Updates to ACEEE's Greenercars Rating System for Model Year 2022
American Council for an Energy-Efficient Economy
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This document details our updates for the analysis of model year 2022 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.

Change from the model year 2022 methodology:

- Updated Embodied Emissions based on GREET 2021

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GreenerCars relies on GREET to model the emissions from the materials used to manufacture vehicles, including the sourcing and processing of minerals for vehicle batteries. For MY 2020 we updated our methodology for battery electric vehicles (BEVs) to calculate emissions factors for the different lithium-ion cathode materials. GREET 2021 included considerable updates to its methodology around manganese (used in many Li-Ion batteries) and lithium. As a result, we are updating our embodied emissions figures for plug-in vehicles.

Argonne National Lab (ANL) conducted a literature review to update its manganese modelling, resulting in an increase in the assumed manganese content of manganese ore, 55% versus 35%. ANL does not state the impact or direction of impact of this change but it likely reduces emissions given that less ore is now assumed to be mined and processed to produce the same amount of manganese needed for battery manufacturing (Winjobi & Kelly 2021). The significant changes to GREET's lithium assumptions were based on original research by ANL into the emissions from the production and processing of lithium from both Chilean-based brine resources and Australian-based ore resources. ANL undertook new life cycle analyses to inform the cathode emissions assumptions used in GREET for NMC811 and NMC622 batteries, which led to a 9% and 20% increase in greenhouse gas emissions for the full 84kWh versions of those battery types, respectively. According to ANL, this is the first life cycle analysis of lithium compounds using primary industry data from Chile and Australia, two primary producers of lithium (Kelly, Wang, Dai & Winjobi 2021).

For consistency, we have decided to also update the embodied emissions factors for all vehicles to be in line with the most current version of GREET.

Table 1. Changes in EDX from Embodied Emissions Updates

	Overall average EDX	Overall BEV EDX	ICE Car EDX	ICE Light Trucks EDX	NCA EDX	NMC111 EDX	NMC622 EDX
Final 2021	1.52	0.90	1.48	1.65	0.97	0.86	0.89
Modified Embodied 2021	1.51	1.04	1.47	1.64	1.17	0.94	1.03
DIFFERENCE	**-0.01**	**0.14**	**-0.01**	**-0.01**	**0.20**	**0.08**	**0.15**

Note: A positive difference means a worsening of environmental impact and vice-versa. BEV = Battery Electric Vehicles or fully-electric vehicles. ICE= Internal Combustion Engine vehicles, excluding hybrids and fully-electric vehicles.

While embodied emissions assumptions were updated in 2021 for all vehicle technologies, the most significant changes were for vehicles using a Li-Ion battery. The change in the EDX between the final MY 2021 values and the values when only updating the embodied emissions calculations is most significant and positive (worse) for fully-electric vehicles with Li-Ion batteries at 0.14 and very small and negative (better) for internal combustion engine (ICE) vehicles at -0.01. For vehicles without Li-Ion batteries, the update to GREET 2021 was minor.

The change in average EDX was significant (and worse) for all three lithium battery types found in MY 2021 vehicles. The largest change observed was for NCA batteries, exclusively used by Tesla, at 0.20 while the smallest change was for NMC111 batteries at 0.08, which is used as Greenercars' default or when we know a NMC cathode is used but we do not have the exact formulation. We also updated the emissions factors for NMC811 batteries but no vehicle in our MY 2021 scoring had or was assigned that cathode type and so it was not modelled using MY 2021 data but may be included in the upcoming or future GreenerCars rankings. Based on the updated modelling assumptions for NMC811 batteries, we would expect the change in EDX for vehicles with these batteries to be similar to those with NMC622 batteries.

To demonstrate the impact of these proposed changes, we looked at the impact these changes would have had on the 2021 Greenest list. Given that this proposed update will change the EDX of vehicles using Li-Ion batteries, largely high-performing plug-in vehicles, more significantly than other largely traditional internal combustion vehicles, we would have seen a significant shift in the Greenest List as a result.

Table 2. Change in Greenest List from Embodied Emissions Update

Final MY2021			Modified MY 2021		
Greenest	Power Train	EDX	Greenest	Power Train	EDX
Hyundai Ioniq Electric	EV	0.60	Toyota Prius Prime	PHEV	0.62
Mini Cooper SE Hardtop 2 Door	EV	0.61	Hyundai Ioniq Electric	EV	0.64
Toyota Prius Prime	PHEV	0.64	Mini Cooper SE Hardtop 2 Door	EV	0.67
BMW i3s	EV	0.65	Nissan Leaf	EV	0.68
Nissan Leaf	EV	0.66	Honda Clarity	PHEV	0.69
Honda Clarity	PHEV	0.70	BMW i3s	EV	0.73
Hyundai Kona Electric	EV	0.71	Toyota Rav4 Prime AWD	PHEV	0.74
Kia Soul Electric	EV	0.72	Toyota Corolla Hybrid	HEV	0.74
Tesla Model 3 Standard Range Plus	EV	0.75	Honda Insight	HEV	0.76
Toyota Rav4 Prime AWD	PHEV	0.76	Toyota Camry Hybrid LE	HEV	0.77
Toyota Corolla Hybrid	HEV	0.76	Hyundai Sonata Hybrid Blue	HEV	0.78
Honda Insight	HEV	0.77	Kia Soul Electric	EV	0.79

The number of traditional hybrids on the Greenest List has increased from 2 to 4, replacing 2 EVs. A plug-in hybrid now takes the top spot as EVs move further down the list as their larger batteries disproportionately increase their emissions. PHEVs improved their performance as the emissions embodied in their non-battery components improved more than the reduction in performance from their Li-Ion batteries, which are considerably smaller than those of EVs. The first EV that left the list is the Hyundai Kona Electric, which saw a large increase in its EDX, from 0.72 to 0.81. The other EV that has left the list is the Tesla Model 3 Standard Range Plus, which with its NCA battery, also saw a large increase in its EDX, increasing from 0.75 to 0.89. The traditional hybrids, much like the PHEVs, increased slightly in their performance but the additional 2 are only on the list because of the downward movement of plug-in vehicles. The overall EDX of the Greenest list has increased, ranging from 0.62 to 0.79 compared to 0.60 to 0.77 in the final MY 2021 ranking.

References:

Kelly, Jarod C., Michael Wang, Qiang Dai, Olumide Winjobi. "Energy, greenhouse gas, and water life cycle analysis of lithium carbonate and lithium hydroxide monohydrate from brine and ore resources and their use in lithium ion battery cathodes and lithium ion batteries." *Resources, Conservation and Recycling* 174 (2021): 105762. https://doi.org/10.1016/j.resconrec.2021.105762

Winjobi, O., and J.C. Kelly. (2021). *Update of the Manganese Pathway in GREET 2021. https://greet.es.anl.gov/publication-mn_update_2021*