Propane vs. Electric School Bus: Don't Rush to Judgement

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Recently, the EPA announced the availability of the first round of funding under the $5 billion Clean School Bus Program, which was a major component of the bipartisan Infrastructure, Investment and Jobs Act, colloquially called the Infrastructure Law. Under this law, there is a guaranteed $2.5 billion available for implementing electric vehicle school buses while the remainder could be used for implementing electric, propane, and natural gas school buses. Several organizations are advocating the usage of the funds for just electric school buses.

At the Propane Education & Research Council (PERC), we developed a tool to compare the lifecycle equivalent carbon dioxide (CO2eq) emissions of a propane vehicle and an electric vehicle. The tool largely is an extension of a whitepaper I published two years back, where I have documented the procedure of computing lifecycle emissions [1]. There are several factors governing lifecycle emissions. For simplicity, I want to focus on only couple of parameters chiefly, baseload vs. non-baseload emission factors and net energy consumption of an electric school bus. Typically, it is assumed that medium-duty electric vehicles (Class 5-6) have an energy consumption of 1.3-1.4 kWh/mile, and this is largely used in published marketing material. Figure 1 shows the typical range of energy consumption for Type C electric school buses based on data published in the School Transportation Network Buyer's Guide 2022 [2].

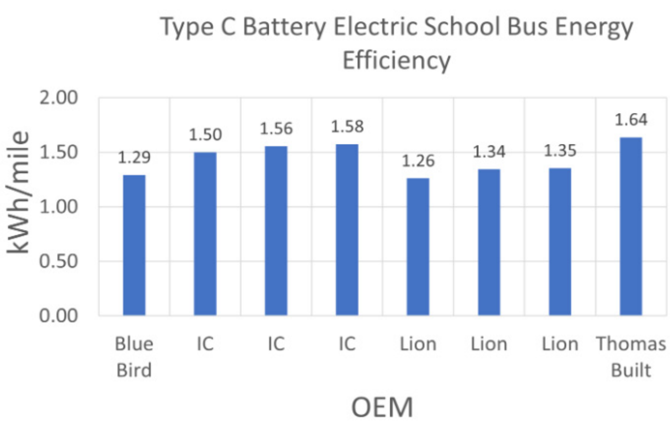

***Figure 1**: Type C electric school bus energy consumption calculated using battery size and expected vehicle range [2]*

However, we have seen real-world data portray a completely different story. For example, Twin Rivers Unified School District (CA), which transports approximately 5,000 students employs a fleet of 43 electric buses (eLion). For the months of October, November and December of 2018, an average of 10 (11,075 miles), 9 (7,882 miles) and 11 electric school buses (8,176 miles) were dispatched. The average route varied between 43.9 miles to 47.4 miles. The average energy consumption for those months were 1.99 kWh/mile, 1.79 kWh/mile and 1.9 kWh/mile, respectively [3]. This is markedly higher than the 1.26-1.35 kWh/mile values calculated using published manufacturer data. As per the report prepared for the Massachusetts Department of Energy Resources by the Vermont Energy Investment Corporation [4], the measured energy efficiency of Lion electric school bus was 2.38 kWh/mile for Amherst Regional Public School District (MA). According to the report, this was in stark contrast with the 1.3-1.4 kWh/mile as published by the manufacturer due to accounting for vampire loads that occur during charging. In fact, the report found that leaving the school bus plugged in for longer than 10 hours (which is common during weekends, school vacations, and some weeknights) can result in an energy consumption of 3 kWh/mile.

In terms of the emissions attributed to the electric grid, one could argue that non-baseload emission factor is perhaps the right metric to be used for

1. https://propane.com/research-development/emissions/decarbonization-of-md-hd-vehicles-with-propane/
2. https://content.yudu.com/web/1qiu9/0A1rp8i/bg22/html/index.html?page=10&origin=reader
3. Sustainable Fleet Technology Webinar Series 2021, Session #10: Real World EV Durability, Long Term Maintenance and Operating Cases, July 29 2021.
4. https://www.veic.org/Media/default/documents/resources/reports/veic-ma-doer-electric-school-bus-pilot-project.pdf
5. Burton, T., Powers, S., Burns, C., Conway, G. et al., "A Data-Driven Greenhouse Gas Emission Rate Analysis for Vehicle Comparisons," SAE Int. J. Elec. Veh. 12(1):2023.
6. https://www.epa.gov/egrid/data-explorer

calculating the emissions from a marginal load that is added to the grid. However, electric vehicle advocates would argue that using average baseload emission factor would make appropriate sense. A recent paper published by Burton et al. conducts a detailed analysis for each balancing authority in the U.S. and accounts for marginal emissions (including from renewable energy sources and electricity imports) [5]. This is probably the best way to quantify the emissions from a marginal load but for simplicity, we will use the EPA eGRID2019 [6] state specific baseload and non-baseload CO2eq emission factors here for comparisons. Note, these emission factors were corrected for upstream/feedstock emissions to account for lifecycle emissions of site electricity.

Case 1 with 1.4 kWh/mile

- Electric school bus energy efficiency - 1.4 kWh/mile
- Nominal propane school bus fuel economy – 4.5 MPG
- Miles per day – 50
- Miles per year - 15,000
- Bus life - 15 years

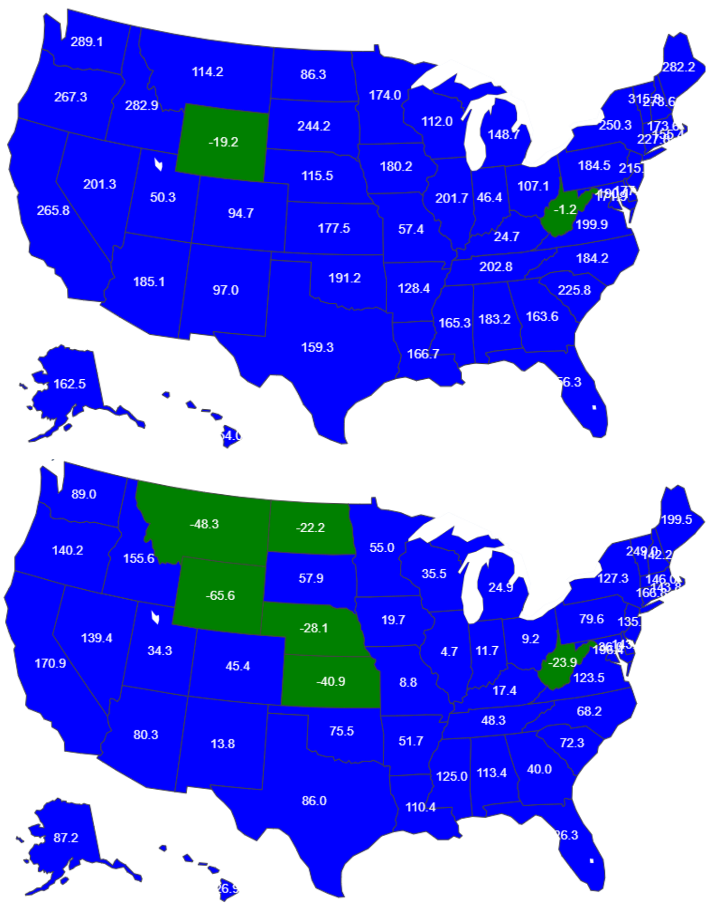

Figure 2: CO2eq emissions comparisons between a propane and an electric school bus using baseload (above) and non-baseload (below) emissions.

The plots show the difference in CO2eq emissions between a single propane and single electric bus. The numbers in the map indicate the difference in lifecycle CO2eq emissions between a propane bus and an electric bus in metric tons/year. In the plots, favorable states for propane school bus have been colored green while favorable states for electric school bus have been colored blue. Considering baseload emissions, propane is better than an electric school bus only in West Virginia, and Wyoming. Considering non-baseload emissions, a propane school bus is better in 6 states including Kansas, Montana, Nebraska, North Dakota, West Virginia, and Wyoming.

Case 2 with 2 kWh/mile

- Electric school bus energy efficiency - **2 kWh/mile**
- Nominal propane school bus fuel economy – 4.5 MPG
- Miles per day – 50
- Miles per year - 15,000
- Bus life - 15 years

Considering baseload emissions, propane is better than an electric school bus only in 15 states while considering non-baseload emissions, a propane school bus is better in 35 states than an electric school bus.

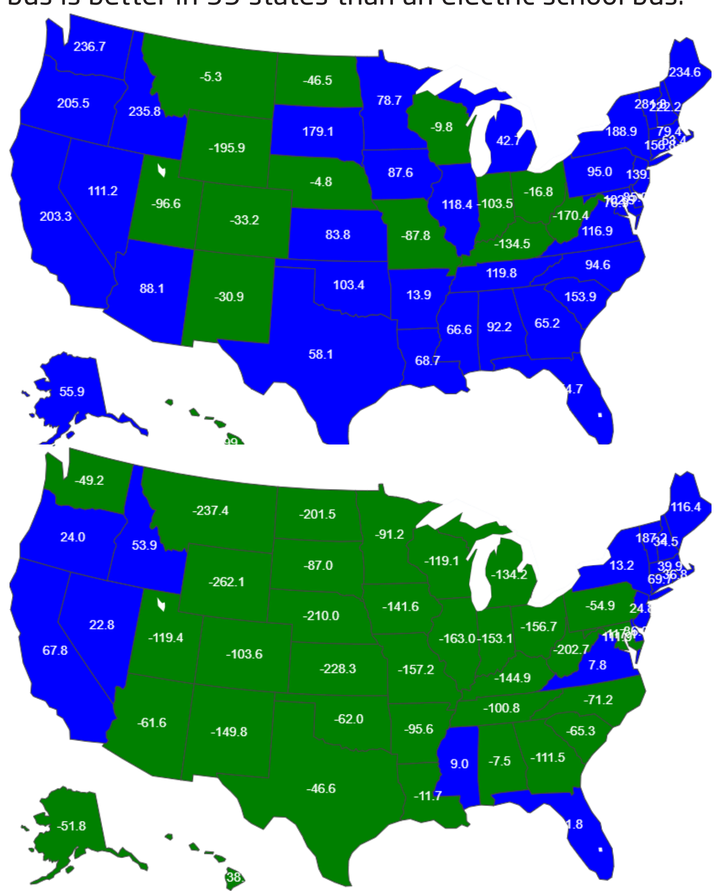

Figure 3: CO2eq emissions comparisons between a propane and an electric school bus using baseload (above) and non-baseload (below) emissions.

Case 3 with 2.4 kWh/mile

- Electric school bus energy efficiency - **2.4 kWh/ mile**
- Nominal propane school bus fuel economy – 4.5 MPG
- Miles per day – 50
- Miles per year – 15,000
- Bus life – 15 years

Considering baseload emissions, propane is better than an electric school bus only in 22 states while considering non-baseload emissions, a propane school bus is better in 48 states than an electric school bus.

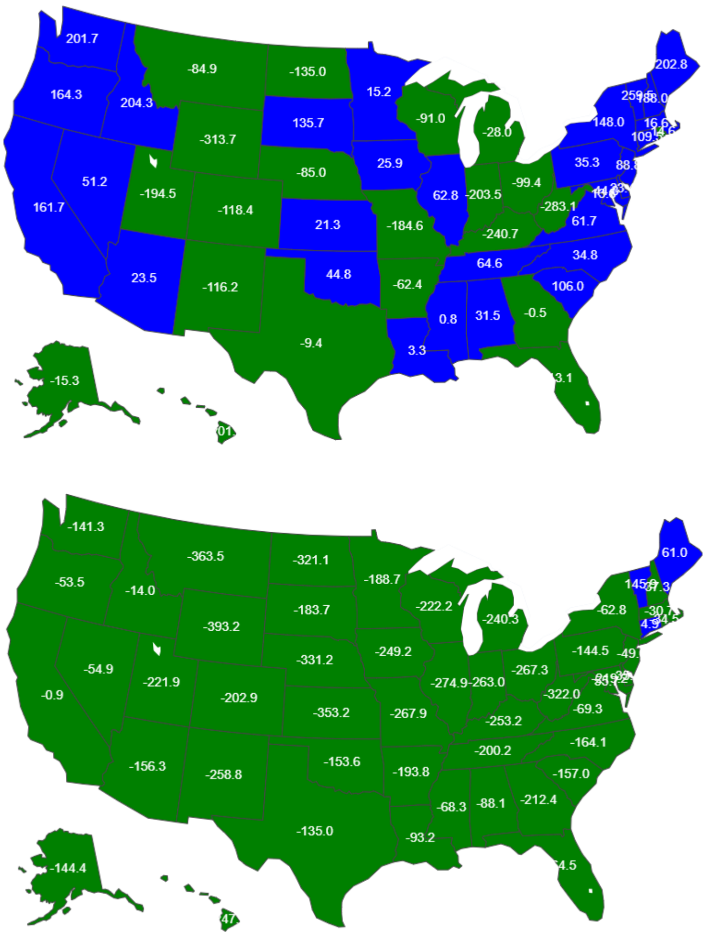

***Figure 4**: CO2eq emissions comparisons between a propane and an electric school bus using baseload (above) and non-baseload (below) emissions.*

So, which is correct? The answer is it depends on a number of factors. The sensitivity conducted here is only for emissions attributed to marginal load and net energy efficiency of an electric vehicle.

Conclusions:

- Electric vehicle (in this case school bus) is not the only solution for mitigating transportation-related greenhouse gas emissions. Predictions made using baseload and non-baseload emissions factors may not be completely accurate, but the answer lies somewhere in between. Setting goals for emissions reductions is more effective that picking technology winners and losers. This would bridge the chasm between policymakers and the technical community.
- Greenhouse gas emissions, based on real world duty cycles and not manufacturer published data, should be used in truly assessing the benefits of electric vehicles over other technologies. Measuring electric vehicle inefficiencies is critical for achieving this.
- It is unclear why hybridization is not being sort as a solution for this market and why it is not being incentivized. There is a better distribution of resources/minerals (e.g., smaller battery) and technologies like start-stop and regenerative braking are a perfect fit for the school bus application. A near-zero emission propane mild-hybrid vehicle (Note: Propane engines for school buses are currently being certified for the optional California low nitrogen oxides standards of 0.02 g/ hp-hr [7] and emit virtually no particulate matter) can be a great solution for this market and would be an even more convincing solution than an electric school bus.
- Medium and heavy duty vehicles consume nearly 41 billion gallons of diesel per year [8]. At a 37.8 kWh/gallon lower heating value of diesel and 35% tank-to-wheels efficiency, the traction energy consumption is ~542 TWh. To power all of these vehicles with an 80% efficient electric powertrain would require 678 TWh of electricity per year. To put this in perspective, U.S. annual consumption of electricity is roughly 4,000 TWh. Hence, a mix of technologies will be needed for decarbonizing medium and heavy-duty on-road transportation. Thus, investments in internal combustion engine technologies, hybrids, and electric vehicles along with investments in renewable energy, renewable fuels, energy storage and electric grid modernization are all equally important.

7. https://www.eia.gov/tools/faqs/faq.php?id=427&t=3
8. http://www.departmentof.energy/

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