries.
USEPA eGRID2010 Version 1.0 December 2010

We propose to update the EV calculator to identify the generation mix and scale EV Green Scores based on a state grid composition. eGrid reports electricity grid mix for each state that is based on aggregations of plant-level data that EIA collects. This change is most beneficial for users from states that are completely within a subregion with other states, such as Washington State, and is least beneficial for a user from a state that's divided between subregions, such as Wisconsin. For the latter, using zip code would determine which distinct grid the Wisconsin user lived in but two of the subregions include multiple other states as well. This means that a user in one of these two subregions (MROW or RFCW) may get a result in part based on generation occurring in states across the upper plains and Midwest that is not reflective of the electricity they receive. This change along with the proposed change described in the next section would also mean that all our PEV analysis in Greenercars would be state-based. This would provide consistency for users of the calculator and those examining the national scores or the EDX of a particular PEV model.

Table 1 presents a few examples to highlight the trade-offs from this change. First, we the grid emissions for select regions along with the states that make up that region. In this section you can see how a state-based approach would give you greater accuracy because some subregions are large and contain multiple states almost completely. The second section in Table 1 shows the opposite, it gives the grid emissions for select states and the multiple subregions that state intersects with. This shows the downside of our proposed state-based system because emissions could vary considerably within a state due to the way the electricity grid is divided up.

The emission factors presented in Table 1 are also weighted based on expectations of lifetime vehicle miles travelled (VMT) for EVs and the decline in emissions rate over time. Since vehicles are driven less over time and we expect the grid to become cleaner, we used VMT-weighting to generate a lifetime upstream emission factor. In this way, the average grid that we assume a MY 2020 vehicle uses over its lifetime is based on the grid emissions in the next three decades but is heavily weighted towards the first decade. AEO emissions projections for CO2 were used for the decline grid emissions over time (EIA 2020).

Table 1. CO2 emissions from combustion of fuels only (g/kWh)[1] for select states and subregions

Select subregions containing multiple states

Subregion	States partially or wholly contained within Subregion					
NWPP	WA	OR	ID	UT	MT	
233.9	88.1	130.1	70.0	739.4	465.7	
RFCE	PA	NJ	MD	DE		
319.2	408.8	217.0	440.7	441.1		
RFCW	IN	OH	WV	IL	PA	
488.4	777.7	658.2	836.3	386.6	408.8	
MROW	ND	SD	MN	IA	NE	
419.5	656.6	230.0	454.5	527.7	554.7	
NEWE	ME	VT	NH	MA	CT	RI
207.4	153.2	0.7	159.0	338.7	206.2	386.4
SRVC	VA	NC	SC			
289.3	352.7	426.0	307.4			

[1]Combustion-only emissions exclude the emissions from the processing of fossil fuels. State level grid mixes are from 2014 to match what is currently used for eGrid Subregions.

Select states intersecting with multiple subregions

State	Subregions within the State			
TX	AZNM	ERCT	SPSO	SRMV
480.8	369.7	397.1	488.4	373.8
IL	SRMW	RFCW		
386.6	615.9	488.34		
NY	NYUP	NYCW	NYLI	
198.2	139.6	231.1	344.7	

Some of the biggest differences resulting from this methodology change for the calculator are in the Northwest where state-specific grid mixes yield very different results for users. In Washington, Oregon, and Idaho EV drivers would see much lower pollution figures under the state-level version while those in Utah and Montana, would get poorer Green Scores and EDXs reflecting the fact that while the region as a whole has significant hydropower generation, these two states use more coal than the other three. Significant variations also exist among the states in the New England subregion (NEWE) and the RFCW subregion, which covers much of the Midwest.

On the other hand, in some cases using subregion may be more accurate. This is especially true in the few cases where a state contains multiple subregions that do not extend beyond the state as in New York, Hawaii, and Alaska. New York contains three subregions that have differing grid mixes with NYUP (representing upstate NY) having large amounts of hydropower and low emissions while the downstate subregions are more reliant on fossil fuels.

In addition to updating our methodology approach, we also plan to update the grid data as well as the data for electricity prices and gasoline in the state-level based calculator. For electricity mix, that would involve using 2018 eGrid electricity generation mix, which involved a shift towards natural gas and renewables and away from coal. There would be a general increase in Green Scores for electric vehicles as a result of the declining GHG and criteria emissions from the electricity grid with this update.

Table 2. eGrid National Grid Mix Data

	Coal	Oil	Natural Gas	Nuclear	Renewable and Other
eGrid 2014, current	38.7%	0.7%	27.5%	19.5%	13.6%
eGrid 2018	27.5%	<0.1%	35.2%	19.4%	17.4%

State Sales-Weighted Upstream Emissions for EVs

To assess the emissions impact of the electricity that plug-in vehicles use, Greenercars includes upstream factors that detail emissions rates in grams per kilowatt hour for the following pollutants: carbon monoxide (CO), non-methane hydrocarbons (NMHC), nitrogen oxides, particulate matter (PM_{10}), sulfur oxides (SO_X), methane (CH4), nitrous oxide (N_2O), and carbon dioxide (CO_2). These emissions factors are currently based on the national electricity grid mix and have a combustion and feedstock component.

ACEEE proposes to weight grid emissions by plug-in vehicle sales by state to reflect where EVs are largely being driven and charged. Plug-ins (PEVs) are not sold evenly throughout the country and they draw from grids that vary significantly in composition. Therefore, using national grid emissions averages that are weighted by plug-in vehicle sales will produce a more accurate picture of the average environmental impact of a particular plug-in model in a given model year.

We use sales data from the Auto Alliance (2020), which reports monthly battery electric (BEV) and plug-in hybrid sales (PHEV) for each state through October 2019. We chose to base our state-sales weighting on the latest 12-months of plug-in sales (PEV) available based on both BEV and PHEV sales. This 12-month period from November 2018 through October 2019 includes about 356,000 PEV sales. California is by far the largest market for PEVs, representing over 45% of PEV sales followed by New York, a distant second at 4.7%.

Table 3. Top 10 States by PEV Sales

State	Percent PEV Sales
California	45.4%
New York	4.7%
Florida	4.5%
Washington	4.0%
New Jersey	3.0%
Colorado	2.7%
Massachusetts	2.6%
Illinois	2.4%
Oregon	2.2%
Maryland	2.2%
All Other States	26.2%

To obtain state grid emissions data we used our EV calculator (described in the section above) to produce upstream factors for each state based on eGrid 2018 data (ANL 2018). For our purposes, we use state generation mix figures (percentage of electricity generation from coal, oil, etc.)[i] to generate state-level grams/kWh values for each of the pollutants we examine: CO, NMHC, NO_X, PM_{10}, SO_X, CH_4, N_2O, and CO_2 (EPA 2020).

We modified the Greenercars EV calculator to generate state-level emissions factors for the pollutants we evaluate by running the calculator for each state based on the grid-mix data from eGrid. We multiplied the grid-mix for each state with the combustion and feedstock emission rates for each fuel to generate total grid emission rates for each state and pollutant. The EV calculator contains our assumptions on g/mBTU or g/kWh for each fuel source (with a combustion and feedstock component) and each of the pollutants stated above. We then used these state-level values to generate a weighted average for the nation based on state PEV levels. Some of these assumptions are included in Table 7.

As stated in the previous section, we use a VMT-weighted grid for vehicles to account for expectations of a cleaner grid over time. We do this for all the pollutants we examine and use multiple projections from AEO. Specifically, projections of NO_x and SO_2 emissions estimates from AEO are used to create a trend for NO_x and SO_x, in the Greenercars model while future CO_2 estimates are used to project declines in pollution rates for all other pollutants. This methodology is consistent from previous years rankings but we are proposing to update the AEO data (EIA 2020).

Table 4 compares the upstream factors used in the MY 2020 version of Greenercars to sales-weighted emissions factors to understand the impacts of this proposed change. To most accurately compare the results of this change, we used MY 2020 vehicle data throughout.

Table 4. Upstream Emissions Factors by Pollutants

Upstream Emission Factor (g/kWh)								
Version	CO	NMHC	NO_X	PM_{10}	SO_x	CH_4	N_2O	CO_2
1. MY 2020 Original	0.126	0.045	0.282	0.051	0.897	0.797	0.006	417.487
2. My 2020 – State Sales Weighted, AEO 2018	0.189	0.038	0.291	0.188	0.331	1.938	0.005	283.754
3. MY 2020 State Sales-Weighted, AEO 2020	0.174	0.035	0.249	0.174	0.324	1.780	0.005	262.013
4. MY 2020 State Sales-weighted, AEO 2020, updated feedstock	0.227	0.045	0.272	0.025	0.323	0.807	0.007	262.115

Table 5. Data sources for versions

Version	Edition of AEO, used for VMT-Weighting	Combustion Emission Rates	Feedstock Emission Rates
1	2018	No breakout, based on GREET 2018	
2	2018	GREET 2018	GREET 2012
3	2020	GREET 2018	GREET 2012
4	2020	GREET 2018	GREET 2018

Table 5 details the data sources that were used for each version outlined in table 4, for ease of review. The EV calculator currently uses Argonne National Lab's GREET 1 2018 for combustion emission rates but GREET 2012 for feedstock emissions, as you can see in versions 2 and 3, an error we identified this year. The EV calculator should reflect updates to GREET 1 made in the main Greenercars model, which uses GREET 1 2018 for both combustion and feedstock emissions rates. We have updated the feedstock emission rates to GREET 2018 in version 4. Version 2 shows upstream factors based on sales-weighted grid mix and AEO 2018 for VMT-weighting, for purposes of direct comparison with our MY 2020 methodology. Version 3 updates the proposed methodology to use AEO 2020, which we would use for the MY 2021 Greenercars analysis. We request comment on our proposed use of version 4 for our MY 2021 analysis.

The largest change as a result of using state-based PEV sales weighting is the decline in CO_2 emission from the electric grid. In version 4 the decline is over 37% compared to version 1. This is largely due to the fact that California's grid is much lower-carbon than the national average. The increase in PM_{10} in versions 2 and 3 relative to version 1 is largely due to the use of GREET 2012 feedstock rates in those two versions (see table 7), which we correct for version 4. The increase in CO in version 4 relative to version 1 is due to the shift towards natural gas in the state-based grid (see table 6). As you can see in table 7, natural gas has significantly higher CO feedstock emissions than coal. The decline in SO_x is also due to the shift away from coal and towards natural gas but due to combustion emissions, which make up the majority of upstream SO_x emissions compared to feedstock emissions. The combustion emissions rate for SO_x for coal is almost 30 times that of natural gas (9.07 g/kwh vs. 0.32 g/kWh).

Table 6. Grid Mix Assumptions

	Coal	Oil	Natural Gas	Nuclear	Renewable and other
MY 2020, based on AEO 2018	31.9%	0.4%	31.3%	20.5%	16.0%
Proposed MY 2021, based on PEV sales-weighted from eGrid 2018	10.8%	0.9%	41.0%	15.8%	31.5%

Table 7. Select Feedstock Emission Rates (g/mBTU)

	Coal (GREET 2012)	Coal (GREET 2018)	Natural Gas (GREET 2018)
NMHC	7.63	7.50	8.57
CH4	148.35	147.86	192.54
CO	2.59	2.89	23.04
N20	0.03	.03	0.79
NOx	12.77	13.54	29.41
SOx	7.19	6.89	11.40
PM10	173.73	8.80	0.45
CO2	1,591.61	1,648.05	5,294.27

Table 8. Greenercars Model Results, all with MY 2020 vehicle data.

Version	Average GC Score for BEVs	Average EDX for BEVs	Average difference in GC score relative to Ver. 1	Average difference in EDX relative to Ver. 1
1	51.76	1.17	-	-
2	55.06	1.06	3.30	-0.11
3	55.58	1.04	3.82	-0.13
4	56.18	1.02	4.42	-0.15

In general, shifting to a sales-weighted electricity mix raised Green Scores of BEVs and lowered their EDX compared to MY2020 values. The largest changes were when the AEO projection was updated to 2020 and the feedstock emission rates were updated to GREET 2018, which significantly lowered PM_{10} and methane emission rates (version 4). As seen in table 8, version 4 had the largest average increase in Green Score of 4.42 points (8.5%) and the largest average decline in EDX of 0.15 (12.8%). In this version, 11 of the top 12 greenest cars would be BEVs compared to 6 in the MY 2020 results. In both versions 2 and 3, 10 of the top 12 greenest cars would be BEVs.

The main benefit of this approach is that it more accurately reflects the environmental impacts of the PEVs being sold today. The environmental impact of PEVs varies considerably by geography because of the regional differences in the electricity they use. Additionally, PEV sales as a percentage of total vehicle sales are concentrated in particular states. This approach attempts to address these variations. Therefore, the EDX impact for say, a BMW i3, is more reflective of where i3s are actually being sold today since they are not sold uniformly across the U.S.

A secondary benefit of this approach is that it is more reflective of policy decisions around grid cleanliness and PEV deployment. The fact that such a large portion of PEV sales have occurred in California and that California has a cleaner than average grid is in part, because of their policy choices. This means that our scores for these vehicles will be more responsive to state-level policy changes and will more accurately reflect changes in future policies. An EV driven on a cleaner grid is inherently a greener vehicle and this year's proposed update will assign a higher Green Score than previous years to reflect the additional benefits. We welcome comments on our proposal to change the grid assumption to one based on BEV sales at the state level.

References

ANL (Argonne National Laboratory). 2018. *Summary of expansions and updates in GREET 2018.* Argonne, IL: Argonne National Laboratory. greet.es.anl.gov/publication-greet-2018- summary

EIA (U.S. Energy Information Administration). 2012. *PADD Regions Enable Regional Analysis of Petroleum Product Supply and Movements.* Washington, DC: U.S. Energy Information Administration. www.eia.gov/todayinenergy/detail.php?id=4890

EIA (Energy Information Administration). 2020. *Annual Energy Outlook 2020.* Washington, DC: Energy Information Administration, Department of Energy. www.eia.gov/outlooks/archive/aeo20/

EPA (U.S. Environmental Protection Agency). 2020. *The Emissions & Generation Resource Integrated Database: Technical Support Document for eGRID with Year 2018 Data.* Washington DC: Clean Air Markets Division, Office of Atmospheric Programs, U.S. Environmental Protection Agency. www.epa.gov/sites/production/files/2020-01/documents/egrid2018_technical_support_document.pdf

Auto Alliance (Alliance for Automotive Innovation). 2020. *Advanced Technology Vehicle Sales Dashboard.* Accessed November 30. autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/