International Journal of Multidisciplinary Research and Growth Evaluation.

Environmental Benefits of Transition to Electric School Buses

Hiren Saini
Net Zero Transition, Zum Services Inc., 275 Shoreline Drive, Suite200, Redwood City CA 94065, USA

* Corresponding Author: **Hiren Saini**

Article Info

ISSN (online): 2582-7138
Volume: 05
Issue: 06
Novembar-Decembar 2024
Received: 06-09-2024
Accepted: 07-10-2024
Page No: 07-12

Abstract
The research paper titled *Environmental Benefits of Transition to Electric School Buses* examines the substantial environmental and public health advantages of replacing diesel-powered school buses with electric school buses (ESBs) in the United States. With over 500,000 school buses transporting around 27 million students daily, more than 90% of them rely on diesel engines, which emit harmful pollutants such as nitrogen oxides (NOx), particulate matter (PM), and carbon dioxide (CO2). These pollutants contribute to air pollution, climate change, and serious health issues, particularly for children who are more vulnerable to the harmful effects of diesel exhaust.
This paper explores the environmental impacts of diesel school buses, including their contribution to greenhouse gas emissions, and highlights the disproportionate effects on disadvantaged communities, which are often located near highways or bus depots where pollution is concentrated. Diesel emissions contribute to climate change through the release of CO2 and black carbon, a potent climate-forcing agent. The paper also emphasizes the health risks associated with diesel exhaust, such as respiratory diseases and increased asthma rates, particularly among children.
The transition to ESBs offers a promising solution to these issues. ESBs produce zero tailpipe emissions, reducing NOx, PM, and CO2, which directly improves air quality and lowers greenhouse gas emissions. Additionally, the use of ESBs can significantly reduce the incidence of respiratory problems, improve overall student health, and lead to better academic performance due to fewer absences caused by illness.
Beyond environmental and health benefits, ESBs can play a crucial role in advancing climate action by cutting emissions, especially when powered by renewable energy sources. As school districts across the U.S. explore the adoption of electric school buses, the research highlights the transformative potential of ESBs in creating a cleaner, healthier, and more equitable future for children and communities alike.

DOI: https://doi.org/10.54660/.IJMRGE.2024.5.6.07-12

Keywords: air quality, electric buses, environmental sustainability, public health, school transportation

Introduction

The U.S. school transportation system is one of the largest mass transit networks in the world, transporting approximately 27 million students daily across the country. With over 500,000 school buses in operation, more than 90% are powered by diesel engines, which contribute significantly to air pollution, greenhouse gas (GHG) emissions, and public health challenges. Diesel-powered school buses pose a serious environmental threat and jeopardize the health of millions of students who rely on them for transportation.
In recent years, as environmental awareness has grown, the transition to electric school buses (ESBs) has gained traction as a crucial solution for reducing harmful emissions and improving the well-being of communities. The advantages of ESBs go beyond their zero-emission profile; it provides an opportunity to address climate change, improve air quality, and protect public health, particularly for children and disadvantaged communities [i].

This paper delves into the environmental impact of diesel school buses and explores the benefits of transitioning to electric school buses, with a focus on air quality improvements, reduction in greenhouse gas emissions, and the positive impacts on public health, especially for children.

Materials and Methods

This study emerges from a deep curiosity about the intersection of technology, health, and environmental sustainability—a passion ignited during a summer program at New York University (NYU), where I built a portable air quality monitoring device aimed at aiding individuals with respiratory conditions. The experience cultivated my awareness of how pollution disproportionately affects vulnerable populations, particularly children with special needs and those from disadvantaged communities. These early explorations fueled my drive to investigate cleaner, more equitable transportation solutions.

Building on this, my involvement with Zum Services Inc., which focuses on electrifying school buses, provided practical insight into the transformative impact of electric vehicles (EVs) on children's health, especially those with respiratory challenges or disabilities. Through the Oakland Yard project, where old diesel buses were replaced with electric models designed for children with special needs, I observed firsthand the significant reduction in air pollutants and the improvement in transportation safety and reliability. This solidified my commitment to researching the benefits of electric school buses (ESBs).

The research presented here draws upon data from multiple environmental and public health studies. Key sources include the Environmental Protection Agency (EPA), the Union of Concerned Scientists, and health impact assessments from various state and local initiatives. By comparing emissions data from traditional diesel buses with those from ESBs, I aim to quantify the reductions in greenhouse gas emissions (GHGs) and assess the associated health improvements, particularly in students with compromised health or disabilities. Additionally, this study explores how ESB adoption can mitigate environmental inequities in communities historically burdened by diesel emissions.

Through this research, I hope to demonstrate the broader societal benefits of transitioning to ESBs, particularly in fostering a healthier, more inclusive future for students most vulnerable to air pollution.

Environmental Impact of Diesel School Buses

Diesel engines are a major source of harmful emissions, which contribute significantly to air pollution, climate change, and negative health outcomes. School buses powered by diesel fuel emit large quantities of nitrogen oxides (NOx), particulate matter (PM), and carbon dioxide (CO2), all of which are detrimental to the environment and human health. Children, in particular, are highly susceptible to the adverse effects of diesel exhaust, as their respiratory systems are still developing, and they breathe at a faster rate than adults.

1. Diesel Emissions and Climate Change

The transportation sector is the largest contributor to greenhouse gas (GHG) emissions in the United States, accounting for nearly 40% of nation's total GHG emissions [ii]. Diesel-powered school buses play a significant role in this producing 10.14 Kg of CO_2 emissions per gallon of diesel consumed [iii]. Considering a conservative figure of 6 miles per gallon and average distance of 50 miles run by a school bus, a single school bus produces 84.96 Kg of CO2 daily on an average, contributing approximately 8.4 million metric tons of GHG emissions annually across the US. These emissions, particularly CO2, are the primary drivers of climate change, which has led to rising global temperatures, more frequent and severe weather events, and disruptions to ecosystems.

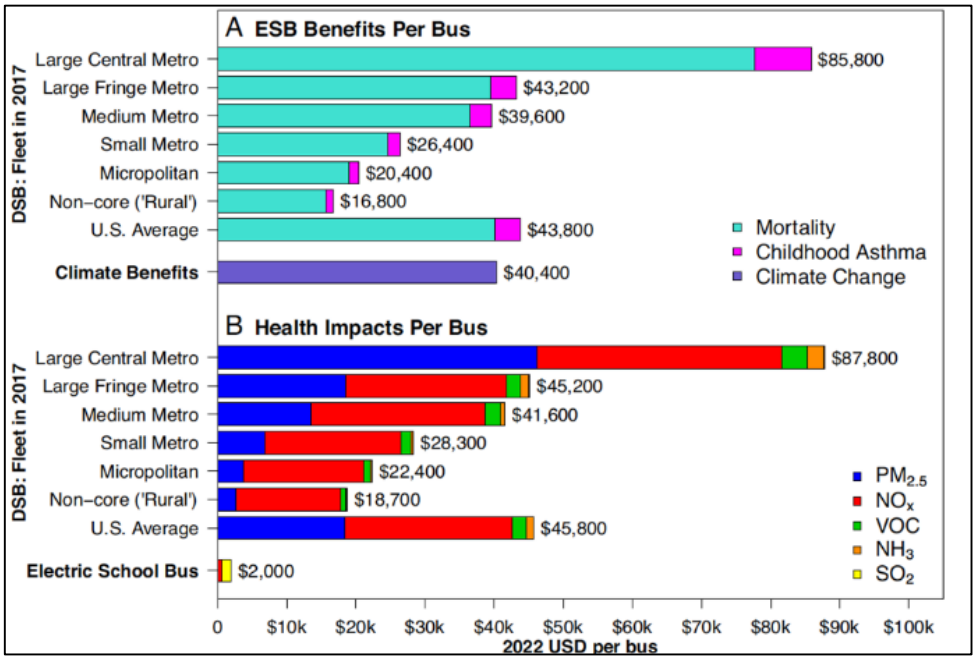
The problem is accentuated by the presence of black carbon in diesel exhaust, a potent climate-forcing agent with 460-1,500 times the global warming potential of CO2 over a 20-year period [iv]. Black carbon absorbs sunlight, warming the atmosphere and accelerating climate change. Additionally, nitrogen oxides (NOx) and nitrous oxide (N_2O), two other pollutants from diesel engines, contribute to both global warming and ozone layer depletion. The cumulative environmental effects of diesel emissions are not only harmful to the climate but also to ecosystems that are increasingly disrupted by rising temperatures and changing weather patterns.

2. Health Impacts of Diesel Exhaust

The health impacts of diesel exhaust are well-documented, with children being among the most vulnerable populations. Diesel emissions are linked to respiratory diseases, cardiovascular problems, and premature death. Nitrogen oxides (NOx) and particulate matter (PM) are the two primary pollutants from diesel engines that pose significant risks to human health. NOx contributes to the formation of ground-level ozone, which can trigger asthma attacks, reduce lung function, and increase the risk of respiratory infections. Long-term exposure to NOx has also been linked to the development of chronic respiratory diseases such as bronchitis and emphysema [v].

Particulate matter, especially fine particles (PM2.5), can penetrate deep into the lungs causing chronic respiratory issues such as asthma, bronchitis, and emphysema. According to the Environmental Protection Agency (EPA), diesel exhaust is classified as a likely human carcinogen, with long-term exposure increasing the risk of lung cancer. Children are especially vulnerable because their respiratory systems are still developing, and they breathe more air per unit of body weight compared to adults. Studies have shown that children exposed to high levels of diesel exhaust are more likely to suffer from asthma, bronchitis, and other respiratory conditions, leading to increased absenteeism from school and lower academic performance [vi].

A recent study [vii] by the Harvard T.H. Chan School of Public Health found that the health impacts of electric buses are significantly lower than those of diesel buses. The study estimates that in 2017, the entire school bus fleet was responsible for 170 PM2.5-attributable deaths and 280 new childhood asthma cases annually. However, if the fleet had been fully electrified, these numbers would have dropped to just 7 deaths and 12 new asthma cases. With school buses traveling 6.8 billion miles that year, the study attributed 2.43 deaths and 4.08 new asthma cases per 100 million miles driven by diesel buses, compared to just 0.10 deaths and 0.17 asthma cases for electric buses.



***Source*:** https://www.pnas.org/doi/10.1073/pnas.2320338121

Fig 1: School bus health Impact per bus and benefits of electrification: Fleet in 2007

3. Disproportionate Impact on Disadvantaged Communities

The environmental burden of diesel emissions falls disproportionately on low-income communities and communities of color. Many of these communities are located near highways, industrial zones, or bus depots, where diesel exhaust pollution is most concentrated. Black and Hispanic Americans are exposed to 56% and 63% more pollution from diesel vehicles than the national average, respectively, leading to higher rates of asthma and other pollution-related illnesses. This environmental injustice exacerbates existing health disparities, as these communities already face higher rates of respiratory diseases and limited access to healthcare [viii].

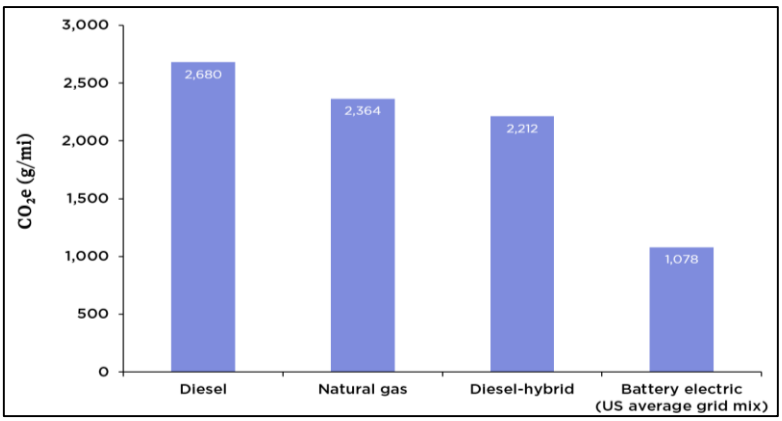
The health disparities caused by diesel emissions reflect broader patterns of environmental injustice. Low-income families, often with limited access to healthcare, face heightened risks due to their proximity to pollution sources. Reducing diesel emissions by transitioning to electric school buses can mitigate these injustices and improve public health in the most affected communities.

Environmental and Health Benefits of Electric School Buses

ESBs present a cleaner, more sustainable alternative to diesel-powered buses. They offer numerous advantages, ranging from environmental and health benefits to economic and operational efficiencies. ESBs eliminate tailpipe emissions, reduce the reliance on fossil fuels, and improve air quality in the communities they serve [ix, x].

1. Zero Tailpipe Emissions and Improved Air Quality

The most significant environmental advantage of electric school buses is the elimination of tailpipe emissions. Electric buses produce no nitrogen oxides (NOx), particulate matter (PM), or carbon dioxide (CO2) during operation, directly improving air quality in the communities they serve. This shift is particularly important in urban areas where air pollution is a major concern.



***Source*:** https://blog.ucsusa.org/jimmy-odea/electric-vs-diesel-vs-natural-gas-which-bus-is-best-for-the-climate/#:~:text=Electric%20bus%20emissions%20range%20from%2029%20to%2087,to%2085%20percent%20lower%20than%20natural%20gas%20buses.

Fig 2: Life cycle global warming emissions from different types of transit buses

For instance, studies conducted in Los Angeles, California, demonstrated that the adoption of electric buses in schools reduced local NOx emissions by 2,300 pounds per year, contributing to significant improvements in regional air quality.

Cleaner air means fewer respiratory problems, especially for children, who are the most susceptible to pollution-related health issues. The American Lung Association estimates that the switch to electric buses could prevent up to 60,000 asthma attacks and save $200 million in health costs annually across the U.S.

Students with disabilities depend more heavily on school transportation than their non-disabled peers, often encountering additional challenges in accessing a reliable, safe, and accessible ride. The shift to electric school buses, however, offers a valuable opportunity to not only reduce exposure to harmful diesel exhaust but also to enhance accessibility for students with disabilities, ensuring a more inclusive and healthier transportation experience [xi].

Moreover, the reduction of emissions around schools and residential areas can lead to decreased absenteeism due to illness, improved student health, and better academic performance. Schools located near busy streets and highways would see a dramatic improvement in air quality, benefiting not only the students but also teachers, staff, and nearby residents.

2. Reduction in Greenhouse Gas Emissions

By transitioning to electric school buses, school districts can reduce their carbon footprint significantly. While the exact environmental benefits depend on the source of electricity used to charge the buses, electric vehicles (EVs) still outperform diesel buses even when powered by grids that include fossil fuels.

Research from the Union of Concerned Scientists found that an electric bus powered by a grid using 60% fossil fuels emits 29% less CO2 than a diesel bus. In regions where renewable energy sources like solar and wind dominate the grid, electric buses can reduce emissions by as much as 87%.

eGRID subregion name	Battery electric bus grams CO_2e/mile[a]	Battery electric bus emissions-equivalent MPG diesel[b]	Battery electric bus grams CO_2e/mile relative to diesel[d]	Battery electric bus grams CO_2e/mile relative to natural gas[e]
ASCC Alaska Grid (AKGD)	1,209	10.7 (2.22x)	-55%	-49%
ASCC Miscellaneous (AKMS)	590	21.9 (4.54x)	-78%	-75%
ERCOT All (ERCT)	1,108	11.7 (2.42x)	-59%	-53%
FRCC All (FRCC)	1,132	11.4 (2.37x)	-58%	-52%
HICC Miscellaneous (HIMS)	1,353	9.5 (1.98x)	-50%	-43%
HICC Oahu (HIOA)	1,901	6.8 (1.41x)	-29%	-19%
MRO East (MROE)	1,748	7.4 (1.53x)	-35%	-26%
MRO West (MROW)	1,289	10.0 (2.08x)	-52%	-45%
NPCC Long Island (NYLI)	1,320	9.8 (2.03x)	-51%	-44%
NPCC New England (NEWE)	652	19.8 (4.11x)	-76%	-72%
NPCC NYC/Westchester (NYCW)	740	17.5 (3.62x)	-72%	-69%
NPCC Upstate NY (NYUP)	347	37.3 (7.73x)	-87%	-85%
RFC East (RFCE)	837	15.4 (3.20x)	-69%	-65%
RFC Michigan (RFCM)	1,356	9.5 (1.98x)	-49%	-43%
RFC West (RFCW)	1,311	9.9 (2.04x)	-51%	-44%
SERC Midwest (SRMW)	1,676	7.7 (1.60x)	-37%	-29%
SERC Mississippi Valley (SRMV)	949	13.6 (2.82x)	-65%	-60%
SERC South (SRSO)	1,186	10.9 (2.26x)	-56%	-50%
SERC Tennessee Valley (SRTV)	1,257	10.3 (2.13x)	-53%	-47%
SERC Virginia/Carolina (SRVC)	878	14.7 (3.05x)	-67%	-63%
SPP North (SPNO)	1,468	8.8 (1.83x)	-45%	-38%
SPP South (SPSO)	1,338	9.7 (2.00x)	-50%	-43%
WECC California (CAMX)	609	21.2 (4.40x)	-77%	-74%
WECC Northwest (NWPP)	690	18.7 (3.88x)	-74%	-71%
WECC Rockies (RMPA)	1,429	9.0 (1.88x)	-47%	-39%
WECC Southwest (AZNM)	1,124	11.5 (2.38x)	-58%	-52%

[a] Battery electric bus generation-weighted average: 1,078 grams CO_2e/mile

[b] Battery electric bus emissions-equivalent generation-weighted average: 12.0 MPG

[c] Diesel bus: 2,680 grams CO_2e/mile

[d] Natural gas bus: 2,364 grams CO_2e/mile

Good (less than 2x diesel)
Better (2-3x diesel)
Best (greater than 3x diesel)

***Source*:** Union of Concerned Scientists, The Equation, Electric vs. Diesel vs. Natural Gas: Which Bus is Best for the Climate?

Fig 3: Life cycle global warming emissions from battery electric buses in different grid regions across the United State

A study by the World Resources Institute (WRI) found that transitioning to electric school buses could reduce GHG emissions by as much as 50% compared to diesel buses, depending on the energy mix used to power the buses. In regions with a high percentage of renewable energy, the reduction in emissions could be even greater. This makes

electric school buses a key component of efforts to mitigate climate change and transition to a low-carbon economy [xii].

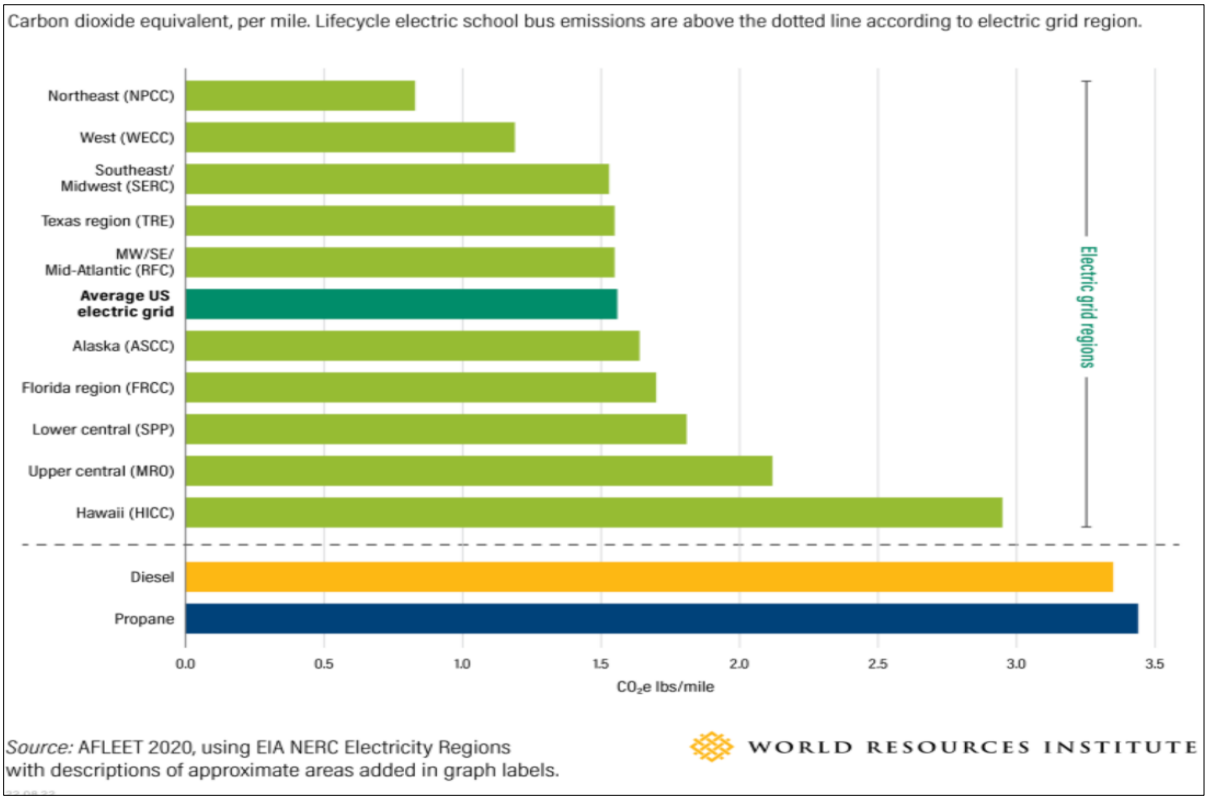


Fig 4: Lifecycle greenhouse gas emission from electric school buses are lower than diesel and propane across all region

Electric vehicles (EVs) experience only 15% to 20% energy loss in their electric drive systems, significantly lower compared to the 64% to 75% energy loss seen in gasoline engines.[xiii] Additionally, EVs feature regenerative braking, which recovers energy typically lost during braking, and they consume no energy while idling. Electric motors are also more efficient in converting energy into motion compared to internal combustion engines, further enhancing their overall efficiency [xiv, xv].

3. Health Benefits for Students and Communities

The health benefits of electric school buses extend beyond the elimination of tailpipe emissions. By reducing air pollution, ESBs help improve the overall health of students, drivers, and the broader community. Children who ride electric buses are no longer exposed to the harmful chemicals in diesel exhaust, leading to fewer asthma attacks, reduced absenteeism, and better academic outcomes. Studies have shown that children who are exposed to lower levels of air pollution tend to have better lung function and are less likely to develop chronic respiratory diseases [xvi].

Studies have indicated [xvii] that reducing students' exposure to air pollution from diesel-burning school buses can have positive and significant effects on student test scores – in some cases, on par with increased teacher experience levels.

Communities located near bus depots and along bus routes also benefit from the reduction in pollution. Diesel buses often idle for extended periods, especially during pick-up and drop-off times, releasing large amounts of NOx and PM into the air. Electric buses, on the other hand, do not emit any pollutants while idling, contributing to cleaner air and healthier communities.

Conclusion

The environmental and public health benefits of transitioning from diesel-powered to electric school buses are clear and substantial. Diesel buses contribute to significant GHG emissions, air pollution, and health problems, particularly for children and disadvantaged communities. In contrast, electric school buses offer a cleaner, more sustainable alternative, eliminating tailpipe emissions and significantly reducing greenhouse gas emissions.

As school districts across the U.S. continue to explore the adoption of electric school buses, it is evident that the environmental and health benefits make this transition not only desirable but essential for achieving long-term sustainability goals. Through reduced emissions, improved air quality, and better public health outcomes, electric school buses represent a transformative shift toward a cleaner, healthier future for children and communities alike.

Acknowledgements

I would like to thank Zum Services Inc. for their invaluable support and inspiration throughout this research. Their commitment to electrifying school transportation and promoting sustainable, clean energy solutions deeply influenced this study. The opportunity to witness the Oakland Yard project, where diesel buses were replaced with electric models for children with special needs, was especially impactful. I am grateful to the Zum team for their dedication to improving student health and advancing environmental sustainability.

References

1. https://www.epa.gov/cleanschoolbus/benefits-clean-school-buses
2. https://www.wri.org/initiatives/electric-school-bus-initiative
3. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references
4. Bond TC, Doherty SJ, Fahey DW, Forster PM, Berntsen T, DeAngelo BJ, *et al*. Bounding the role of black carbon in the climate system: A scientific assessment. Journal of Geophysical Research: Atmospheres. 2013;118(11):5380-5552.
5. Austin W, Heutel G, Kreisman D. School bus emissions, student health and academic performance. Economics of Education Review. 2019;70:109-126.
6. Choma EF, Robinson LA, Nadeau KC. Adopting electric school buses in the United States: Health and climate benefits. Proceedings of the National Academy of Sciences; 2024:121(22).
7. Harvard T.H. Chan School of Public Health. Electric school buses may yield significant health and climate benefits, cost savings. Harvard T.H. Chan School of Public Health; 2024:20(5).
8. Tessum CW, Apte JS, Goodkind AL, Hill JD. Inequity in consumption of goods and services adds to racial–ethnic disparities in air pollution exposure. Proceedings of the National Academy of Sciences; c2019.
9. Gauderman WJ, Urman R, Avol E, Berhane K, McConnell R, Rappaport E, *et al*. Association of improved air quality with lung development in children. N Engl J Med. 2015;372(10):905-913. https://doi.org/10.1056/NEJMoa1414123.
10. Cerf E. A Maryland school district switched to electric buses to save kids' lungs. Can others follow? PopSci. 2021; May 24. https://www.popsci.com.
11. Electric School Bus Initiative: Prioritizing Students with Disabilities in the Transition to Electric School Buses. Article; c2024. https://doi.org/10.1073/pnas.1818859116
12. https://electricschoolbusinitiative.org/why-we-need-transition-electric-school-buses
13. https://www.shriramgi.com/article/impact-of-electric-vehicles-on-the-environment#:~:text=EVs%20are%20also%20highly%20efficient, and%20appealing%20and%20sustainable%20choice.
14. Rhodes K, Kok D, Sohoni P, Perry E, Kraska M, Wallace M. Estimation of the Effects of Auxiliary Electrical Loads on Hybrid Electric Vehicle Fuel Economy. SAE Technical Paper. 2017;2017-01-1155. https://doi.org/10.4271/2017-01-1155
15. Office of Energy Efficiency and Renewable Energy, US Department of Energy, https://www.fueleconomy.gov/feg/atv-ev.shtml
16. SF Camilleri, *et al*., Air quality, health and equity implications of electrifying heavy- duty vehicles. Nat. Sustain. 2023;6:1643-1653. 10.1038/s41893- 023-01219- 0. 7.
17. Austin W, Heutel G, Kreisman D. School Bus Emissions, Student Health, and Academic Performance. NBER Working Paper Series; 2019:25641. http://www.nber.org/papers/w25641

[i] https://www.epa.gov/cleanschoolbus/benefits-clean-school-buses

[ii] https://www.wri.org/initiatives/electric-school-bus-initiative

[iii] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

[iv] Bond TC, Doherty SJ, Fahey DW, Forster PM, Berntsen T, DeAngelo BJ, Flanner MG, Ghan S, Kärcher B, Koch D, Kinne S, Kondo Y, Quinn PK, Sarofim MC, Schultz MG, *et al*. Bounding the role of black carbon in the climate system: A scientific assessment. Journal of Geophysical Research: Atmospheres. 2013; 118(11):5380-5552.

[v] Austin W, Heutel G, Kreisman D. School bus emissions, student health and academic performance. *Economics of Education Review*. 2019; 70:109-126.

[vi] Choma EF, Robinson LA, Nadeau KC. Adopting electric school buses in the United States: Health and climate benefits. *Proceedings of the National Academy of Sciences*. 2024; 121(22)

[vii] Harvard T.H. Chan School of Public Health. Electric school buses may yield significant health and climate benefits, cost savings. *Harvard T.H. Chan School of Public Health*. 2024; 20(5).

[viii] Tessum CW, Apte JS, Goodkind AL, Hill JD. Inequity in consumption of goods and services adds to racial–ethnic disparities in air pollution exposure. *Proceedings of the National Academy of Sciences*. 2019.

[ix] Gauderman WJ, Urman R, Avol E, Berhane K, McConnell R, Rappaport E, Chang R, Lurmann F, Gilliland F. Association of improved air quality with lung development in children. *N Engl J Med.* 2015; 372(10):905-913. https://doi.org/10.1056/NEJMoa1414123.

[x] Cerf E. A Maryland school district switched to electric buses to save kids' lungs. Can others follow? *PopSci.* 2021; May 24. https://www.popsci.com.

[xi] Electric School Bus Initiative: Prioritizing Students with Disabilities in the Transition to Electric School Buses. Article. July 22, 2024. https://doi.org/10.1073/pnas.1818859116

[xii] https://electricschoolbusinitiative.org/why-we-need-transition-electric-school-buses

[xiii] https://www.shriramgi.com/article/impact-of-electric-vehicles-on-the-environment#:~:text=EVs%20are%20also%20 highly%20 efficient, and%20 appealing%20and%20 sustainable%20choice.

[xiv] Rhodes K., Kok D., Sohoni P., Perry E., Kraska M., Wallace M. Estimation of the Effects of Auxiliary Electrical Loads on Hybrid Electric Vehicle Fuel Economy. SAE Technical Paper. 2017; 2017-01-1155. https://doi.org/10.4271/2017-01-1155

[xv] Office of Energy Efficiency and Renewable Energy, US Department of Energy, https://www.fueleconomy.gov/feg/atv-ev.shtml

[xvi] S. F. Camilleri *et al*., Air quality, health and equity implications of electrifying heavy- duty vehicles. Nat. Sustain. 6, 1643–1653 (2023), 10.1038/s41893- 023- 01219- 0. 7.

[xvii] Austin W., Heutel G., Kreisman D. School Bus Emissions, Student Health, and Academic Performance. NBER Working Paper Series. 2019; 25641. http://www.nber.org/papers/w25641