ELECTRIFICATION OF NEW JERSEY'S SCHOOL BUSES

BENEFITS, BARRIERS, AND OPPORTUNITIES

CHARGEVC | NJ

BETTER TRAVEL, STRONGER GRID.

Acknowledgements

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Table of Acronyms

ANL	Argonne National Laboratory
BEV	Battery Electric Vehicle (powered solely by a battery, charged with an external source of electricity)
CNG	Compressed natural gas
CO_2	Carbon dioxide
DOE	(United States) Department of Energy
EIA	(United States) Energy Information Administration
EPA	(United States) Environmental Protection Agency
ESB	Electric School Bus (for the purpose of this study, ESB are assumed to be fully powered by a battery)
GHG	Greenhouse gas
GWh	Gigawatt-hour
HDV	Heavy-Duty Vehicles
ICE	Internal Combustion Engine (particularly, vehicles with internal combustion engines)
IRA	Inflation Reduction Act of 2022
kW	Kilowatt
kWh	Kilowatt-hour
MDV	Medium-Duty Vehicles
MHDV	Medium- and Heavy-Duty Vehicles
NJ DEP	New Jersey Department of Environmental Protection
NJ DOE	New Jersey Department of Education
NO_X	Nitrous Oxides
PEV	Plug-in Electric Vehicles (powered by a battery, charged with an internal source of electricity)
PHEV	Plug-in Hybrid Vehicles (powered by a battery, charged with an internal source of electricity, but can also run on traditional vehicle fuels)
PM2.5	Particulate matter (inhalable particles, with diameters that are generally 2.5 micrometers and smaller)
PPA	Power Purchase Agreement
SCF	Standard Cubic Feet (a volumetric measure of compressed natural gas)
SO_2	Sulfur dioxide
TBW	Tire and brake wear (as they pertain to particulate emissions)
TCO	Total Cost of Ownership (accounts for the initial purchase costs, but also factors in costs associated with the routine operation of the vehicle)
TOU	Time-of-Use (Rates)
V2B	Vehicle-to-Building (a bi-directional charging technology that reduces building load but does not export to the grid)
V2G	Vehicle-to-Grid (a bi-directional charging technology that exports to the grid)

1 Executive Summary

New Jersey is a leading state in the adoption of Electric Vehicles (EVs). Yet electric school buses (ESBs) remain a nascent segment despite high expectations and significant potential. Developing the ESB market will require specific focus and a range of actions, some of which will require significant policy work. ChargEVC-NJ, with funding-support from Environment New Jersey, completed a study to explore the potential impacts of ESBs, quantify ESB-related benefits, and identify barriers and associated solutions. This report summarizes the results of that study.

A primary benefit of ESBs is the reduction of air emissions, since exhaust associated with fuel combustion is replaced with electricity supplied through the public grid. The study quantifies detailed impacts on air emissions, and what the economic benefits of those emission reductions are. In addition, the study explores the essential economics of ESBs, especially the dynamic by which higher up-front costs (for the bus) are offset by operational savings. Finally, key barriers to attracting private investment to the ESB market are identified, along with proposals to address those barriers. Key findings include:

- Electrifying the statewide fleet of school buses under the current electricity generation mix would result in a 74.7% reduction in emissions and would shift nearly all remaining emissions to a more remote generation facility where they have less impact on local public health in communities overall. This benefit increases to a nearly 100% reduction when the electricity comes from clean sources, with the only remaining emissions being unmitigated tire and brake wear.

- These reduced air emissions have economic benefits related to climate change and public health. A fully electrified New Jersey school bus fleet under the current generation mix would provide $55.6 million in annual benefits, a reduction of emissions-related harm of 69.6%. These annual benefits grow to $78.3 million if the electricity used to power the ESBs comes from clean sources.

- Electrification of the school bus fleet in New Jersey would result in fueling and maintenance cost savings of approximately $202.3 million annually, a reduction of 61.4%. When the economic value of reduced emissions is combined with savings in fuel expenditures and maintenance, a fully electrified school bus fleet in New Jersey would generate $257.9 million in annual benefits for the current generation mix, growing to $280.6 million annually when using clean electricity.

- Total Cost of Ownership (TCO) for ESBs is currently challenging due to higher up-front costs, but those costs are offset by operational savings. At current cost levels, and without reflecting incentives that may be applicable, ESBs approach parity for buses with longer routes, but do not quite reach parity. Economics improve significantly when lower bus prices and inflationary factors are considered long term. These economics could potentially be improved if ESBs are enabled to provide grid services that relieve loading on the public grid through bi-directional charging.

- Attracting private capital is a primary strategy for assisting districts with the electrification of their school bus fleets, but current procurement constraints are significant barriers. These barriers can be addressed through recommended policy actions, detailed in Sections 6 and 7 of this report.

2 Introduction

Based on a comprehensive and market-leading approach to market development, New Jersey has become one of the top markets for electric vehicle (EV) adoption in the country. Light-duty vehicle (LDV) sales are ramping up rapidly, and the State is now focused on accelerating adoption of electrified vehicles in the Medium- and Heavy-duty (MHDV) segment. The transportation sector is the single largest sector for greenhouse gases (GHG) and other emissions in New Jersey, and transportation electrification is a primary strategy for achieving the State's clean energy goals.

Of particular interest within the MHDV market are school buses, since they currently generate a high level of air emissions that impact one of the most vulnerable populations – children, especially in disadvantaged communities. School buses, which regularly transport more than 800,000 children to and from school in the State, travel within and through all New Jersey communities, impacting local air quality and public health for all residents. Strong electrified alternatives are now available, and real-world experience with electric school buses (ESBs) is rapidly growing nationwide. These factors combine to make the school bus segment one of the highest priorities for electrification in New Jersey.

This study will explore the current landscape of school buses in New Jersey, quantify the environmental impacts of the current statewide school bus fleet, and estimate economic impacts that come with full electrification. The study will explore the synergy that can be realized when the electricity used to charge these buses is generated using clean sources[1]. This study was funded by Environment New Jersey in combination with funding from ChargEVC-NJ.

ESBs currently command a significantly higher up-front investment compared to diesel or gasoline-powered alternatives, which will be explored through a Total Cost of Ownership (TCO) analysis. This TCO comparison will quantify the extent to which higher initial costs can be offset by lower fuel and maintenance costs over the full lifecycle, including potential enhancement through grid service revenues (such as Vehicle-to-Grid (V2G) solutions).

Lastly, this study will identify the most crucial barriers to school bus electrification in the State and identify specific pathways to address those issues and recommendations to make them feasible. A primary focus is on structural issues that limit the use of private capital to accelerate ESB adoption, and the policy changes necessary to address those issues.

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[1] All references to "clean sources" mean clean generation with zero air emissions, such as solar, wind, and nuclear, typically characterized at "carbon free".

3 The New Jersey School Bus Landscape

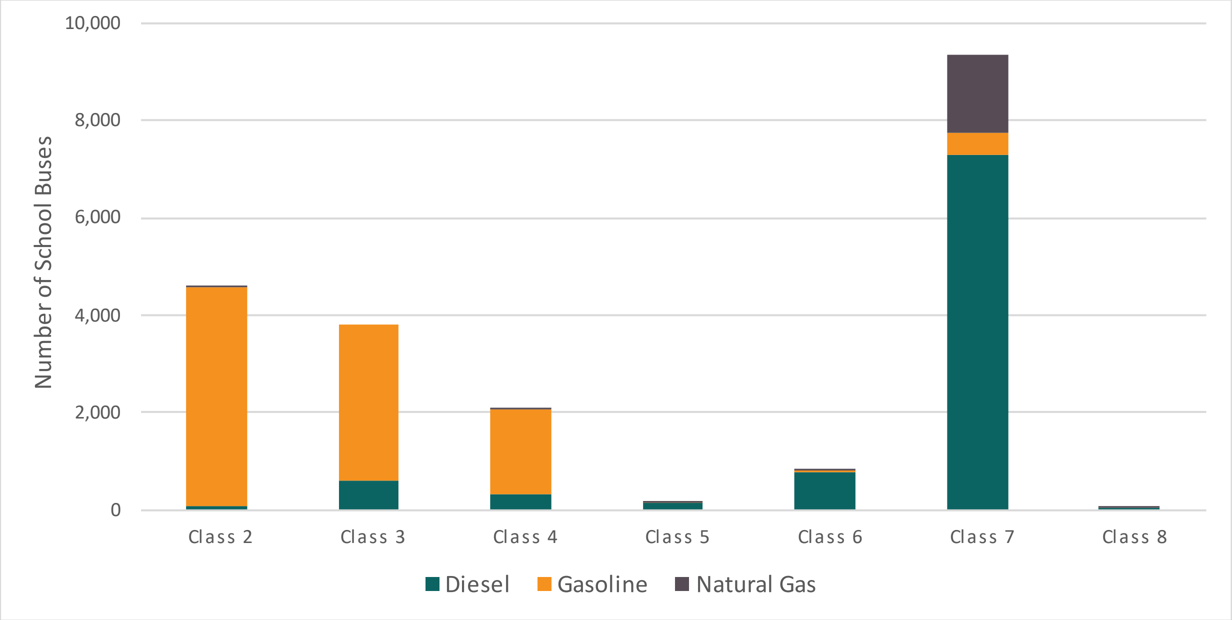
To fully understand the potential for widespread ESB adoption in New Jersey, it is necessary to characterize the fleet of existing school buses, how they are used, and important ownership and operating considerations. This section will establish that foundation, upon which the more detailed analysis that follows is based.

3.1 New Jersey's School Bus Fleet

According to vehicle registration data provided by the New Jersey Department of Environmental Protection (NJ DEP), as of December 2021, there was a total of 20,946 school buses in the State of New Jersey. These buses range in size from medium-duty, Class 2 buses to heavy-duty, Class 8 buses.[2]

School buses throughout the State also vary in terms of fuel type. Approximately 44% of the school buses in New Jersey run on diesel fuel, approximately 48% on gasoline, and the remaining 8% on natural gas. Discussions on the benefits of electrifying school buses are often centered on impacts to public health, climate, and operational costs, all of which are impacted by the fuel type being replaced by an electric alternative. The dominant segment, by far, is Class 7 diesel buses, as shown below.

Figure 3.1 - 1: Distribution of School Buses in New Jersey (mid-2022)



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[2] "Weight Classes" are a federal designation that segments vehicles by weight, ranging from light duty passenger vehicles (Class 1) up to heavy-duty trucks (Class 8). School buses are further segmented by "body type", ranging from small 9-12 seat vehicles that are a little larger than a shuttle, to the much more common "Type C" and "Type D" buses that support the majority of school bus passenger-miles.

According to the United States Department of Energy's (DOE) Alternative Fuels Data Center, the average school bus travels approximately 12,000 miles per year.[3] New Jersey State Law requires schools to be in session for a minimum of 180 days per year, typically from late August to June (varying by district). Assuming that this mileage is dispersed evenly over these minimum days of operation, the average New Jersey school bus travels approximately 66.7 miles per day of operation. New Jersey Statute and Code does not place limits on the amount of time a student may spend on a school bus.[4]

3.2 How New Jersey School Buses Are Owned and Operated

The school bus market in New Jersey is complex, reflecting the relatively local decision-making that happens in most school districts. There are 2,511 K-12 schools in New Jersey, most of which are organized and managed within 697 school districts. Approximately 80% of these are Elementary Schools, while the remaining 20% are Secondary Schools, or schools that combine Elementary and Secondary education.[5]

Because most decision-making happens at the district-level in the State, districts employ a variety of approaches to busing. This is a significant complication when considering bus electrification, since the ESB market is fragmented based on different ownership and operating models – i.e., there is no single "silver bullet" that will facilitate electrification uniformly. For example, some districts:

a) Own and operate their own buses, and therefore have significant decision-making authority on electrification plans, but must also fund that transition through their own budgets.

b) Outsource their busing entirely to third-party operators that own and provide the vehicles (using private capital) and operate those vehicles using their own (non-district) staff, typically through a competitive contract that is re-bid periodically. Electrification decision-making by these districts is closely tied to what those third-party operators are willing to do (or not do), and the details related to contract management.

c) Implement a "hybrid" scenario (e.g., owning their own buses but outsourcing operations), of which there are multiple variations.

Based on anecdotal information provided by the New Jersey Department of Education (NJ DOE), roughly a third of the overall school bus fleet falls into each of these three categories.

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[3] United States Department of Energy, Alternative Fuels Data Center, "Average Annual Vehicle Miles Traveled by Major Vehicle Category; retrieved from https://afdc.energy.gov/data/widgets/10309. In 2019, the New Jersey Department of Environmental Protection estimated that, specifically in New Jersey, the average school bus traveled 8,581 miles per year. Since this number is now several years old, this study defers to the national DOE average which was verified across a number of sources.

[4] The State of New Jersey; Department of Education; retrieved from https://www.state.nj.us/education/finance/transportation/procedures/NonpublicTransportationRequirementsandRecommendations.pdf

[5] New Jersey Department of Education; New Jersey Public Schools Fact Sheet 2022-2023; retrieved from https://www.nj.gov/education/doedata/fact.shtml

A recent analysis by the NJ DEP indicated that there are approximately 599 school bus fleets that operate Class 6 to Class 8 buses. Among these fleets:

a) 53% of buses are in fleets that are privately owned (likely by a third-party operator or leasing company);
b) 47% of buses are in fleets that are publicly owned (likely a school district);
c) the four largest fleets (> 200 buses each) are privately owned;
d) 79% of the fleets have fewer than 20 buses each, representing 23% of buses;
e) half of all buses are in the 40 largest fleets out of the sample of 599 fleets analyzed.

Strategies to understand, facilitate, and accelerate school bus electrification will need to reflect these market structure considerations, and will likely require a range of business models, procurement strategies, and operating practices.

3.3 Operating Models

In addition to the fleet characteristics and market structure considerations noted above, it is also important to recognize the diverse ways that buses are housed and fueled today. Just as districts adopt a diverse set of approaches to providing bus services, where the buses are based and how they are fueled can also vary widely.

School buses are housed (or "based") at sites where they typically spend most nights consistently – buses leave from and return to these locations each time they are used. Common scenarios include:

- Buses are sited at the school to which students are being delivered each day;
- Buses are sited at a particular school within the district, but deliver students to multiple schools within the district;
- Buses are sited at a "central depot" that is not on a school property, from which they are dispatched for all busing operations within the district – this approach is more common when third-party bus operators are involved, and;
- In some cases, especially in smaller and more rural districts, the bus drivers take the buses to their home where they reside overnight.

The siting configurations have an impact on how buses are fueled, ranging from fueling where they are based at an on-site fuel station (typically a large diesel storage tank), fueling at the off-site "central depot", or fueling at a public gasoline/diesel station. Details about where buses are based, and how they are currently fueled, have bearing on where charging infrastructure will need to be developed for electrified alternatives. As a related consideration, in cases where the buses will be charged on school property, whether that charging service is interconnected with the existing building's electrical supply, or whether it will be set up under new, separate, dedicated electrical service focused on charging could have a large impact on infrastructure development costs and operating expense. Questions about who owns and operates charging infrastructure, where it is located, and how it is interconnected are also related to the details about which entities (and under which contracting arrangement) own and operate the buses.

4 The Impacts of School Bus Electrification

School bus electrification enables a wide range of impacts, most of which are beneficial and can be quantified in detail. Those impacts (and potential benefits) have been documented extensively, and there is a high degree of concurrence regarding those conclusions; please see the Bibliography in Section 9 for representative examples. This ChargEVC-NJ study looks specifically at the impacts, and where applicable benefits, that are projected to result from widespread K-12 school bus electrification in New Jersey based upon State-specific details.

Many of those benefits are the result of significantly lower air emissions, since fueling with electricity reduces air pollution relative to fueling with a traditional fuel (even after accounting for emissions associated with generation of electricity). While the pollutants focused on in this study are all either directly or indirectly contributing to the climate crisis and environmental degradation, they also have negative impacts on public health, which are experienced most acutely by bus passengers (mostly school-age children that are particularly vulnerable with regard to air pollution exposure) and the communities in which these buses operate – i.e., nearly everybody. These impacts are especially significant in low-income and minority communities. The following sections quantify the impacts of school bus electrification from both an environmental and public health perspective, along with other types of benefits that are also expected to be realized. All analysis (both for impacts, and for the economic model in Section 5), are based on an "average" vehicle that reflects a weighted composite based on the school bus market in New Jersey.

4.1 Impacts Related to Emissions

Changes in air emissions are a primary impact from widespread school bus electrification, since ESBs shift tailpipe emissions resulting from combustion engines to generation facilities that provide the electricity used to charge ESB batteries. This section summarizes the methodology and results associated with the quantification of those impacts using New Jersey-specific details.

4.1.1 Estimating Impacts - Methodology

This study focuses on quantifying the physical impacts of four types of emissions resulting from internal combustion engines (ICE) in typical K-12 school buses: carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and particulate matter. These four types of emissions are particularly impactful on both the climate crisis and public health and are representative indicators for the full spectrum of emissions associated with traditional fuel use in an ICE vehicle. CO_2 is a primary GHG and contributes directly to the many consequences of accelerating climate change and is – by far – the largest ICE emission by mass. NO_x emissions are especially acute from diesel ICEs and contribute directly to the development of smog and "acid rain," in addition to being harmful to lung tissue (among many other impacts). SO_2 can lead to the atmospheric formation of particulates that are especially harmful to public health as well as act as a contributor to "acid rain". Traditional fuel combustion always results in fine "soot" emissions, especially particulates that are 2.5 microns or smaller (i.e., PM2.5), which are especially harmful to public health and has been linked to a wide range of negative health outcomes. This ChargEVC-NJ study specifically quantifies the emissions of these four pollutants with traditional fueled vehicles compared with electrified alternatives.[6]

When considering these four types of emissions, it is important to recognize how each manifests geographically. CO_2 tends to mix widely in the atmosphere and has global impacts, including implications for all residents of the State. NO_X and SO_2 tend to have more regional impacts, although those emission plumes can be blown across state borders. PM2.5 tends to have more local impacts, with implications for the populations near where the vehicles travel. This study considers both the PM2.5 associated with combustion (in the exhaust), and particulates associated with tire and brake wear (TBW). When quantifying the economic impact of these emissions, this study considered not just changes in the absolute mass of emissions, but importantly *the location* where particular types of emissions.

The emission profiles of generation facilities are highly dependent on the combination of the various fuels and resources used to create electricity, known as the "generation mix." To allow for meaningful comparisons that demonstrate how electrification changes school bus emissions, a "snapshot" model was developed that quantifies the absolute mass of emissions under three different cases for the entire population of buses:

- **Current ICE Scenario:** The emissions associated with the current statewide population of K-12 school buses, assuming the current mix of vehicle weight classes and fuel use. This scenario represents the "as is" baseline against which the other two electrification scenarios are compared.
- **Electrified – Current Supply Mix:** The emissions that would result if the entire existing fleet was electrified, assuming no changes in the distribution of vehicles across weight classes or travel patterns, based on the current electricity generation mix (for the New Jersey region, known as "RFC-East").
- **Electrified – Clean Electricity Mix:** The emissions that would result if the entire existing fleet was electrified, assuming no changes in the distribution of vehicles across weight classes or travel patterns, but assuming all electricity was supplied by clean (combustion-free) sources.[7] This scenario is relevant because New Jersey has committed to transition to a clean and renewable electricity supply mix, and that transition is happening in parallel with vehicle electrification. This scenario therefore illustrates the potential synergy between vehicle electrification and electricity supply de-carbonization.[8]

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[6] There are numerous other emissions associated with ICE vehicles.

[7] This analysis focuses on "clean" sources of electricity, which could include both renewable sources, such as solar and wind, and carbon-free nuclear generation.

[8] For context, on February 15, 2023, Governor Phil Murphy committed the State by executive order to 100% clean energy by 2035. In the scenario where the State reaches 100% renewable generation, electric school buses would produce no tailpipe emissions and would be charged using electricity that results from emission-free generation. The only remaining emissions related to the operation of the full electrified school bus fleet would be particulate matter resulting from tire and brake wear, and even those would be reduced through regenerative braking.

In each of these scenarios, the total number of school buses in the State and the typical operating profiles of those buses (mileage, driving patterns, etc.) was assumed to remain constant. Fuel efficiency factors (miles per gallon) for fueled buses and efficiency factors for ESB (kWh per gallon) were generated based on data sourced directly from bus manufacturers. The total vehicle miles traveled (VMT) of each bus segment was divided by the corresponding efficiency factors in each case to determine the estimated total annual expenditure of each fossil fuel and, in the case of ESBs, electricity.

For fueled buses, CO_2 content emission factors were determined using fuel-specific emissions coefficients provided by the United States Energy Information Administration (EIA). Criteria pollutant emissions (NO_X, SO_2, and PM2.5) were calculated based on total fuel expenditures and emissions coefficients provided by Argonne National Laboratory.

For ESB emissions impacts, most emissions are shifted from the tailpipe to the electricity generation facility. The United States Environmental Protection Agency's Emissions and Generation Resource Integrated Database (eGRID) was used as an authoritative source for emission factors, and the latest corresponding regional emissions factors were used to calculate the estimated emission impacts of a fully electrified school bus fleet.

Emissions reductions can also be quantified in terms of economic social cost. These monetary values estimate the economic, environmental, and social value of not emitting particular emissions that impact climate change and public health.[9]

4.1.2 Physical Impacts

Currently, school buses in New Jersey consume an estimated 12.7 million gallons of diesel fuel, 26.6 million gallons of gasoline, and 947.2 million Standard Cubic Feet (SCF) of compressed natural gas (CNG) annually. Combustion of those fuels in the ICE school bus fleet contribute 457,299 tons of CO_2, 505 tons of NO_X, 2.5 tons of SO_2, 3.8 tons of PM2.5 resulting from tailpipe emissions, and 4.4 tons of PM2.5 resulting from TBW each year. It is important to note the significant difference in scale between the absolute mass of CO_2 emissions and the other three pollutants.

Key Finding: Full electrification of school buses in New Jersey would eliminate all fossil-fuel use but require 319.3GWh of electricity for vehicle charging (at the point of consumption).[10] The net impact of displacing the fuel use with electricity for the current electricity generation supply mix would be an annual reduction of CO_2 emissions by 341,620 tons (74.7%), a reduction of NO_X emissions by 454 tons (89.9%), and a decrease of TBW PM2.5 by 2.7 tons. Annual emissions for SO_2 and PM2.5 (exhaust) increase by 55 tons and 4.5 tons, respectively.

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[9] Economic values for CO_2 used in this study were based on a New York State Department of Environmental Conservation study, "Establishing a Value of Carbon: Guidelines for Use by State Agencies. Economic Values for NO_x, SO_2, and PM2.5 used in this study were published by the United States Department of Transportation's National Highway Traffic Safety Administration.

[10] Electricity measured at the point of generation would be 343.9 GWh.

The figures below illustrate these findings.

Figure 4.1.2 -1: Total Annual CO_2 Emissions

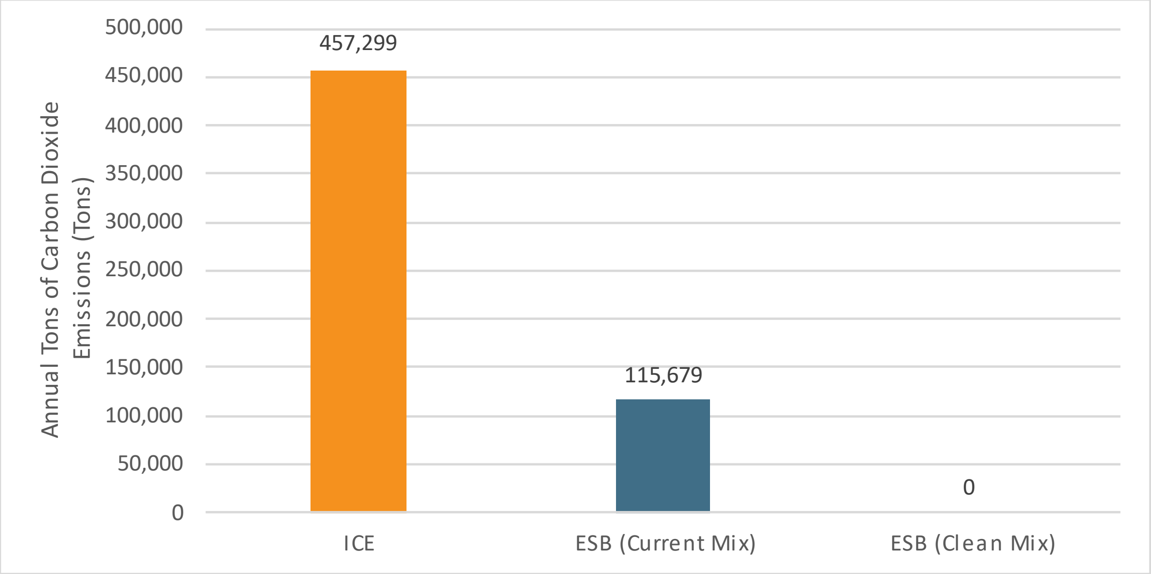
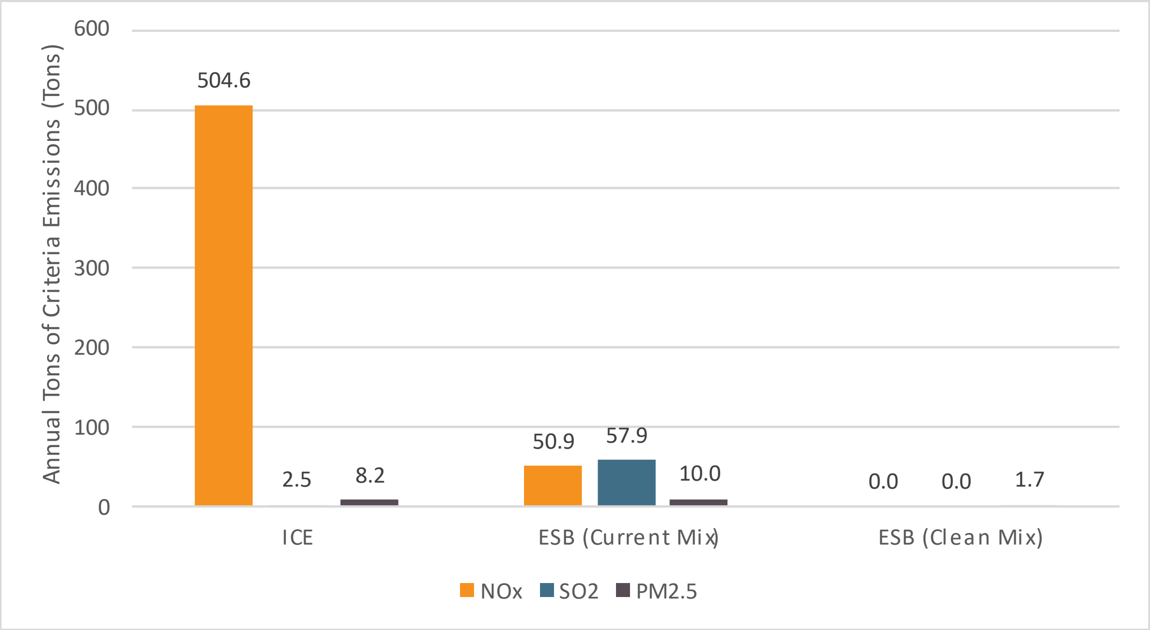


Figure 4.1.2 -2: Total Annual Criteria Pollutant Emissions



There is clear benefit to the absolute reduction in CO_2 and NO_X emissions, as well as lower PM2.5 associated with TBW (through regenerative breaking). While both SO_2 and PM2.5 (exhaust) increase in the current-mix case, two related considerations are important:

- Even though the absolute emissions of SO_2 and PM2.5 (exhaust) go up, electrification results in significant changes in *where* those emissions take place: electrification shifts the location of the emissions from the communities where school buses travel (directly correlated with population density) to more remote power plants.[11] When measured at the tail pipe, ESBs are completely clean compared to existing fossil-fueled buses and that cleaner emission profile will be felt directly by the communities where ESBs travel[12].
- The increase in SO_2 and PM2.5 is primarily a function of the current generation mix, which includes a significant amount of coal generation. As New Jersey moves to a cleaner generation mix, those emissions will naturally decline and eventually drop to zero. This outcome demonstrates the synergy associated with grid decarbonization happening in parallel with vehicle electrification.

Taking all pollutants together, full electrification of the State's school buses would result in a net emissions reduction of 342,016 tons at the current generation mix, representing a net decrease of 74.7%. All tailpipe emissions are eliminated entirely in the communities where ESBs travel. Importantly, as the grid decarbonizes, net emission reductions decrease to nearly zero with only TBW emissions retained, but at reduced levels (depending on the extent of impact from regenerative braking).

As noted above, school bus electrification will displace fuel use with increased electricity use, up to an estimated 319.3 GWHrs of electricity each year. Of potentially greater impact, however, are power impacts on the distribution system and the need for new service connections, upgrades to existing service, and/or reinforcement of feeders and substations necessary to deliver that power, estimated to be as high as 400MW (if highly coincident). The extent of these impacts, especially due to increased power, will depend heavily on the extent to which vehicle charging can be scheduled during off-peak times when the grid is less loaded. Much more detailed engineering analysis will be needed to anticipate those impacts, and to ensure grid readiness in support for widespread ESB adoption. Costs for such reinforcement, if needed, require further assessment to be quantified with confidence, but they should be considered "required upgrades" alongside other actions to enable and accelerate ESB adoption.

4.1.3 Economic Impacts Due to Emission Changes

The beneficial impact of the net reduction of emissions, combined with the impact of where those emissions take place, can be translated into economic terms. This study uses economic impact factors that consider implications for both the climate and environment, as well as public health.

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[11] Generation facilities can also more easily apply pollution controls that make it easier to partially remediate negative impacts related to the emissions of criteria pollutants.

[12] Where ESBs are powered by existing power plants, residents near those plants could experience an increase in SO2 and PM2.5 emissions even as residents through which ESBs travel experience lower emissions. This dynamic has been raised as a concern for disadvantaged communities that typically live near those power plants. This challenging trade-off is eliminated (from an emissions perspective) as generation is transitioned to renewable sources.

Reductions in CO_2 are the single largest emissions benefit associated with school bus electrification, since CO_2 is one of the most dominant GHGs that drive the accelerating climate crisis. Economic factors that measure these impacts consider the long-term results of sea level rise; increased frequency, severity, and duration of extreme weather events; emerging fresh water scarcity; food insecurity; and a long list of numerous impacts that reach into nearly every facet of modern life worldwide. Many of these impacts are felt disproportionally by the world's poorest and most vulnerable populations. Vehicle electrification, including school buses, is a primary strategy for reducing these GHG emissions and dampening the climate crisis escalation. In addition, fossil fuel use can also contribute to the contamination of water and soil, and eliminating petroleum use has significant geo-political benefits.

Reduced emissions from ESBs also have significant public health benefits, resulting in a very "human visible" facet of the electrification benefit portfolio. School buses travel largely within communities where people live, work, and attend school. Their emissions are therefore typically concentrated in areas where people spend the most time, which increases their negative impacts on public health. While children and the elderly are among the most vulnerable, these health impacts extend to the broader population and can include decreased lung function, lung cancer, increased mortality in infants, increased hospitalization admissions for cardiovascular disease (including heart attacks and strokes), chronic obstructive pulmonary disease (COPD), asthma, impaired cognitive function, increased risk of Parkinson's disease, increased risk of Alzheimer's disease and other dementias, and diabetes.[13] These morbidities are especially pronounced in segments of the population who live near roads with heavy traffic, specifically low-income and minority communities who typically live along major corridors. A 2001 Natural Resources Defense Council (NRDC) study rose awareness on the public health impacts of combustion school buses, estimating that up to 46 million children may eventually develop cancer from the exhaust that they inhaled while traveling on a school bus.[14] Measurements conducted during that study found that levels of exhaust inside school buses were up to four times higher than in passenger cars, and up to eight times higher than in a sample of ambient local air. Children are anatomically and physiologically more prone to harmful vehicle emissions due to their smaller, developing lungs and because they breathe more rapidly and inhale more air per pound of body weight compared to developed adults.

Key Finding: This ChargEVC-NJ study quantified the economic benefits associated with air emission reductions, with a focus on both climate change and public health implications. Today, the existing fueled school bus fleet in New Jersey results in over $79.8 million in harm per year due to air emissions. Compared to that baseline, a fully electrified New Jersey school bus fleet under the current generation mix would reduce that harm by $55.6 million annually, a reduction of 69.6%.

These results reflect the impact of individual pollutants as follows:

- $50.4 million in reduced harm due to net CO_2 reductions,

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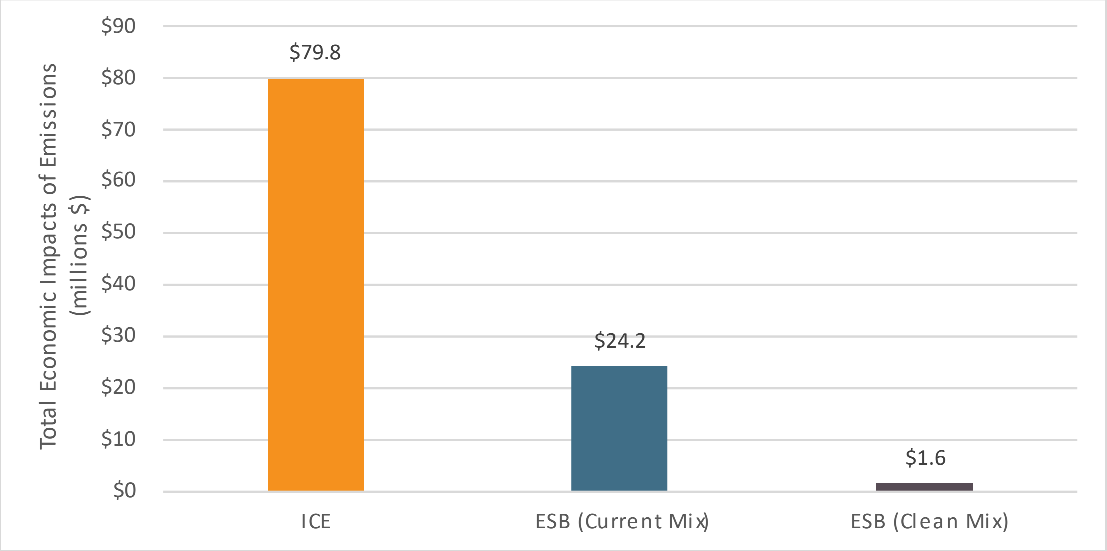
[13] American Lung Association, "State of the Air 2022," 2022.

[14] Natural Resources Defense Council, "No Breathing in the Aisles: Diesel Exhaust Inside School Buses," January 2001.

- $4.2 million in reduced harm due to net NO_X reductions,
- $3.0 million in increased harm due to net SO_2 increases,
- $1.6 million in reduced harm due to exhaust PM2.5 reductions, and
- $2.4 million in reduced harm due to TBW PM2.5 reductions.
- Taken together, electrifying the New Jersey school bus fleet reduces environmental and public health harm by 69.6%, even with the current generation mix.

Figure 4.1.3 -1: Total Economic Impacts of Emissions-Harm



In the case of PM2.5, even though emissions increase on an absolute mass basis, the shift of these emissions to a remote generation facility (away from population centers) provides a societal economic benefit. The reductions in PM2.5 from TBW result primarily from the regenerative braking enabled by ESBs.

Key Finding: Under a fully renewable generation mix, as is expected to emerge given New Jersey's clean energy goals, widespread school bus electrification would provide $78.3 million in net economic benefits each year. The only remaining emissions would be very small amount of residual PM2.5 impact from unmitigated tire and brake wear. That represents a reduction of economic harm from school bus air emissions by nearly 100% further illustrating the synergy between ESB adoption and the transition to clean sources of electricity.

The economic impact of these "externalities" means that each ESB would deliver $2,653 in benefits each year of its operating life under the current supply mix, and $3,736 in benefits annually when the electricity comes from clean sources.

4.2 Lower Fueling and Maintenance Costs

ESBs are typically expected to reduce fueling and maintenance costs when compared to comparable ICE buses. The current school bus fleet in New Jersey consumes diesel, gasoline, and compressed natural gas at an estimated annual cost of $171.4 million for fuel, and an estimated $158.4 million each year for maintenance.

Key Finding: A fully electrified fleet would present significant fuel and maintenance savings, and overall lower operating costs. Full electrification of the New Jersey school bus fleet would result in total annual electricity costs of $44.5 million and total maintenance costs of $83.0 million, leading to savings of $126.9 million annually (74.0%) and $75.4 annually (47.6%), respectively.

Section 5 of this report more fully explores the impacts of the costs and savings associated with the ownership and operation of ESBs through a Total Cost of Ownership (TCO) analysis.

Key Finding: When the economic value of reduced emissions is combined with savings in fuel expenditures and maintenance, a fully electrified school bus fleet in New Jersey would generate $257.9 million in benefits annually for the current generation mix, growing to $280.6 million annually when the electricity is from clean sources.

4.3 Other Benefits

In addition to the environmental, public health, and economic benefits summarized above, there are a variety of other benefits that are harder to quantify at this time – but which are likely significant. These potential sources of additional electrification value are summarized below.

4.3.1 Grid Services Through Bi-Directional Charging

School buses are vehicles with very specific and predictable travel profiles, typically traveling twice per day to bring students to and from school. This leaves the buses at rest for several hours in the middle of the day, in the evenings, and overnight.[15] Most school buses are completely unused during the summer, especially during times of peak grid load in late afternoon. For this reason, electric school buses are often identified as an enormous opportunity to employ bi-directional charging that would deliver "demand reduction" and "load balancing" services to the public grid (including generation, transmission, and distribution benefits). Two types of bi-directional charging become technically feasible with resting electric school buses: Vehicle-to-Grid (V2G) and Vehicle-to-Building (V2B).

V2G technology allows an electric bus to deploy energy stored in the battery back to the grid, particularly during the times of day when the grid is most stressed. This export of power could potentially enhance grid stability, reduce capacity, transmission, and generation peaks in the wholesale market, and potentially lower peak-load costs within the distribution system that impact all utility customers. While

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[15] This travel profile also creates fertile conditions for lower operating costs of ESB since they are typically unused when electricity costs are the highest and parked overnight when electricity costs are the lowest.

V2G is not yet widely in practice, school districts could potentially earn revenue by providing this service to public utilities (and/or the wholesale market), helping to offset the cost of electrifying their bus fleets. At large scale, utilities could potentially use energy stored in school buses to reduce the need for building additional distribution infrastructure, such as reinforced feeders or new substations.

According to a study conducted by Environment New Jersey and NJPIRG, replacing every school bus in operation in the United States with a V2G-capable school bus would create a total of 61.5 gigawatt-hours of additional stored energy capacity, enough to power more than 200,000 average American homes for a week.[16] A key characteristic of all V2G systems is that the bus exports power onto the grid, at optimum times, in exchange for revenue associated with these grid services. Implementation of "full-blown" V2G requires the development of utility interconnection methods, and tariffs that define compensation for grid export, neither of which currently exist in New Jersey.

V2B technology works in a similar way, however, energy from the bus battery is not exported to the grid. Instead, stored energy is used to power the facility where the bus typically charges. This allows the bus to charge and store the battery during times when energy is least expensive, then deploy that energy back to the building at times when energy is most expensive thereby reducing peak grid loads. V2B solutions may be more achievable short term since they do not require the utility tariffs (with associated regulatory approval) that enable (and provide compensation for) grid export, even though they provide much of the same technical benefit – i.e. lowering building load can have the same aggregate impact on a feeder/substation as V2G-style export.

In any scenario, ESB batteries can be used to store renewable energy which is often intermittent and (for solar especially) at its peak during the day when school buses could be plugged in for charging. Through bi-directional charging, excess renewable energy can be stored in the bus battery and deployed later at a time when the renewable source may not be generating power, allowing for higher levels of renewable deployment, and reducing reliance on non-renewable sources that contribute to climate change and negative public health impacts.

There are not yet V2G tariffs (covering both interconnection and compensation rates) in New Jersey that enable full blown V2G with export, so the benefits associated with those solutions cannot yet be realized. V2B solutions may be more immediately feasible, while delivering much of the same technical benefit and customer savings through reduced capacity/transmission and demand costs and lower utility bills. Based on a review of known projects and relevant studies, there is an exceptionally large range of revenue levels being contemplated or proposed for bi-directional charging, which in many cases reflect very location-specific considerations (like grid loading, existing tariffs, etc.) and/or which have been implemented in very small trial configurations that are not easily scalable. It is therefore difficult to predict what V2G revenue streams might be in New Jersey until such programs are proposed and considered through the regulatory approval process. That situation is further clouded by the fact that the technology is still

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[16] Environment New Jersey and NJPIRG Education Fund; "Electric School Buses and the Grid: Unlocking the power of school transportation to build resilience and a clean energy future," 2022.

relatively new, and there is little operating experience with real-world projects. Based on the literature review conducted for this ChargEVC-NJ study, a review of "generic" V2G studies is likely not a strong indicator for V2G tariffs that may be appropriate or approved in New Jersey. That said, bi-directional charging represents a significant potential strategy for improving ESB economics, while also helping to optimize loading on the public grid. This topic is addressed further in the TCO section below.

4.3.2 Reduced Noise

ESBs are much quieter than school buses with conventional combustion engines, particularly when idling at a bus stop and when traveling at low speeds through residential neighborhoods. A 2020 study, published in the International Journal of Sustainable Transportation, calculates that electric buses generate about 5 dBA less exterior noise during acceleration compared to a diesel bus and that the noise from an electric bus is more easily absorbed by building facades.[17]

Aside from the reduced noise disturbance, impacts of low-frequency noise produced by bus engines has been linked to sleep disorders, sensitivity and irritability to noise, stress, hearing loss, fatigue, cardiovascular diseases, anxiety, depression, and other health impacts. A study in Gothenburg, Sweden that focuses on the impacts of bus noise found that when hybrid buses were replaced by buses fully powered by electricity, the health of residents living alongside bus routes had improved.[18]

A 2014 study from the University of Burdwan, published in the International Journal of Sustainable Built Environment, found that vehicle-engine noise has detrimental effects on bus drivers, linking engine noise to adverse health impacts related to the cardiovascular and digestive system. The study concludes with a strong recommendation that vehicle engines should be noise proof.[19]

4.3.3 Improved Academic Outcomes

Diesel exhaust is linked to disruption in cognition and academic performance in children. A 2019 study from Georgia State University found that school bus retrofits, that reduced student exposure to exhaust, had positive and significant effects on student English test scores and a smaller, precise effect on math scores.[20]

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[17] Boren, Sven, "Electric buses' sustainability effects, noise, energy use, and costs," International Journal of Sustainable Transportation, 2020.

[18] Green Car Congress, "Study finds reduction of low-frequency noise from transition to electric buses improved residents' health," May 2022.

[19] "Vulnerability of bus and truck drivers affected from vehicle engine noise" Naba Kumar Mondal; Department of Environmental Science, The University of Burdwan.

[20] Georgia State University; "School bus emissions, student health and academic performance," March 2019.

4.3.4 Reduced Absenteeism

A 2015 study from the University of Michigan and University of Washington found that schools adopting cleaner fuels and related technologies resulted in improved lung function and lower absenteeism, which decreased by 8% among children who were able to ride on retrofitted school buses.[21]

5 Total Cost of Ownership Analysis

In addition to the numerous benefits associated with widespread ESB adoption quantified above, and the positive economic impacts associated with that transition over time, it is also important to consider the essential economics of ESBs today, in the future, and if augmented with new value streams like V2G or V2B. Traditional ICE buses typically require relatively modest up-front investment (i.e., vehicle purchase price), but also substantial operating costs for fuel and maintenance.[22] ESBs have the reverse profile, with much higher up-front costs (currently), but substantially reduced operating costs. Total Cost of Ownership (TCO) analysis is a calculation method that captures all facets of school bus economics over time and is commonly used by fleet managers to make informed decisions related to the replacement and procurement of vehicles, products, and services. When determining the TCO of a vehicle, this method accounts for the initial purchase costs, but also accounts for costs associated with the routine operation of the vehicle, such as maintenance, fueling, insurance, and other factors. TCO analysis is a rigorous way to clearly show meaningful lifetime cost factors for ESBs compared with traditional vehicles.

5.1 Total Cost of Ownership Framework

This ChargEVC-NJ study includes a detailed TCO analysis of diesel and gasoline school buses, which make up most of the New Jersey school bus fleet, compared with a typical ESB under several sensitivities. TCO is calculated on a $/mile basis (nominal) for both ICE school buses and ESBs for three cases:

- **"Current Case":** All costs and revenues are estimated based on current prices and are assumed to remain constant over a 15-year life cycle of one school bus. The values of all costs and revenues are based on current conditions and data. This case does not include revenue from V2G, nor inflationary considerations. This scenario provides a clean baseline for considering TCO outcomes without being cluttered by the numerous assumptions associated with how costs might vary over time.
- **"Future Case":** All costs and revenues are determined over a 15-year life cycle of one school bus, based on projections of costs by roughly 2030. This scenario factors in projections of future

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[21] Adar, S.D., D'Souza, J., et.al., "Adopting Clean Fuels and Technologies on School Buses: Pollution and Health Impacts in Children," American Journal of Respiratory and Critical Care Medicine, 2015.

[22] Other operating costs – such as costs for drivers – are expected to be nearly identical for traditional vehicles and ESBs.

reductions in battery pricing, projections of future energy costs, and typical inflation rates associated with each of the mechanisms that factor into the TCO. This case does not include revenue from V2G.

- **"V2G Case":** The values of all costs and revenues are based on current conditions and data and increase annually according to typical inflation rates associated with each of the mechanisms that factor into the TCO, but without projecting potential changes in bus up-front cost assumptions. This case incorporates revenue from V2G into the TCO for ESB.

Whereas the impacts of electrifying the entire school bus fleet were determined for the benefits analysis summarized above, TCO analysis is focused on the economics of a single bus to make comparisons clear. In each case, the following economic elements are included, representing the major categories of costs when owning and operating school buses.

- **Purchase price:** This study utilized published ICE and ESB school bus purchase pricing from the last two years to calculate the average purchase price[23]. These averages are weighted by the actual prevalence of school bus types (A, C, and D) in New Jersey since, in both the diesel and ESB cases, there is a significant difference in ESB-premium across bus types. Future costs of ESBs are based on projections of reduced battery prices between now and 2030.
- **Fueling costs:** This study uses the current and projected retail costs of diesel and gasoline based on regional data from the EIA. Electricity costs, considered to be the "fuel" for ESBs, are based on the average "all-in" commercial price of electricity in New Jersey normalized on a per-kilowatt-hour-basis (kWh), based on annual 2022 data from EIA. Electric vehicles typically have significantly higher fuel efficiency than ICE models and the price of electricity is considerably more stable compared to gas and diesel which makes operational costs for fueling more predictable over the long-term.[24] Average efficiency (i.e. miles per gallon for fueled vehicles, and miles per khwr of electricity for ESB) were developed from supplier specifications.
- **Maintenance costs:** Maintenance costs for both ICE and ESBs were calculated using a "per mile" cost metric based on a synthesis of studies by other researchers and pilot projects. Electric vehicles save considerably on costs because they eliminate common ICE vehicle maintenance expenses such as oil changes, parts replacements, and transmission repairs.[25]

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[23] A TCO analysis would typically also include end-of-life "salvage value", which improves economics slightly. Given that ESBs are so new to the market, and few (if any) have reached their natural end of life, there is no data available on this parameter and it was therefore not included in the model.

[24] Effective managed charging programs, where they can be used, and enrollment in specialized TOU rates may help further improve ESB economics.

[25] Many ESB manufacturers currently offer warranties on batteries that range from 8-12 years, however, it's possible that battery replacement may be required over the full lifecycle of the vehicles. There is little available data on the expected battery life of ESB, as well as the future costs associated with such replacements, and was therefore not considered as part of the TCO model.

- **Insurance costs:** While the model accounts for insurance costs, there was little data available to quantify differences between ICEs and ESBs. These costs were therefore assumed to be equal in ICE and ESB scenarios, making use of a mid-point factor distilled from other studies.

- **Charging infrastructure costs:** For ESBs, this study factors in the cost of the purchase of a 14.4 kW Level 2 charger and includes annual costs for data services and network contracts. These costs are based on data published by the Rocky Mountain Institute (RMI) and apply only to ESBs. Costs to replace the charger one time during the full ESB lifecycle are included in the TCO model after 8 years. [26]

- **Charger Operation Costs:** For ESBs, this study factors in ongoing costs for maintenance and data related to the charger.

- **V2G system equipment:** In the V2G sensitivity, the TCO analysis accounts for the cost of upgrading charging equipment to accommodate V2G services.

- **V2G revenue:** Since ESBs present an opportunity to provide bus operators revenue through the use of V2G technology, this revenue is applied to ESBs in the V2G sensitivity and effectively offsets costs. Given that V2G tariffs do not exist in New Jersey yet, and there are no V2G programs proposed, there is no meaningful way to assume what potential bi-directional charging revenues might be. The study team completed a survey of projects and other pilot initiatives to identify appropriate working assumptions – but there was an exceptionally wide range of figures noted, ranging from $500/year to $15,000/year. To establish a planning assumption for the TCO model, the study team found reference to a recommendation to the NJ BPU (by EnerNOC) to value peak load reductions at $30/KW in avoided transmission and distribution costs, assumed to be delivered for ESBs averaging 60KW at discharge (2012$). [27]

- **Up-front cost incentives for ESBs:** The model allows for accounting of vehicle incentives – such as rebates – that offset the up-fronts. Given that such incentives are not yet widely available, none were assumed for the TCO analysis. See Section 5.3 for more details on this point.

- **Inflation Reduction Act (IRA) Tax Incentives:** The 2022 IRA provides tax incentives for both ESBs and electric vehicle chargers. For ESBs, the credit is equal to either 30% of the capital investment or the incremental cost of the ESB (the difference in purchase cost between an electric model and a comparable ICE model), up to $40,000. Since, in all cases, the current purchase cost and incremental cost of an ESB exceeds this threshold, a maximum tax credit of $40,000 was applied

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[26] The TCO model does not reflect costs that may be necessary to upgrade the distribution system (broadly, or as part of a specific customer electrification project). These costs vary widely from utility-to-utility, and from project-to-project. Given that wide range, and a general lack of available hard data on this point, these impacts were not included in the model.

[27] Declining battery performance and/or degradation over time will likely be a factor in lifecycle economics and could be particularly amplified in V2G applications. Increased battery usage (and impacts on battery life) may be a factor that dis-incentivizes V2G/V2B applications. There is little available data on these factors at this time and they were not considered as part of the TCO model.

to the TCO analysis. Additionally, the IRA provides a tax credit equal to 30% of charger costs which was applied to the TCO Analysis. The IRA includes a provision that allows for the option of an elective payment for certain qualified tax-exempt entities (such as school districts), allowing for the economization of these tax credits for non-tax paying entities.

Given the trade-off between up-front investment and operating savings, TCO is strongly influenced by the distance traveled by the ESB each year – the longer the route, the greater the operating savings. For this reason, TCO sensitivities were developed for three route types.

- Average Route: Based on typical school bus mileage data provided by the U.S. DOE and the typical days of New Jersey school operation.
- Short Route: Assumed to be 50% of the average route.
- Long Route: Assumed to be 150% of the average route.

5.2 Total Cost of Ownership Comparisons

The results of the TCO analysis are summarized in the following table.

Figure 5.2-1: Total Cost of Ownership Results - Summary

Sensitivity	Route Length	Diesel Avg. $/mile	Gasoline Avg. $/mile	ESB Avg. $/mile
"Current Case"	Short	$3.95	$3.41	$5.55
	Average	$2.52	$2.23	$3.03
	Long	$2.05	$1.83	$2.19
"Future Case"	Short	$5.07	$4.44	$5.08
	Average	$3.26	$2.92	$2.86
	Long	$2.65	$2.41	$2.13
"V2G Case"	Short	$4.38	$3.84	$1.94
	Average	$2.82	$2.52	$1.26
	Long	$2.30	$2.09	$1.03

The "Current Case" sensitivity accounts for high incremental up-front cost investments currently evident in the market, with all other costs fixed over time to allow easy comparison based on current conditions. This scenario makes clear that price parity (on a full-lifecycle per-mile basis) can be approached only for ESBs with longer routes, where the operational savings are maximized. For buses with short or average routes, the much higher up-front costs of an ESB is difficult to surmount through operational savings alone, even over the life of the bus. In summary, this model demonstrates that ESB economics (without incentives, other than the known IRA credits) are challenging, and cost parity scales with the number of miles driven over the bus lifetime.

As the gap in incremental purchase costs closes between an ICE and ESB, the economics improve significantly in favor of ESBs, especially when inflationary impacts on operating costs over time are also considered. The “Future Case” is based on projections of bus, infrastructure, energy, and other costs for a 15-year period, with the analysis targeting the 2030 timeframe. Battery costs are projected to be reduced in 2030 by as much as 50%, bringing ESB up-front costs nearly on par with traditional vehicle costs. These factors bring ESB economics into ICE parity for most sensitivities on a TCO basis, but not on an up-front cost basis.[28] Additionally, electricity has historically been remarkably consistent in price,[29] while fossil fuel pricing generally increases significantly from year to year, and fuel prices often suffer from substantial volatility. This dynamic widens the ongoing savings associated with the “fueling” of buses and provides an additional value: electrification can act as a hedge against future fuel price increases and volatility that can directly impact district budgets.

Potential revenue generated through delivery of grid services in the “V2G Case” provides a significant improvement in economics, leading to a significant advantage for ESBs under all route lengths. As noted in Section 4.3.1, V2G is not currently feasible in New Jersey due to the lack of utility interconnection methods and tariffs that provide compensation for grid export. However, this sensitivity demonstrates that there could be significant merit to using V2G revenues to help finance ESB investments, while delivering valuable services to the grid. If such compensation arrangements are established in New Jersey, they could have a large impact on ESB economics, and could potentially serve to reduce the need for up-front incentives, such as grants and rebates, regardless of the route length.

5.3 Potential Incentive Needs

The TCO sensitivities explored in Section 5.2 do not reflect potential incentives that could improve ESB economics, other than application of federal tax credits enabled through the recent IRA legislation. The TCO model can be used to estimate what offset to ESB up-front costs (such as through a grant, for example) would be needed to achieve TCO parity. Focusing on a modification of the “Current” scenario (i.e. current bus prices, and fixed operation costs over time), the following table summarizes the reduction in up-front costs (i.e. grant levels) that would achieve TCO parity for each route length.

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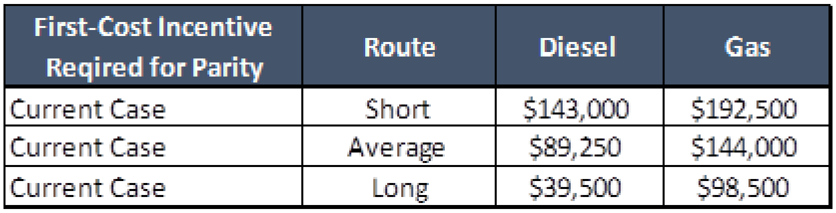
[28] For the “Future Sensitivity” even though bus costs approach traditional vehicle costs, there are incremental costs for charging infrastructure that still imply higher up-front cost burden for ESBs.

[29] In the decade between 2010-2020, the average year-over-year change in the price of commercial electricity in New Jersey, on a per-kWh basis, was a decrease of 1%.

Figure 5.3 - 1: Up-front Incentives Required to Achieve ESB TCO Parity



First-Cost Incentive Reqired for Parity	Route	Diesel	Gas
Current Case	Short	$143,000	$192,500
Current Case	Average	$89,250	$144,000
Current Case	Long	$39,500	$98,500

For example, a roughly $143,000 grant for a short range ESB would bring economics for that vehicle into TCO parity with an average diesel bus. However, it should be noted that this figure represents what is required to break-even on lifetime costs. Many districts are very sensitive to up-front costs, and it is challenging to make higher up-front investments even when there is confidence in longer term savings operationally. Furthermore, the figures noted represent a zero-savings threshold (i.e. break-even), devoid of profit or economic motivation. For these reasons, the above figures should be considered the minimum level of incentive required to achieve TCO break-even, and higher incentive levels would be required to create district savings and/or a return on investment. Generally speaking, most districts need to see parity on an up-front (not TCO) basis to justify ESB investment. The incentives required are very sensitive to bus up-front costs, and as those costs decline the required incentives also decline. Other incentives, such as V2G revenues can also help improve economics – as illustrated in the V2G scenario.

As noted in both Sections 4 and 5, the analysis in this study is based on factors gleaned from other studies, as adapted to New Jersey conditions to the greatest extent possible. While that is the best approach possible at the current time, there remains a significant lack of detailed information specifically about the school bus market in New Jersey. As the market begins to emerge, it will be important to collect as much New Jersey specific information as possible, and to share that information widely to better document impacts and encourage ESB adoption.

6 Pathways to Accelerate Electrification

ESBs represent a transformative change to the way school children (and supporting adults) are transported to and from school and extracurricular activities each day. ESBs eliminate local air emissions and offer lower operating costs (for both “fuel” and maintenance) over their life. However, ESBs are roughly $100K - $200K more expensive than traditional gas or diesel vehicles on a up-front cost basis. In addition, there will usually be significant up-front costs associated with charging infrastructure. Even though the unit operating cost for electricity is much lower than for fuel, the up-front investment challenge is a major barrier to broader widespread ESB adoption.

This economic barrier is especially challenging for school districts, most of which face heavily constrained capital budgets. While that cost premium may decline longer-term as battery prices drop, current estimates are that in the medium-term a substantial price premium will persist because reductions in battery prices are being used to increase vehicle range (through larger batteries), thereby making them feasible for a broader fraction of the market. Given the strict capital budget constraints that most districts face, the significant incremental cost over traditional vehicles cannot be easily absorbed, particularly in lower-income districts – so a solution that addresses that up-front cost premium is required.

Today, that up-front cost premium is being addressed through grant funding – often well in excess of $200K per vehicle. This initial phase of grant-funded growth is critical, since it allows pioneer projects to begin, accelerates the operational learning needed for this segment, and encourages growth of the manufacturing-scale and supply chain for new ESBs. That grant funding is currently available (on a limited basis) from both state and federal sources. While a grant-funded approach is a good short-term solution to help jump-start the market, it is not scalable to achieve the high level of ESB adoption that is necessary to cost effectively meet emission reduction targets. For example, if an average of $200K were required for each of the 20,946 registered school buses in New Jersey, that would require over $4.2 billion in grant funding. In the current market, the primary option for addressing ESB up-front cost barriers is grant funding which will be difficult to fund at the scale required.

For the ESB market to begin widespread scale-up, attracting private investors into the segment is critical and would enable a new phase of ESB adoption with reduced dependence on publicly-funded grant resources.[30] In response to this strong need, there are traditional private investors (of various types) that are ready to invest in this segment, as well as an emerging market of service providers that can operationalize vehicle and/or charging costs, including infrastructure implementation, to facilitate school district electrification.

At the current time, however, there are procurement constraints that limit the ability for private capital to support districts that want to put ESBs into service in New Jersey. Public School Contracting Law (PSCL) defines the rules under which contracts may be awarded, and those rules do not currently allow for the use of optimal financing solutions for ESBs. There are numerous advantages to enabling private investment in the ESB sector, including the inherently scalable character of private investors, the ability to provide important support services (such as charging and vehicle maintenance), and the fact that financed solutions shift the expertise required and risk profile for the electrification transition from the school district to entities enabled by private investors.

Overcoming the up-front cost premium associated with ESBs is critical to encouraging school districts to deploy ESBs, and private investors are ready, willing, and able to provide the necessary solutions. But existing technicalities in PSCL (as further detailed below) prohibit leveraging these private investment strategies to eliminate ESB adoption barriers for districts. The good news is that these technicalities can be eliminated through relatively small and straightforward changes in law which have well-established precedent. The next section of this study provides a detailed framework to address the legal challenges facing more robust school bus electrification in New Jersey.

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[30] Some level of incentive – potentially grants – may still be required even if private investors are engaged to help finance ESB adoption, especially if cost parity is required compared with traditional vehicles. But even if required, the magnitude of such incentive resources will be dramatically reduced if private capital can be leveraged to address the up-front cost barrier.

7 Legislation Changes to Enable Large Scale Private Investment

7.1 A Market Precedent: Solar Financing

There is a strong and highly successful example that can guide thinking about how to leverage private capital in support of New Jersey's clean energy goals – especially for ESBs. In the late 1990s, New Jersey legislation created the Renewable Portfolio Standard (RPS) and new innovations like Net-Metering. Once these mechanisms were translated into the necessary regulations and programs, the market was poised for growth.

That growth didn't happen immediately, especially in the public sector. The reason was because solar installations require very large up-front investment but benefit from nearly zero operating costs over a long term. This is the reverse of traditionally fueled-power plants, which have much lower up-front unit capital costs, but also significant operating costs (especially for fuel). Most customers were used to simply buying electricity from the utility as an operating expense, at rates that benefit from long term investment cycles and low capital costs.

This is a structural problem - trading monthly utility bills for large up-front investments in an on-site solar project was out of reach for most customers. This is particularly true for public entities like school districts and municipalities that are especially sensitive to up-front costs. Even in cases where the TCO (or equivalently, the levelized cost of solar energy) was advantageous compared with traditional electricity costs, customers were unable to participate in the solar market simply because it required a large up-front investment.

This situation represented an ideal opportunity for private investment, since third-party entities are willing to make the capital investments that customers cannot (or will not) make, thereby translating up-front capital investments into operating expenses that are more feasible for customers to consider. These third-party entities would provide the up-front capital and project development expertise, in exchange for a per-kWh rate that recovered that investment over the long term. This investment strategy – commonly referred to as a Power Purchase Agreement (PPA) – was exactly what the market needed since it eliminated the need for capital, allowed solar economics to be structured similar to how traditional power is purchased on a cashflow basis (i.e., a monthly bill at an agreed upon per-kWh rate), and also allowed for professional management and maintenance of the solar equipment. Once PPAs were introduced in the solar market (in roughly 2002), solar adoption across all segments exploded. The original RPS and net-metering legislation created critical favorable market conditions – but that wasn't sufficient to spur adoption until financing solutions like PPAs were introduced.

For public sector customers, however, public procurement constraints limited the ability for them to participate in PPAs. Public procurement law – as it existed at that time – limited the term over which public contracts could be structured, and also imposed constraints on the form procurement could take, which in most cases required simple "lowest cost" awards that couldn't reflect important details about how PPAs are structured and the associated services being delivered. The established procurement framework did not support the new financing arrangements required to make solar a viable option.

To address these issues, the State adopted legislation that (1) authorized school districts to utilize competitive contracting to procure on-site renewable energy solutions, thereby allowing school districts to consider price and other factors when making renewable energy project awards; and (2) authorized a contract duration exception of up to 15 years for on-site renewable energy PPAs.

7.2 Lessons Learned and Applied to ESBs

Once longer terms and competitive contracting were enabled, solar PPAs were extremely successful in the public sector in New Jersey – including school districts. This same structural situation exists with ESBs and related charging infrastructure. While there are new ESB financing models that are very similar to PPAs, there are also multiple variations (such as leases) that might also be appropriate as well. The common thread across these various ESB financing solutions is reduced requirements for public capital investment, shifting cost from capital investment to operating expense paid over time, and bundling services like maintenance and vehicle charging that are essential for success.

The solar experience in New Jersey demonstrates that once financing solutions for public entities are enabled, current barriers related to up-front costs (and other factors) can be overcome, private capital can be leveraged, and adoption should explode. This precedent demonstrates the potential to dramatically expand school bus electrification through private capital financial solutions, and also highlights the changes that need to be made in existing procurement rules and practice to enable such investment. This highly successful experience with solar financing in New Jersey informed the proposals made below.

It is worth noting that there are multiple private ESB investors that now offer financing solutions similar to solar PPAs, optimized for the ESB market. Generically speaking, these solutions bundle the cost of the ESB, the cost of necessary charging infrastructure, long term maintenance, providing the electricity needed for vehicle charging (in some cases), and advanced services (such as “managed charging” to reduce electricity costs) into a turn-key solution whereby the districts pay a single per-mile or per-month fee. Given current constraints in New Jersey public procurement rules, districts are not able to take advantage of these solutions except in the infrequent cases where significant grant funding has been made available.

7.3 Goals For Legislative Changes

Given the conditions summarized above, ChargEVC-NJ recommends legislative changes to enable private capital to make investments in ESBs in support of district electrification plans. To do that, existing procurement constraints need to be addressed.

There are three constraints that currently limit the use of private capital in ESB adoption, and they are the key objectives for ESB-related legislation:

- Contracting Term: Current PSCL severely limits the terms allowed for school bus contracting, which if applied to ESBs, results in unfavorable economics compared with traditional vehicles. Allowing school districts to award contracts with longer terms – 12 years at least, preferably longer where allowed[31] – will allow recovery of the initial investment over the full service life of the asset. The longer the term, the lower the per-unit costs (such as per-mile contracts or monthly service fees), thereby helping ESBs attain price parity (or better) with traditional vehicles. Conversely, artificially restricting contracting terms (as exists in the market today) to shorter duration forces the accelerated recovery of the investment, at unit-cost levels that are not competitive with traditional vehicles. This extended term requirement should be equally applicable to a range of financing solutions, such as PPA-style contracts, leases, or other similar arrangements that minimize up-front costs by the districts and instead allow cost recovery of the vehicle investment through operating expense. A fifteen-year term has become common for solar PPAs, and it would be reasonable to allow ESB contracting terms consistent with the approved service life of the vehicle (at least 10 years, but typically 15 to 20 years for most vehicles currently in operation). To enable this approach, an exception to the PSCL constraints on contract term must be allowed via legislation.

- Competitive Contracting: There are several pathways for acquiring goods and services in New Jersey's public procurement law. One pathway – referred to as "Competitive Contracting" - allows public entities (including school districts) to award competitive contracts based on "cost and other factors" for comprehensive turn-key solutions. The "other factors" provision allows competitive proposals to be evaluated based on factors besides just cost, including details such as the strength of the private investor, maintenance and buy-out terms, and special services, which in the case of ESBs could include details such as charging infrastructure and the cost of electricity required for vehicle charging. This approach also allows proposals with a variety of economic structures to be considered, such as per-mile, per-month, or flat-fee scenarios. These factors – beyond simple cost – have proven to be essential components for PPA contracting in the solar market and will be equally important in the ESB financing sector as well. Only programs specifically approved in legislation for competitive contracting can be used by school districts, and financing solutions for ESBs are not currently allowed – but can be easily added through the legislative changes being proposed.
- Aggregation: As with many products, cost efficiency can be gained on a larger scale by enabling aggregated purchasing strategies. Arranging for the acquisition of 50 ESBs (for example) will typically be much more cost effective than the procurement of a single bus. This aggregation could apply to the buses themselves, but also to bundled solutions that are both financed (through private investment) and bundled with critical services (like maintenance and charging management). One unique aggregation entity – the Alliance for Competitive Energy Services (ACES) program – is sponsored by the New Jersey School Boards Association (NJSBA, and its

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[31] Under current rules, school buses manufactured on or after April 1, 1977, with GVW under 25,000 pounds, may remain in service for 12 years – see 39:3B-5.1. School buses manufactured on or after January 1, 2007, with GVW under 25,000 pounds and with closed-crankcase technology, may remain in service for 15 years – see 39:3B-5.1. School buses of the transit type with a GVW in excess of 25,000 pounds may remain in service for up to 20 years – see 39:2B-5.2. In some cases, one-time one-year extensions in service may be granted.

partners), and was explicitly enabled through legislation. Since it is sponsored by the NJSBA, of which all school districts are members, ACES is a particularly important aggregation pathway. Aggregation of products/services (and construction projects directly related to said products/services) through ACES can only be accomplished for specific products and/or services that have been explicitly authorized in law. Today, aggregation is not explicitly enabled for ESBs, especially if construction (for charging infrastructure, for example) is included.[32]

These three innovations – allowing longer contracting terms, the ability to use competitive contracting, and authorization for aggregated procurements through the ACES program – can all be addressed through legislation, and they represent small changes in law for which there are both established frameworks and relevant precedent. These modest changes can unleash billions in private investment, while also allowing for the inclusion of important related products and services (like charging infrastructure) that will make ESB adoption feasible for capital-constrained school districts. New Jersey's PSCL (and closely related rules) is currently a barrier to ESB adoption, but with small enabling modifications, it would become a powerful tool for stimulating faster, more wide-spread ESB adoption, while also reducing the need for grant-based funding.

7.4 Proposed Legislative Advancements

In order to authorize school districts to leverage private investment through the strategies outlined above, existing legislation would need to be amended as follows:

1. Revision of the contract duration exemption provisions of the PSCL (N.J.S.A. 18A:18A-42):

   p. The provision of goods and/or performance services for the purpose of providing electric school buses, on or off-site electric school bus charging infrastructure, and related maintenance and other related services, or any combination thereof for a specified price for a term up to the maximum allowable service life for the vehicle(s) being contracted.[33]

2. Revision to the competitive contracting provisions of the PSCL (N.J.S.A. 18A:18A-4.1):

   l. electric school buses, on-site charging infrastructure for electric school buses and on or off-site related electric school bus and charging infrastructure operation and maintenance services, or any combination thereof;[34]

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[32] It is possible to interpret the legislation authorizing ACES to include a wide variety of energy related goods and services but adding an explicit reference to ESB and related products/services (and construction activity directly related to said products/services) would remove all doubt and ensure the ability of ACES to support ESBs.

[33] For recently manufactured ESBs, this language should represent terms of 15 to 20 years, consistent with current legislated service life for school buses.

[34] Alternatively, if an electric school bus procurement will include offering proposers the opportunity to utilize school district property to construct and operate on-site electric school bus charging facilities, then the procurement could qualify as a concession for which a school district can utilize competitive contracting. N.J.S.A. 18A:18A-4.1(k.). But

3. Revision to law related to aggregation: Pursuant to the Electric Discount and Energy Competition Act (N.J.S.A. 48:3-49 et. seq., "EDECA"), the "New Jersey School Boards Association," established pursuant to N.J.S. 18A:6-45 is authorized to serve as a government aggregator to obtain electric generation service, electric related service, gas supply service or gas related service, either separately or bundled, in accordance with the "Public School Contracts Law, " (N.J.S. 18A: 18A-1 et seq.), for members of the association who wish to voluntarily participate. (N.J.S.A. 48:3-91 (h)). The legislation (N.J.S.A. 48:3-51) needs to be amended to explicitly enable ESBs as follows (necessary addition underlined):

   "a service that is directly related to the consumption of electricity by an end user, including, but not limited to, the installation of demand side management measures at end user's premises, the maintenance, repair, or replacement of applications, lighting, motors, or other energy-consuming devices at the end user's premises, ~~and~~ the provision of energy consumption measurement and billing services; and electric school buses and related goods and services, including construction projects that are directly related to those goods and services either individually or in combination."

These modest amendments enable financed ESB procurement within the existing PSCL framework but will allow for a longer contracting term (up to 20 years under current service life rules, depending on the vehicle), the use of Competitive Contracting for ESB financing solutions, and the efficiency that comes with aggregation through the commonly used ACES program sponsored by the NJSBA. While these changes enable a wide range of procurement options, any given district would still have the freedom to make use of a solution that works for them – for example, choosing to be part of an aggregated purchase, rather than a PPA-style ESB contract. The proposed legislative changes are intended to be as simple as possible, while maintaining flexibility in the market.

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this approach applies only to charging services and wouldn't normally apply to the buses themselves. A concession-based strategy therefore isn't as comprehensive or flexible as the proposed changes.

8 Findings and Recommendations

There are currently 20,946 school buses in New Jersey, that range in size and type, and run primarily on gasoline and diesel fuel. A wide range of studies conclude that exhaust from school buses with combustion engines are particularly harmful to the public health of the communities they travel in, especially children who are among the most vulnerable, while also contributing substantially to the climate crisis. This study explored the impacts associated with widespread ESB adoption – most of which are beneficial, and the basic economics of ESB investments. Key Findings include:

- New Jersey's fueled school buses currently emit more than 457,000 tons of CO_2 annually, as well as more than 515 tons of NO_X, SO_2, and particulate matter (PM2.5) each year combined. These emissions are especially impactful for people living in low-income communities in urban areas and near travel corridors.

- Full electrification of school buses in New Jersey would eliminate all fuel use but would require 319.3 GWh of electricity for vehicle charging (at the point of consumption) and an estimated 400MW of additional power (if highly coincident, assuming impacts at existing peak times).

- Electrifying the statewide fleet of school buses under the current generation mix for electricity would result in a 74.7% reduction in emissions and would shift nearly all emissions from densely populated communities to a more remote generation facility with reduced public health impacts.

- Expansion of renewable energy use further amplifies the beneficial climate, environmental, and public health impacts gained from vehicle electrification. If the entire New Jersey school bus fleet is electrified in parallel with a transition to 100% clean electricity, emissions are almost completely eliminated, with the only remaining emissions being unmitigated tire and brake wear.

- These reduced air emissions have economic impacts related to climate change and public health. A fully electrified New Jersey school bus fleet under the current generation mix would provide \$55.6 million in annual benefits, a reduction of emissions-harm of 69.6%. These annual benefits grow to \$78.3 million if the electricity used to charge the ESBs comes from clean sources.

- Electrification of the school bus fleet in New Jersey would also result in fueling and maintenance costs savings of approximately \$202.3 million annually, a reduction of 61.4%. **When the economic value of reduced emissions is combined with savings in fuel expenditures and maintenance, a fully electrified school bus fleet in New Jersey would generate \$257.9 million in benefits annually for the current generation mix, growing to \$280.6 million annually when the electricity is from clean sources.**

- The up-front costs of ESBs are currently significantly higher than traditional school buses. However, those costs are offset to varying degrees by operational savings during the bus lifetime, and while short and average route lengths are not advantageous, the \$/mile benchmark approaches economic parity for longer routes even at current costs. Looking at likely ESB costs in the 2030 timeframe, along with consideration of inflationary factors, ESBs achieve and exceed cost parity on a TCO basis for nearly all route lengths. Additional revenue through grid services such as V2G (or V2B) can improve ESB economics significantly, potentially making ESBs significantly more cost effective than traditional vehicles if compensated appropriately. The tariffs required for such services do not exist in New Jersey yet, but could be a significant strategy for simultaneously improving ESB economics while enhancing grid optimization. V2B solutions may be more feasible short term but deliver much of the same technical benefit.

- The higher up-front cost of an ESB is often addressed almost exclusively through grant funding, which is not a scalable solution to fund a widespread transition. Private capital needs to be unleashed to assist districts with the electrification of their school bus fleets, which is feasible given that operational savings can eventually offset higher up-front investment costs under the right conditions. Some level of grant funding may be needed to enable viable economics, especially for shorter routes, for roughly the next decade – although the level of funding required can be substantially reduced when used in combination with private investment.
- Current procurement constraints act as a barrier to private investment, especially regarding contracting term. Legislative changes that will enable private capital to make investments in ESBs will be critical to the success of electrifying this segment of vehicles.
- Moving forward, better "real world" information about school buses in general, and early ESB experience in particular, will allow for improved impact (and benefits) analysis, as well as increasing operational understanding for districts considering ESB adoption.

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