Effects of battery chemistry and performance on the life cycle GHG intensity of electric mobility

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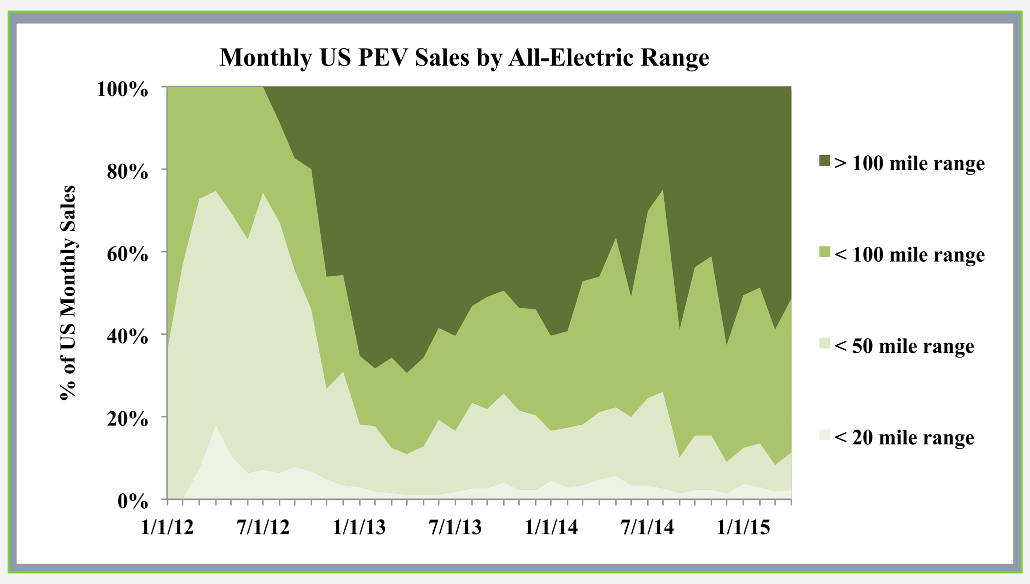
Electric Vehicles, Batteries, and Life Cycle Emissions

A transition to electric vehicles is under way. Fueled by rapidly decreasing lithium battery prices and supportive policies/incentives, electricity increasingly seems the most viable, near-term, low-carbon, transportation fuel pathway. Battery production plays a significant role in the cradle-to-gate impacts of PEV manufacture, and battery life-time and ageing have important impacts on PEV on-road emissions performance. We compare life cycle GHG emissions from lithium- based traction batteries for vehicles using a probabilistic approach based on 24 hypothetical vehicles modeled on the current US market. We simulate life cycle emissions for five commercial chemistries and discuss life cycle GHG emissions implications.

	Conventional ICE	Hybrid HEV	Plug-in Hybrid PHEV	Battery Electric BEV
Power	ICE Engine	ICE Engine + eMotor	ICE Engine + eMotor	eMotor
Battery Size	-	Small	Medium	Large
Gasoline	+	+	+	
Electricity			+	+



Background Literature

- *Li-ion battery production can be responsible for 35-40% of production related climate emissions for a 75-100 mile range BEV.[R1]*
- *GWP for battery production is dominated by a few, well-identified materials, including aluminum and graphite, in addition to the active cathode material.[R2]*
- *A wide range of production carbon emission estimates have been published for li-ion chemistries, from 32-487 kg CO_2/kWh.[R3]*

Methods and Assumptions

- *Battery model and LCIs drawn from GREET2014 and other published sources*
- *Vehicle model and battery data from US AFDC and NREL*
- *US grid emissions based on EGRID2009*

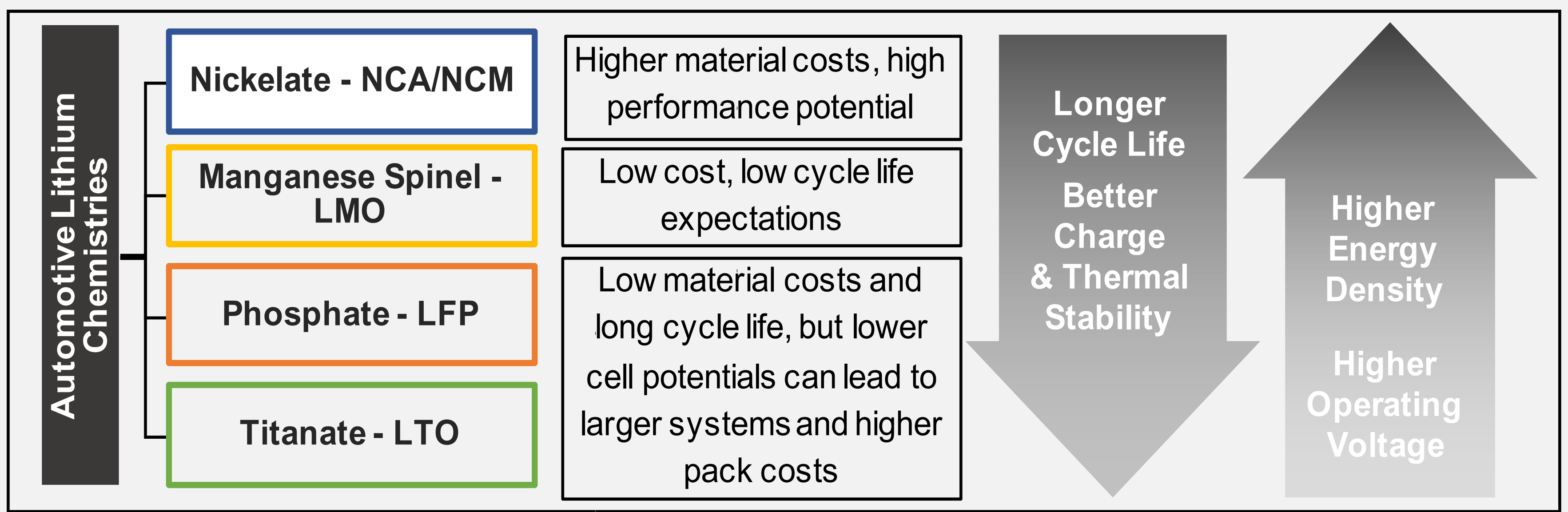
$$ChemLife_i \sim (logN(LBV, 0.3 * LBV))$$

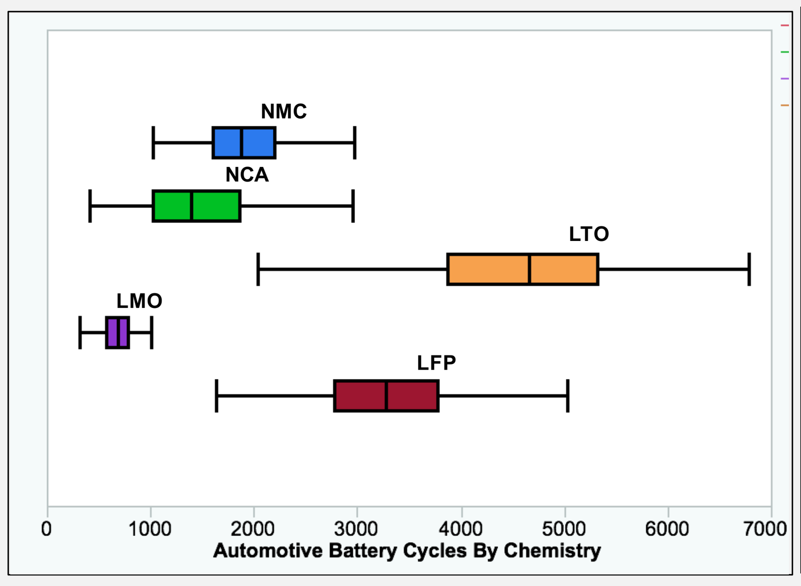
$$Production\ Emissions = \frac{ChemGWP_i}{\sum_k^{Cycle\ life} eVMT}$$

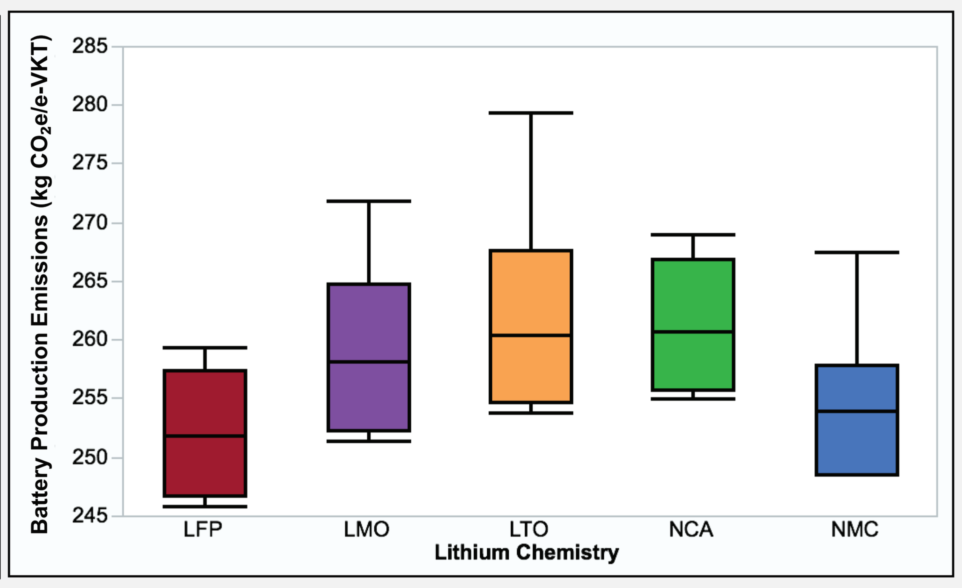
$$Fuel\ Emissions = Grid * \left(\frac{Veh_{eff}}{1 - Climate_{load}}\right) * Charge_{eff}$$

Results

Comparing battery production emissions to operation emissions for several PEV technologies

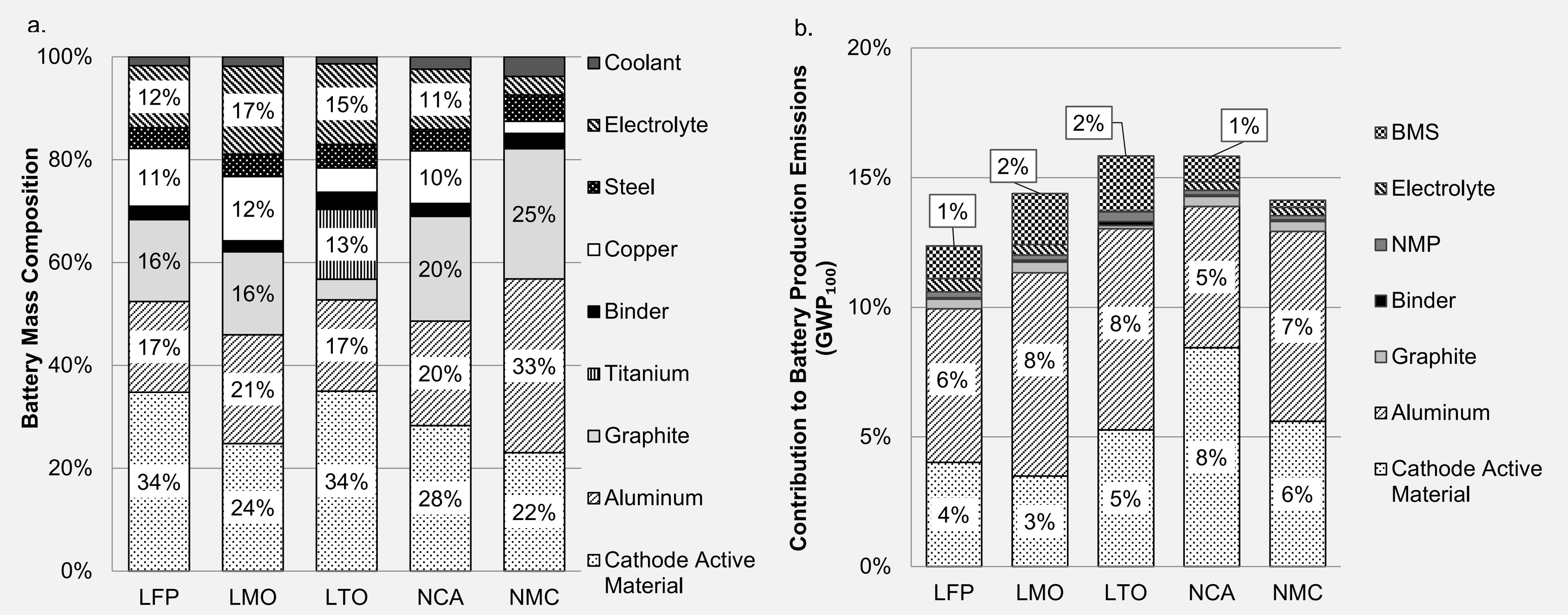


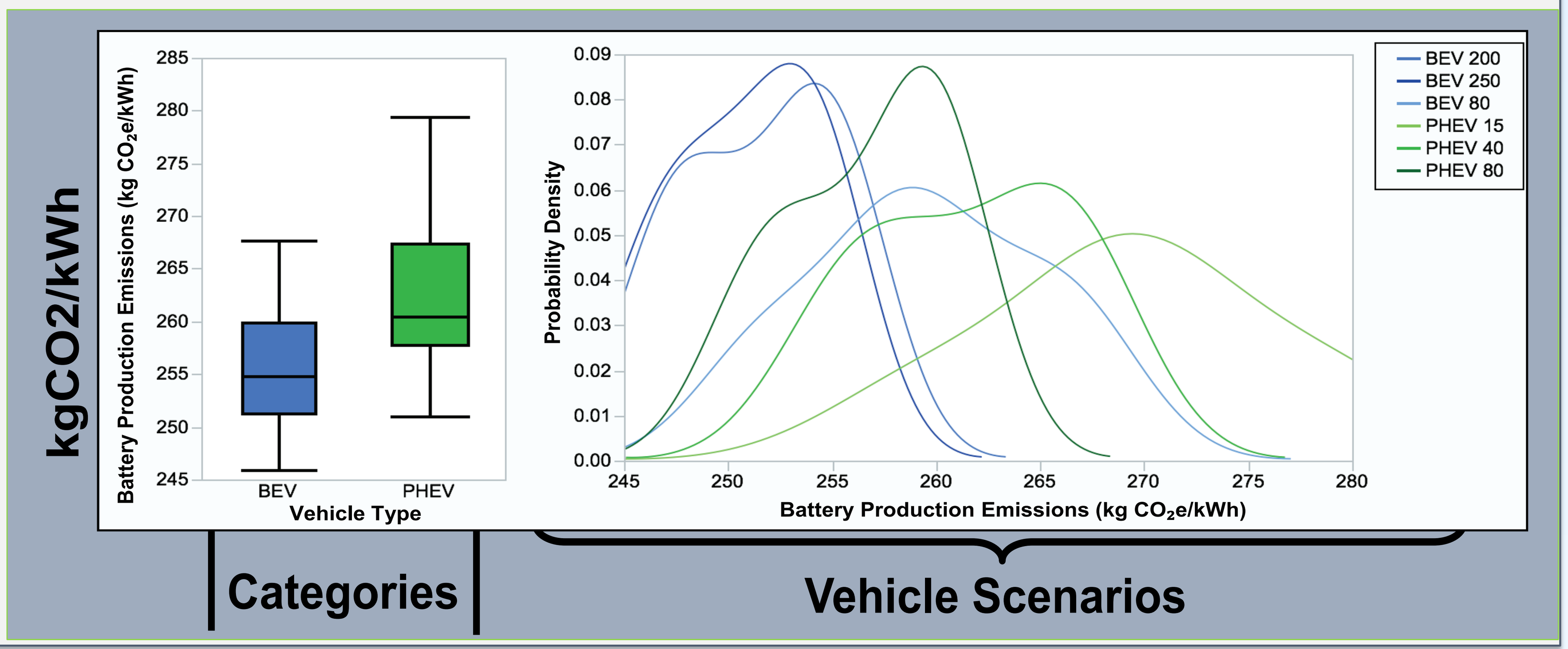




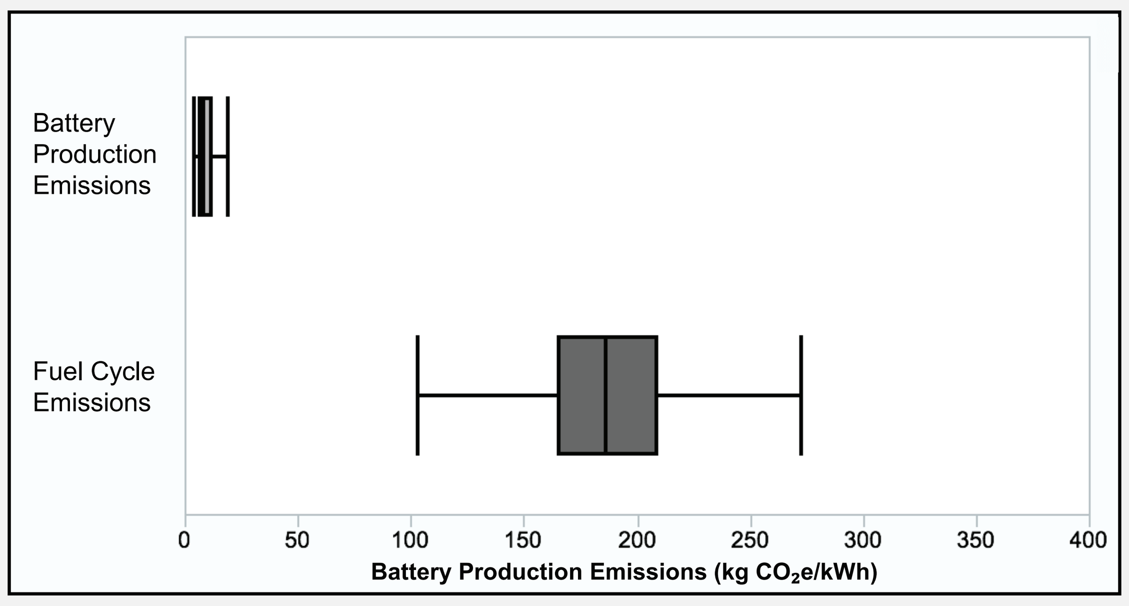
Battery cycles by chemistry - Abbreviations: Lithium Manganese Oxide = LMO, Lithium Nickel Manganese Cobalt Oxide = NMC, Lithium Nickel Cobalt Aluminum Oxide = NCA, Lithium Iron Phosphate = LFP, Lithium Manganese with Titanate Oxide Anode = LTO

Composition of lithium batteries and material GHG emissions by chemistry: (a) mean composition of traction batteries by components (% of total mass) (b) mean GHG emissions from materials by chemistry (% of total battery production emissions)

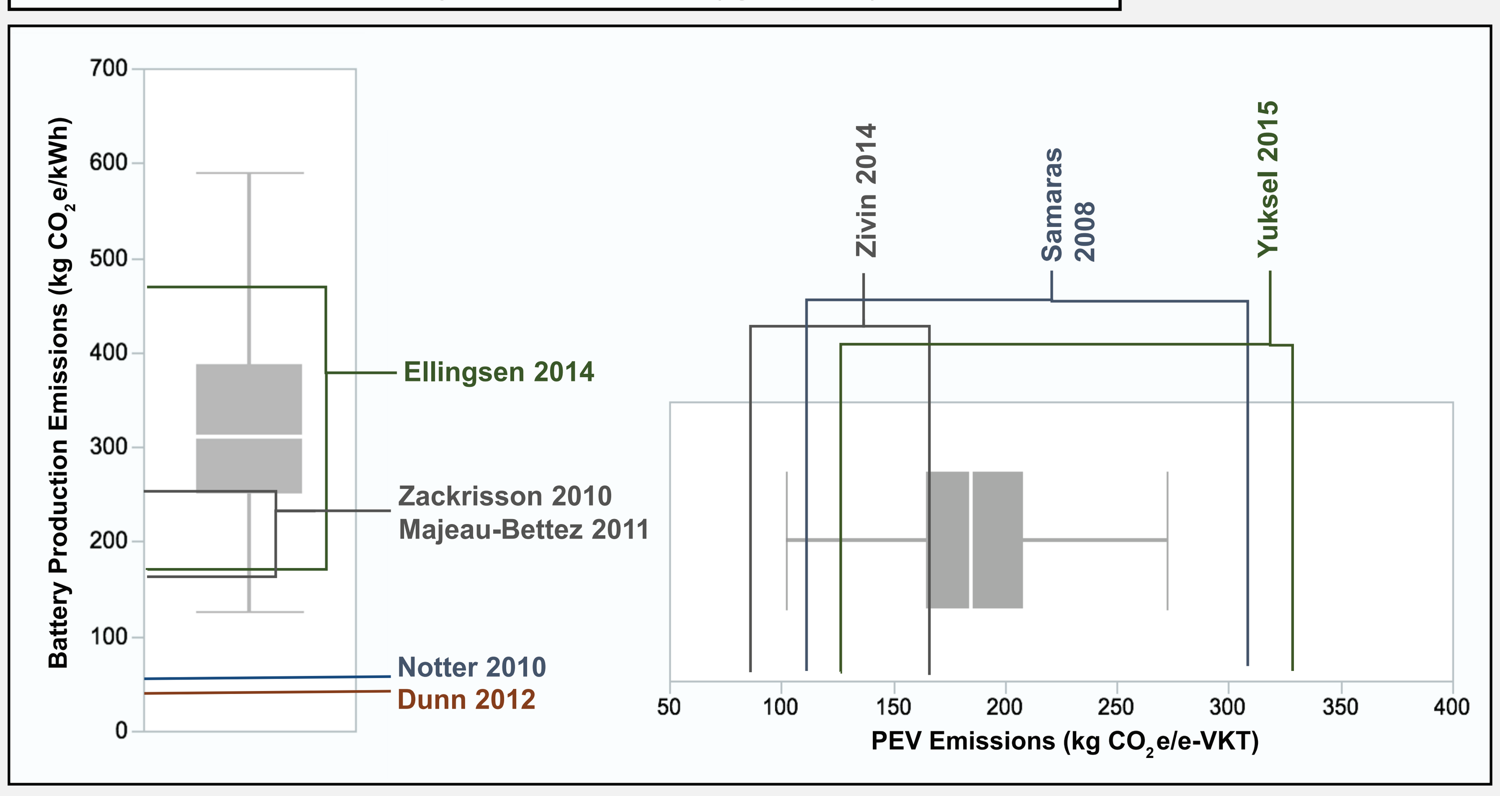


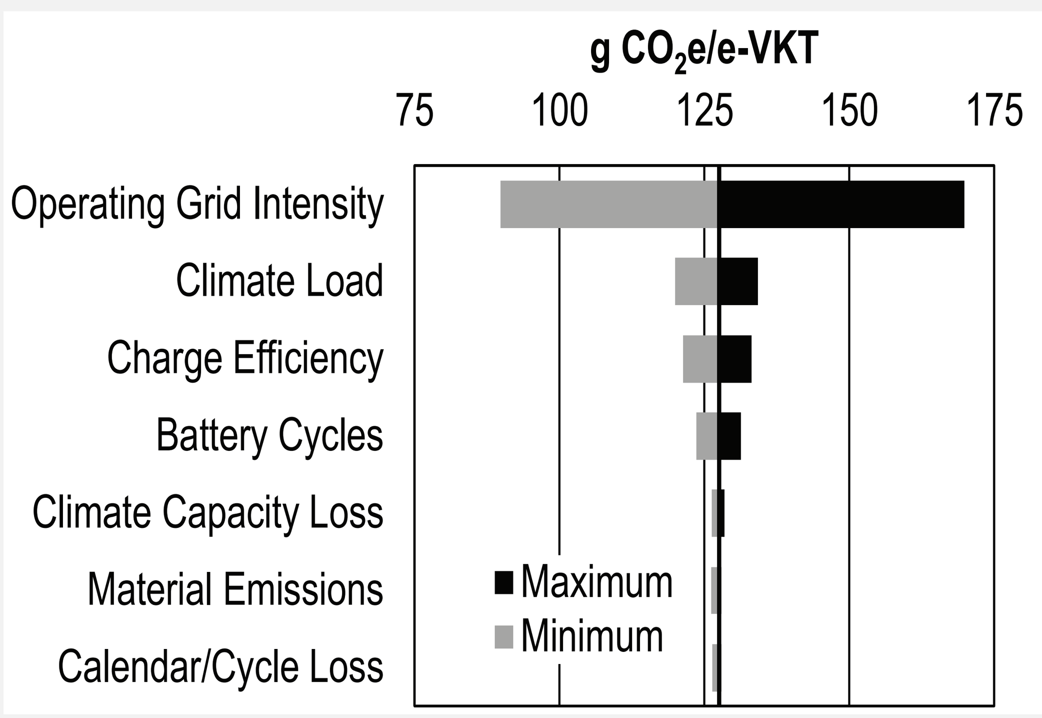


Conclusions: Battery emissions in the context of electric mobility



This research highlights a number of factors that influence the performance of PEVs from a GHG emissions standpoint; these findings can be used to inform the regulatory landscape for deployment of PEVs in the U.S. and globally, as well as shape engineering decisions for vehicle OEMs. This probabilistic approach suggests that the exclusion of production-related emissions for PEVs and realistic operating performance may ignore tradeoffs in production and operation emissions of PEVs, and places the contribution in context of other significant drivers of operation phase PEV GHG emissions.





Ambrose, H. & Kendall, A. (2015). *Lithium traction battery chemistry and performance: life cycle greenhouse gas emissions implications for electric vehicles.* - Manuscript submitted for publication

Selected References

- Hawkins, T. R.; Singh, B.; Majeau-Bettez, G.; Strømman, A. H., Comparative environmental life cycle assessment of conventional and electric vehicles. *Journal of Industrial Ecology* **2013,** *17*, (1), 53-64.
- Dunn, J. B.; Gaines, L.; Sullivan, J.; Wang, M. Q., Impact of recycling on cradle-to-gate energy consumption and greenhouse gas emissions of automotive lithium-ion batteries. *Environmental science & technology* **2012,** *46*, 12704-10.
- Ellingsen, L. A. W.; Majeau-Bettez, G.; Singh, B.; Srivastava, A. K.; Valøen, L. O.; Strømman, A. H., Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack. *Journal of Industrial Ecology* **2014,** *18*, (1), 113-124.
- Burke, A.; Miller, M., Performance characteristics of lithium-ion batteries of various chemistries for plug-in hybrid vehicles. In *EVS24 International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium*, 2009; pp 1-13.
- Yuksel, T.; Michalek, J. J., Effects of Regional Temperature on Electric Vehicle Efficiency, Range, and Emissions in the United States. *Environmental science & technology* **2015,** *49*, (6), 3974-3980
- Notter, D. A.; Gauch, M.; Widmer, R.; Wager, P.; Stamp, A.; Zah, R.; Althaus, H.-J. r., Contribution of Li-ion batteries to the environmental impact of electric vehicles. *Environmental science & technology* **2010,** *44*, (17), 6550-6556
- Graff Zivin, J. S.; Kotchen, M. J.; Mansur, E. T., Spatial and temporal heterogeneity of marginal emissions: implications for electric cars and other electricity-shifting policies. *Journal of Economic Behavior & Organization* **2014**
- C. Samaras and K. Meisterling, *Environmental Science & Technology*, 2008, **42**, 3170-3176.

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