WORLD
RESOURCES
INSTITUTE

Electric
School Bus
INITIATIVE

TECHNICAL NOTE

Recommended total cost of ownership parameters for electric school buses: Summary of methods and data

Michelle Levinson, Phillip Burgoyne-Allen, Alissa Huntington, and Norma Hutchinson

CONTENTS

Technical notes document the research or analytical methodology underpinning a publication, interactive application, or tool.

Suggested Citation: Levinson, M., P. Burgoyne-Allen, A. Huntington, and N. Hutchinson. 2023. "Recommended total cost of ownership parameters for electric school buses: Summary of methods and data." Technical Note. Washington, DC: World Resources Institute. Available online at: doi.org/10.46830/writn.22.00024.

ABSTRACT

This Technical Note is a resource developed by World Resources Institute (WRI) as a reference guide for those conducting the total cost of ownership (TCO)[1] analysis of diesel and electric school buses. The publication presents a landscape analysis of information related to school bus procurement, performance, and operations, and it provides recommended default specifications for key calculation parameters. The recommendations, based upon publicly available information, will increase confidence in the results of analysis undertaken to assess the economics of fleet electrification.

This Technical Note outlines the scope of TCO assumptions, the methodology used to identify the range of data for each parameter, the assumptions used where data were not readily available, and the approach taken to make recommendations. This Technical Note also serves to document the rationale behind default values used in analysis conducted by WRI using open-source total cost of ownership tools.[2] Nonetheless, WRI recommends that analysts use more specific data to reflect local situations where such data are available.

MOTIVATION

Replacing traditional diesel-powered school buses with electric school buses (ESBs) can reduce students' exposure to air pollution and decrease greenhouse gas emissions. School districts and private fleet operators around the United States are increasingly interested in adopting ESBs and want to understand what this transition will mean for their budgets. Calculating the total cost of ownership for ESBs, and their diesel counterparts, can be challenging because industry data needed to estimate input parameters for these calculations have not yet been tracked in a consistent, centralized, public fashion for this new technology, and can vary significantly across sources.

There is a lack of standardized data surrounding the TCO of ESBs—data that are imperative for school districts and other stakeholders interested in transitioning school bus fleets from traditionally diesel-powered vehicles to electric ones. This Technical Note helps fill the gap surrounding TCO information and includes recommended data to enable school districts, policymakers, and advocates to conduct their own TCO analysis.

While there are additional fuel options in the school bus market (gasoline, compressed natural gas, propane), this document focuses only on diesel and electric technologies. Diesel is selected because more than 90 percent of school buses currently on the road are diesel-powered, making it the incumbent technology.[3] Gasoline buses, which are prevalent among the Type A size, are less fuel-efficient than diesel buses, so information that allows for analysis of the diesel TCO enables assessment of the least-cost comparison vehicle.[4] Among the alternative-fuel school bus options, due to their increasing popularity and fundamental technological characteristics (e.g., an electric rather than internal combustion engine), ESBs differ substantially from other technologies and require dedicated review.[5]

METHODOLOGY

The findings and recommendations in this Technical Note are based on a review of current literature and publicly available data, in addition to World Resources Institute's (WRI's) insights drawn from providing technical support to school districts interested in adopting ESBs. The review of current literature included recent English language articles published in international trade publications and academic journals, articles and reports from relevant trade associations, and other articles and publications by global research organizations, consultants, and nonprofits. The literature review also included collection and analysis of TCO assumptions used in published data sets and tools.

These datapoints were assessed, standardized, and then incorporated into the final recommended values. The analytical process and considerations for each parameter category are detailed in the "Data Source, Collection Method, and Analysis" section following discussion of each parameter. This work focuses on TCO analysis parameters that are generally applicable across contexts. On the other hand, calculation parameters like electricity rates, diesel prices, revenue from the sale of credits in low carbon fuel standard markets, and revenue from participating in utility programs or compensation for vehicle-to-grid services are context-specific, and may be quite variable, so they are not included here.

Source Selection Criteria

The following criteria guided our selection of the sources used to build this Technical Note and further allowed us to assess the quality and relevance of the data sources.

- **Publicly available:** TCO data sources should be publicly accessible to ensure transparency and to allow WRI researchers to assess the methodologies used to collect and disseminate the related TCO data.
- **Recent:** To the extent feasible, data should be the most recent available, be regularly updated, and have been updated in the past three to five years.
- **Specific to school buses:** Data should be specific to school buses and school bus size types, where possible, instead of simply generalized data related to transit buses or other types of vehicles that are not school buses.
- **Empirical:** Where possible, WRI researchers used TCO data sources that draw from empirical, instead of modeled, parameters. Although it was not possible to use empirical data in every case, those sources that used empirical data were given a higher consideration than those that did not.

Subsequent to publication of this Technical Note, the WRI's Electric School Bus Initiative plans to establish a mechanism to directly collect data on transactions, vehicle performance, and other TCO elements as part of its broader engagement with school districts. This effort will mitigate some of the shortcomings of sources available to date, as discussed in Limitations. The authors are glad to provide updates on the status of this ongoing data collection effort upon request.

A Note on Sources Referenced

Due to the significant number of sources referenced in this document, Appendix A presents a mapping of these sources to the parameter(s) they inform. Where specific sources are referenced in the main body of the text, the shorthand reference name for the source is noted within parentheses. Additionally, some underlying source observations for specific parameters are detailed in Appendix B, with the remainder available upon request. Information on sources reviewed and excluded from value estimates is also available from the authors upon request.

RECOMMENDED TOTAL COST OF OWNERSHIP PARAMETERS

Tables 1 and 2 below present a summary of the recommended values to be used in TCO analyses where more fleet-specific values are not known.

VEHICLE PARAMETERS

The tables and sections hereafter include a brief explanation of each vehicle-related TCO component; present the final recommended values; and provide context on the underlying sources, collection method, and analysis conducted to determine recommended values.

Table 1 | **Summary of recommended vehicle parameters**

VEHICLE TYPE	TYPE A		TYPE C		TYPE D	
Fuel type	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**
Expected vehicle lifetime (years)	13.5		13.5		13.5	
Annual vehicle mileage (miles/year)	14,084		14,084		14,084	
MSRP 2022 ($/vehicle)	$271,393	$58,484	$352,012	$103,140	$378,459	$127,606
Overall fuel economy (MPGe)	39.46	10.50	22.10	6.59	25.32	6.32
MPGe city	42.00	8.90	24.00	5.50	26.90	4.50
MPGe highway	36.00	12.50	20.40	8.00	35.00	8.50
Overall maintenance and repair costs ($/mile)[a]	$0.24	$0.40	$0.29	$0.57	$0.31	$0.62
Maintenance and repair costs - years 1-5 ($/mile)[a]	$0.22	$0.38	$0.23	$0.40	$0.26	$0.41
Maintenance and repair costs - years 5+ ($/mile)[a]	$0.42	$0.68	$0.43	$0.71	$0.50	$0.74
Diesel exhaust fluid ($/gallon)	n/a	$0.03	n/a	$0.03	n/a	$0.03
Year 8 (2030) Battery replacement cost ($2022)	$9,070	n/a	$15,162	n/a	$14,329	n/a
Liability-only cost to insure ($/year)	$4,786		$6,770		$12,300	
Full coverage cost to insure ($/year)[b]	$14,812	$9,068	$22,548	$12,660	$28,088	$17,575

Notes: n/a = not relevant; MSRP = manufacturer's suggested retail price; MPGe = miles per gallon (or equivalent); NPV = net present value. [a] Battery replacement is listed separately. [b] Full coverage includes liability as well as collision and comprehensive coverage, meaning that fleets select one of the two types, and costs should not be added together.

Source: WRI Authors.

Table 2 | **Summary of recommended charging infrastructure parameters**

INSTALLED STATION ENERGY (KW)	7.7	19.2	19.2	50	70	150	300+	1,000+
Charging level	Level 2 - AC	Level 2 - AC	Level 2 - AC	DCFC	DCFC	DCFC	n/a	n/a
Ports	single	single	dual	dual	dual	dual	n/a	n/a
EVSE cost ($/charger)	$2,200	$3,814	$4,678	$38,665	$54,300	$84,144	n/a	n/a
Network software ($/charger/year)	$454	$454	$484	$522	$522	$522	n/a	n/a
Maintenance ($/charger/year)	$536	$536	$536	$1,704	$1,704	$2,237	n/a	n/a
Customer-side construction and equipment installation cost ($/station)	$3,487	$6,661	$6,661	$28,009	$29,386	$60,186	$116,183	$363,527

Notes: kW = kilowatts; n/a = not relevant; AC = Alternating Current; DCFC = Direct Current Fast Charging; EVSE = electric vehicle supply equipment.

Source: WRI Authors.

Expected Vehicle Lifetime

Expected vehicle lifetime is a key consideration in TCO modeling because many costs are incurred over the entire period of operation of the vehicle. This value represents the vehicle's end of useful life as a bus, regardless of whether the vehicle has changed ownership in the intervening years following its purchase or if its components are repurposed. Each vehicle is expected to perform differently, but generally the expected lifetime for a diesel school bus is 12 to 15 years. Terrain and the amount of inclement weather will affect anticipated lifetimes for a particular vehicle or fleet. Due to their relative novelty, there is insufficient information on the expected lifetime of electric buses so it was assumed they will be in use the same number of years as their diesel counterparts—an assumption that is made for TCO analyses of light-duty electric vehicles.[6] Where a more fleet-specific number is not known, assuming a new vehicle will remain in operation for 13.5 years is recommended (Table 3).

Data Source, Collection Method, and Analysis

Robust data from the Federal Transit Administration on the relationship between minimum service requirements and observed average retirement ages across vehicle categories served as the basis for the lifetime estimates for diesel buses (Laver et al. 2007). Several informal, unvetted data sources were reviewed to supplement (Dynamic Specialty 2019; Metropolitan School 2021; Zic 2019). Though there were insufficient data on the category that most school buses fall into (10-Year Bus), applying the same relationship between minimum service age and average retirement age observed in the other categories reinforces the 12- to 15-year estimates identified from informal sources.

Annual Vehicle Mileage

Expected annual mileage is a key consideration in TCO modeling because many costs depend on how the vehicle is operated. Annual vehicle mileage varies substantially across communities depending on population density and local policies, which determine the nature of school transportation. Where estimates for a specific community are not available, analysts should use 14,084 miles per year (Table 4).

Data Source, Collection Method, and Analysis

The primary source referenced for this value is the default values recommended by the U.S. Environmental Protection Agency (U.S. EPA 2017) for calculations of Diesel Emission Reduc-

Table 3 | **Recommended expected vehicle lifetime, diesel and electric values**

EXPECTED VEHICLE LIFETIME (YEARS)	13.5

Note: This value is recommended for all size and fuel types.

Source: WRI Authors.

Table 4 | **Recommended annual vehicle mileage diesel and electric values**

ANNUAL VEHICLE MILEAGE (MILES/YEAR)	14,084

Note: This value is recommended for all size and fuel types.

Source: WRI Authors.

tion Act emission impacts (U.S. EPA 2017). This source is validated against a second average value that is calculated using two components: (1) the average route length established in a 2013 study on school bus drive cycles covering 200 vehicles in three geographies conducted by the National Renewable Energy Laboratory, and (2) typical school instructional days across states from the National Center for Education Statistics (Duran and Walkowicz 2013; NCES n.d.). The resulting estimate of annual vehicle miles traveled is 13,223—this is less than the value recommended by the EPA but does not account for nonroute mileage such as trips for extracurricular activities or vehicle maintenance. As a result, this estimate is considered to align well with the EPA's recommended value, which is in turn recommended here.

Manufacturer's Suggested Retail Price

Manufacturer's suggested retail price (MSRP) refers to the price at which a manufacturer recommends a vehicle be sold. A school bus's MSRP includes the base price for its particular trim level, as well as the prices of any options, packages, or extras with which it is equipped. Features are typically itemized and specified as included in the base price or available at additional cost. Standard factory warranty and service coverage are included in the price. MSRP does not include any accessories or extended service programs sold by the dealer, nor does it usually include discounts or incentives. Various fees and taxes are also not part of the MSRP.

Due to the relative immaturity of the ESB market, experts anticipate real price declines driven by continued cost reductions for battery technology and scale-up of production.[7,8,9] However, there is significant uncertainty about future prices due to supply chain issues, significant government investment, related demand increases, and other market conditions, so no projection of price trends is provided here. Table 5 presents MSRP values recommended at the time of publication.

Data Source, Collection Method, and Analysis

A sample of publicly available prices from 2022 were compiled by the authors through desk research across a variety of vehicle makes, models, and geographies, provided in Appendix B. To arrive at the recommended values for MSRP, the average price of buses in our sample were used, disaggregated by size type (Types A, C, and D) and fuel type (electric and diesel), with all prices weighted equally.

In nearly all cases, the prices in our sample are drawn from state contracts for school bus procurement, which allow all school districts in a particular state to purchase school bus models at the same price. When interpreting these contracts, the authors used the buses' base price, meaning the minimum price available for purchasing a particular bus model. School districts in these states may pay higher prices depending on the types of additional, nonstandard features they prefer to include in their purchases.

Another driver of price variation among ESB models is their range, which results from multiple factors including the capacity of their batteries. Battery capacity is consistent and comparable across all electric bus models. This information is also publicly available in WRI's "Electric School Bus U.S. Market Study and Buyer's Guide" (Huntington et al. 2022). It is important to note that some school bus manufacturers offer two options to customers for a particular bus model's battery capacity. However, the sources from which prices are drawn do not specify which battery capacity option is included in the price. As a result, for manufacturers offering multiple battery capacity options, we assume the listed price is for the lower capacity.

As shown in Figure 1 below, there is a noticeable correlation between ESBs' prices and their battery capacities. The positive direction of this relationship plays out as would be anticipated and reflects that vehicles with smaller battery capacities, such as Type A models, tend to be priced lower than vehicles with larger capacities. This means that school districts requiring more

Table 5 | **Recommended MSRP values ($/vehicle)**

VEHICLE TYPE	TYPE A		TYPE C		TYPE D	
Fuel type	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**
Average battery capacity (kWh)	104	n/a	202	n/a	168	n/a
MSRP 2022 ($/vehicle)	$271,393	$58,484	$352,012	$103,140	$378,459	$127,606

Notes: kWh = kilowatt-hour; n/a = not relevant; MSRP = manufacturer's suggested retail price.

Source: WRI Authors.

range to serve longer routes should expect to see higher prices. However, it is noteworthy that the best-fit line suggests a battery price of $740/kilowatt-hour (kWh), which is substantially higher than most industry estimates.[10] WRI plans to investigate this relationship further in future projects. It is also important to note that, in Table 5 above, the average battery capacity for Type D models is smaller than that of Type C models—this is the result of variation among the manufacturers contained in our sample, which offer varying battery capacities, and should not be interpreted as generally true of Type C and D ESBs.

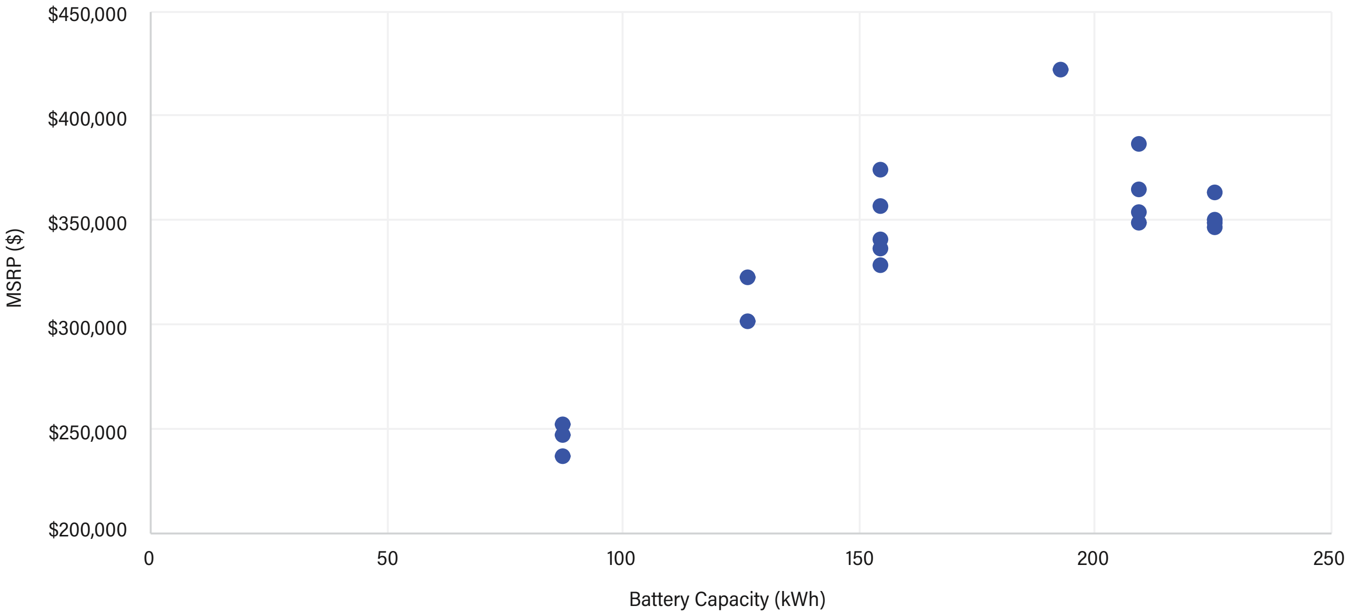
Miles per Gallon (or Equivalent)

Fuel economy, represented by the parameter miles per gallon (or equivalent) (MPGe), measures how far a vehicle can travel using one gallon of diesel fuel, or, in the case of alternative fuel vehicles, its energetic equivalent. In this study, 40.3 kWh is used as the electric energy equivalent of one gallon of diesel.[11] A vehicle's drive cycle, which indicates the speed of the vehicle in operation, has a strong effect on overall fuel consumption and resulting fuel economy.[12] This is especially important when comparing internal combustion engine vehicles and electric vehicles because of the efficiency improvements from regenerative braking technologies implemented in electric vehicles. School buses have a large range in their typical drive cycles due to the geographic, demographic, and land use characteristics of the districts they serve. To enable users of these data to more accurately model performance of specific districts, differentiated fuel economy rates for "city" and "highway" driving cycles are presented. Table 6 presents the recommended fuel economy values.

Data Source, Collection Method, and Analysis

The values used to estimate the MPGe of diesel and electric school buses, respectively, were collected from 12 different sources, provided in Appendix B. There is no publicly available data set containing empirical data on the MPGe of all diesel and electric school bus vehicle models. Therefore, Google with the search term "diesel school bus miles per gallon" or "electric school bus miles per gallon equivalent" (quotation marks included) was used to find various sources that reported this information. Sources with empirical data from project evaluations and other sources that report real, in-service performance were extremely limited and thus had to be supplemented with sources presenting modeled values or performance assumptions. For the sources that did not specify the vehicle type that the data corresponded to, it was assumed that the data were for Types C vehicles, given that this vehicle type is most common in the market and has been deployed at higher rates across the country.

Figure 1 | **Relationship between ESB battery capacity and manufacturer's suggested retail price**



Notes: MSRP = manufacturer's suggested retail price; kWh = kilowatt-hour.

Source: WRI Authors.

The values gathered vary significantly across sources, as illustrated in Figure 2 below. Notably, the recommended MPGe for electric Type D vehicles is higher than that for Type C vehicles. This is not what might be expected and is likely a function of poor data quality. There is only one real-world study among the Type C values and no empirical data for the Type As. The empirical data included in the Type D value are from a study of transit buses (Eudy et al. 2016).

Only a few data sources presented the effect of the driving cycle on school bus fuel economy. Because no source was found discussing differential performance for ESBs specifically, evidence from the light-duty electric vehicle sector was applied, based on the assumption that, while the absolute values would be very different, the relationship between city and highway performance would be similar (U.S. EPA and DOE n.d. [a]). This limited set of data was used to calculate adjusted city and highway MPGe values that both met the city-to-highway ratios established and the weighted average fuel economies found in the literature.

Maintenance and Repair Costs

Ongoing maintenance and repair costs are key contributors to school bus operating costs. As is to be expected, annual maintenance and repair costs escalate as vehicles sustain wear over their lifetimes. ESBs have fewer moving parts than diesel buses, which is anticipated to reduce their maintenance and repair costs.[13] In addition to savings on replacement parts themselves, lower scheduled service requirements also result in labor savings. Notably, none of the data sources explicitly stated that midlife battery replacement for ESBs was part of the estimated maintenance costs. Because this is understood to be the largest maintenance expense for electric vehicles, this value is calculated separately in the following section. Table 7 presents the recommended maintenance and repair cost parameters.

Since 2014, the EPA has required that fleet operators use diesel exhaust fluid (DEF) to reduce the emission of nitrogen oxides from diesel engines.[14] The mandatory fuel additive, as well as

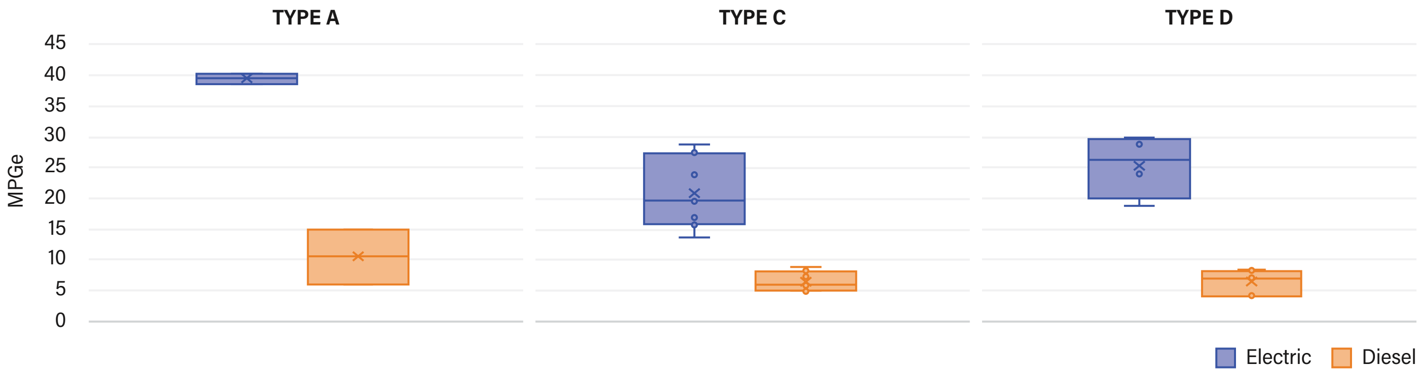
Table 6 | **Recommended fuel economy diesel and electric values**

VEHICLE TYPE	TYPE A		TYPE C		TYPE D	
Fuel type	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**
Overall fuel economy (MPGe)	39.46	10.50	22.10	6.59	25.32	6.32
MPGe city	42.00	8.90	24.00	5.50	26.90	4.50
MPGe highway	36.00	12.50	20.40	8.00	23.00	8.50

Note: MPGe = miles per gallon (or equivalent).

Source: WRI Authors.

Figure 2 | **Variation in MPGe source values**



Note: MPGe = miles per gallon (or equivalent).

Source: WRI Authors.

Table 7 | **Recommended maintenance and repair costs**

VEHICLE TYPE	TYPE A		TYPE C		TYPE D	
Fuel type	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**
Overall maintenance and repair costs ($/mile)	$0.24	$0.40	$0.29	$0.57	$0.31	$0.62
Maintenance and repair costs - years 1-5 ($/mile)	$0.22	$0.38	$0.23	$0.40	$0.26	$0.41
Maintenance and repair costs - years 5+ ($/mile)	$0.42	$0.68	$0.43	$0.71	$0.50	$0.74

Note: Battery replacement costs are presented separately.

Source: WRI Authors.

labor time to check and refill the fluid, incurs an operational cost for diesel vehicles that analysts should also consider when assessing TCO. There is no need for this additive in the operation of electric engines. Table 8 presents recommended per gallon DEF cost parameters.

Table 8 | **Recommended cost of diesel exhaust fluid**

PER GALLON COST OF DEF	$0.03

Notes: This value is recommended for all size and fuel types; DEF = diesel exhaust fluid.

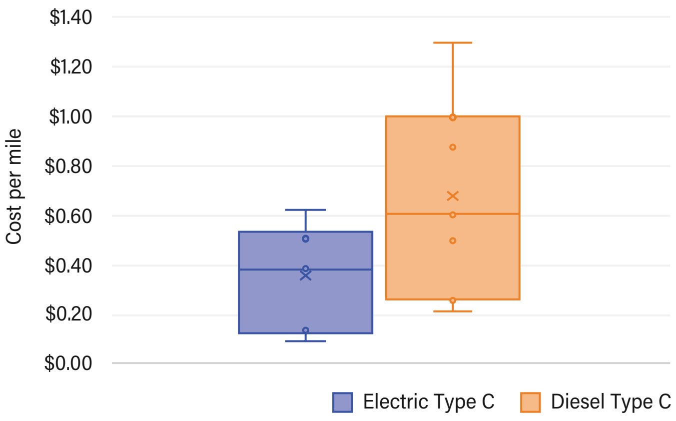
Source: WRI Authors.

Data Source, Collection Method, and Analysis

The data used to calculate the maintenance and repair cost values for diesel and electric school buses were collected from 10 different sources (provided in Appendix B). Four of these sources (Burnham n.d.; Laughlin and Burnham 2014; Newton 2021; and Roush CleanTech. n.d.) drew from real-world observations, but only two specified the number of buses that the fleet being described contained—Roush CleanTech (266) and Newton (53). For the sources that did not specify the vehicle type the data corresponded to, the data were assumed to represent Type C vehicles, given that these are the most common in the market.

Anecdotal evidence from early adopters of ESBs, as well as lessons from the light-duty market, both suggest that the maintenance and repair costs of ESBs are lower than those of their diesel counterparts.[15],[16] However, as depicted in Figure 3, there is significant variation in per mile maintenance and repair cost estimates across sources. Notably, this variation persists across both fuel types. Likely drivers of this variation include differences in climate and road conditions—for example, the highest diesel per mile cost included in the data is from Michigan, known for snowy winters and salty roads, while the lowest diesel per mile cost was observed for a district in coastal Virginia (Burnham n.d.; Laughlin and Burnham 2014).

Figure 3 | **Variation in maintenance and repair data**



Source: WRI Authors.

Another factor that may explain some of this variation is that data sources are rarely clear as to whether labor costs are included in per mile maintenance and repair values. Based on the few cost breakdowns identified for diesel vehicles, labor costs account for two-thirds of total maintenance costs. Because labor costs vary significantly across states and regions, the outsized role that labor costs play in maintenance cost estimates may be driving some of the variation observed across the sources.[17]

The estimated maintenance and repair costs for electric and diesel vehicles increase by vehicle size type, as would be anticipated. Nonetheless, accuracy is uncertain due to poor data quality, as there were no real-world studies among the Type A or Type D values included.

Given this wide range of inconsistent data, the following steps were taken to identify recommended values. First, the values from the only source (PG&E n.d. [b]) that provided costs differentiated by vehicle age were averaged to generate per mile maintenance and repair cost estimates for two periods: years 1–5 and years 5+. In addition to the direct observations for electric vehicles, an observation set at 60 percent of the maintenance and repair costs of the comparable diesel vehicle for each size type was included among the set of values averaged. This was done to reflect the assumption that electric costs are 40 percent–70 percent lower than diesel costs. To arrive at the recommended values for overall per mile maintenance costs, the full set of values for each vehicle type was averaged. This included the following:

- Weighted average of the costs estimated by vehicle age
- Parts-only costs inflated to reflect the 2:1 ratio of labor-to-parts costs
- Addition of an observation set at 60 percent of the maintenance and repair costs of the comparable diesel vehicle for each size type

Of the sources reviewed for maintenance cost information, only Burleigh (2020) explicitly stated that DEF was not included in either vehicle fueling or maintenance cost estimates; the remaining sources were unclear about whether or not DEF was included. Because DEF can result in substantial annual costs, a brief analysis was conducted that analysts can use when fleet-specific information is not available.

Battery Replacement Cost

The lifetime of an ESB battery is largely dependent on the battery's capacity, the charging infrastructure that is used to charge the battery, how the battery is used, and how the bus is driven. Some school districts, for example, might choose to use the ESB's battery to provide vehicle-to-grid (V2G) services, which allows electricity to be stored in the bus batteries and later discharged onto the grid, resulting in a higher number of charge-discharge cycles on the battery. For the purposes of this Technical Note—and in alignment with many vehicle manufacturers' maximum battery warranties—the ESB battery is estimated to require replacement after eight years. Table 9 presents recommended cost for battery replacement in 2030 by size type, provided in 2022 US dollars.

Data Source, Collection Method, and Analysis

The data used to calculate the battery replacement costs for ESBs were collected from multiple sources. Public data provided by ESB original equipment manufacturers (OEMs) were used to calculate average battery capacity for each vehicle class (Huntington et al. 2022). These capacities are assumed to remain the same when the batteries are replaced in the future. Table 10 presents average battery capacity for each electric school bus by size type.

This information was then combined with 2030 cost projections for electric vehicle (EV) battery packs under a variety of scenarios from the California Energy Commission and BloombergNEF (see Appendix B). The average cost across these sources was $97/kWh in 2030. It is worth noting that these

Table 9 | **Recommended battery replacement cost values**

VEHICLE TYPE	TYPE A	TYPE C	TYPE D
Year 8 (2030) battery replacement cost ($2022)	$9,070	$15,162	$14,329

Source: WRI Authors.

Table 10 | **Industry average battery capacities by size type**

VEHICLE TYPE	TYPE A	TYPE C	TYPE D
Average battery capacity (kWh)	119	199	188

Note: kWh = kilowatt-hour.
Source: WRI Authors

estimates do not account for any battery cost reductions that may result from policies and incentives included in the 2022 Inflation Reduction Act. This per kilowatt-hour cost can be used to estimate the nominal battery replacement cost in the future year using the equation below:

$$\text{Cost in 8 years} = \frac{\$97}{kWh} \times \text{Replacement Battery Size (kWh)}$$

Analysts can utilize this methodology, based on the method employed by the California Energy Commission in 2017, and adjust for a specific fleet and purchase based on the warranty details and any anticipated delivery, installation labor, or other replacement costs that are not included in the baseline estimate.

Insurance Costs

To calculate how much a school district will pay on insurance premiums, insurance companies take multiple factors into account, including the primary use of the bus, the age of the vehicle, the make/model of the vehicle, and any information related to a potential vehicle renovation. Insurance costs are complex and, according to discussions with school bus operators, can vary significantly due to factors like deductible structure, market characteristics (character of local juries, repair costs, perceived danger), coverage, caps on payouts, and other considerations.

As such, this Technical Note does not examine insurance costs extensively except to consider how these might differ for otherwise comparable electric versus fossil-fueled school buses. Table 11 presents this comparison.

Based on this analysis, fleets that only take liability insurance should expect no change in their costs from moving to electric. Those that opt for more expansive coverage types should expect some increase to their costs due to the higher replacement value of an electric bus compared to an equivalent diesel. Table 12 presents recommended insurance cost values by size and fuel type.

Data Source, Collection Method, and Analysis

Argonne National Laboratory has undertaken the most comprehensive analysis to date on the question of insurance costs. For the purposes of this Technical Note, Argonne's two-tiered approach to estimating annual insurance premiums, which

Table 11 | **Types of insurance and cost impact of changing to electric**

COVERAGE TYPE	DEFINITION	COST IMPACT OF ELECTRIC VS. DIESEL
Liability	Covers the person, vehicle, or building harmed by the school bus if the vehicle crashes into them (this is required).	No difference—the cost of the damage is based on the value/impact to the other party, which should not differ.
Collision	Pays the vehicle owner for damage to the vehicle when the vehicle is involved in a crash or collision.	Potentially substantial increase—insurance cost is directly proportional to the increased replacement value of the ESB over a diesel.
Comprehensive	Covers costs for situations where the vehicle is stolen, vandalized, or damaged by weather, such as if a tree were to fall on it while in the lot.	Potentially substantial increase—insurance cost is directly proportional to increased replacement value of the ESB over a diesel.

Note: ESB = electric school bus.

Source: WRI Authors.

Table 12 | **Recommended insurance values**

VEHICLE TYPE	TYPE A		TYPE C		TYPE D	
Fuel type	**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**
Liability-only cost to insure ($/year)	$4,786		$6,770		$12,300	
Full coverage cost to insure ($/year)	$14,812	$9,068	$22,548	$12,660	$28,088	$17,575

Note: Full coverage includes liability as well as collision and comprehensive coverage, meaning that fleets select one of the two types and costs should not be added together.

Source: WRI Authors.

hinges on coverage amount, is adopted.[18] Because the Burnham (n.d.) AFLEET tool does not differentiate among school bus size types, this information is supplemented with information on other medium- and heavy-duty classes and from the Burnham et al. (2021) comprehensive TCO publication, as well as from three additional sources (BI HQ n.d.; PG&E n.d. [a]; PG&E n.d. [b]), to produce recommended values.

CHARGING INFRASTRUCTURE PARAMETERS

The tables and sections hereafter include a brief explanation of each charging-related TCO component; present final recommended values; and provide context on the underlying sources, collection method, and analysis conducted to determine recommended values. Electric buses are considered a 1:1 replacement technology for their internal combustion engine predecessors. In contrast, charging infrastructure is an additional capital expense required for ESBs, whereas fueling infrastructure for incumbent petroleum-based fuels is generally already in place, and therefore should be considered a sunk cost. The costs associated with ongoing operation of charging infrastructure are also presented. Comparable operations and maintenance costs of infrastructure for petroleum fuels are deemed beyond the scope of this paper, but when fleets fuel their diesel vehicles at retail pumps, operations and maintenance costs are embedded in the per gallon sale price. Notably, data and analysis in this section are not limited to evidence drawn strictly from the school bus context because charging infrastructure and associated costs are relatively generalizable across fleet contexts.

This section presents charging infrastructure costs as a function of both charger power and project scale to better reflect how these costs vary in real-world applications. Analysts can determine appropriate cost assumptions on a per vehicle basis for 1:1 procurement comparisons using the combination of these parameters that most closely represents their project details, divided by the number of vehicles that are to be supplied by that infrastructure.

Electric Vehicle Supply Equipment Cost

Electric vehicle supply equipment (EVSE), which is sometimes referred to as charger stations, points, stalls, or docks, provide electric power to the vehicle by charging the vehicle's on-board battery. EVSE is hardware that includes electrical conductors, a cable to connect to the vehicle, a port or connector at the end of the cable, communication technology, and other related equipment that delivers energy efficiently and safely to the vehicle. EVSE that is dual-port can plug into and charge two vehicles simultaneously. It is increasingly common for EVSE to have software embedded, referred to as "network-enabled" EVSE.[19] Due to the benefits of managed charging to ensure cost-effective electric consumption, only network-enabled chargers are included here. Most ESBs can be charged by either a high-powered Level 2 Alternating Current (AC) charging station (7 to 19 kW, 240 volts) or a medium-powered Direct Current (DC) fast charging station (24 to 90 kW, 480 volts).[20] Table 13 presents recommended values for EVSE station costs.

Data Source, Collection Method, and Analysis

The data used to calculate the EVSE cost were collected from five studies, analyses, and reports from a variety of publications in both peer-reviewed and industry literature, as well as one expert interview. Five of these sources are quite recent (Bennett et al. 2022; Borlaug et al. 2021; Kresge 2022; Nair et al. 2022; Nelder and Rogers 2019), while the other is more dated (Smith and Castellano 2015); because the EVSE market is rapidly maturing, to the extent feasible, greater emphasis was put on the more recent data points. Five additional sources were reviewed and set aside due to factors such as age of study, lack

Table 13 | **Recommended per EVSE costs for network-enabled EVSEs**

CHARGING LEVEL	L2 - AC	L2 - AC	L2 - AC	DCFC	DCFC	DCFC
Rated power (kW)	7.7	19.2	19.2	50	70	150
Ports	single	single	dual	dual	dual	dual
Cost per EVSE ($/EVSE)	$2,200	$3,814	$4,678	$38,665	$54,300	$84,144

Notes: The dual-port chargers presented here can simultaneously supply two vehicles, but total power will not exceed rated wattage. These costs do not reflect costs of vehicle-to-grid (V2G)-capable EVSE; EVSE = electric vehicle supply equipment; kW = kilowatts; L2 = Level 2; AC = Alternating Current; DCFC = Direct Current Fast Charging.

Source: WRI Authors.

of information on charger specifications, and inclusion of other cost elements like electricity and installation. When appropriate, values were normalized using regional price parity factors.[21]

Customer-Side Construction and Installation Costs

The scale and ambition of an electrification project will shape the ensuing construction and installation costs. Investments and upgrades are often needed on both the utility's side of the electrical meter (referred to as "utility-side") and the customer's side ("customer-side"). Costs are differentiated accordingly because this reflects the prevailing form of the source data; additionally, this accounts for variation across utilities in approaches to assigning these costs. Here, customer-side construction and installation include the cost of materials and labor to plan, trench, lay conduit, fill, install bollards or wheel stops, and permit electrical infrastructure that supplies a charger. These costs are a function of many factors, including site layout, existing electrical infrastructure and panel capacity, and dynamics of the local labor market. Because these are site- or project-level costs, they are aggregated into per station costs based on the cumulative power of the chargers that make up the installation. Generally, these costs decrease on a per charger basis as the number of chargers in the project increases.[22] Table 14 presents recommended values to use for the installation costs associated with projects of various scales.

Data Source, Collection Method, and Analysis

The data used to calculate recommended values for customer-side construction and installation costs were collected from four studies and one expert interview. Four of these sources are quite recent (Bennett et al.; HECO 2022, Nair et al. 2022; SDG&E 2020), while the other is more dated (VTO 2016); because the industry is rapidly maturing, to the extent feasible, greater emphasis was put on the more recent data points. The 2020 study by SDG&E includes data covering 4,975 ports deployed specifically in medium- and heavy-duty fleet contexts, deemed a substantial set of observations for this relatively novel industry. Because some estimates are from high-cost jurisdictions, they have been normalized using regional price parity factors.[23] Three other sources were reviewed and set aside due to factors such as age of study and lack of sufficient detail. The costs are presented in terms of the capacity (kW) of the EVSE that is being installed; this is an imperfect proxy for site-specific costs, due to the site-specific factors noted above, but captures the cost efficiencies of scaling.

Utility-Side Electrical Upgrade Costs

In addition to any customer-side infrastructure that is required, some projects prompt the need for upgrades on the utility's side of the meter. These investments might include an additional separate meter dedicated to the vehicle load, a larger transformer, a new electrical service, or even a new or upgraded feeder circuit or substation. These costs can range by an order of magnitude depending on local site-specific factors. Additionally, in many cases utilities may cover some of or all such costs under existing line extension allowances or make-ready infrastructure programs authorized by their regulators, so project implementers will not need to cover these costs in their project budgets.[24] Due to the high level of variation in these costs, we do not provide estimates but rather recommend for reference the following works included in the References section: Borlaug et al. 2021; Horowitz 2021; Nelder and Rogers 2019; SDG&E 2020.

Electric Vehicle Supply Equipment Maintenance and Networking Costs

Operating costs related to charging infrastructure are included here because this is key information for fleet decision-makers to understand the full budgetary impact of an electrification transition. On the other hand, the costs associated with ongoing operation and maintenance of fueling infrastructure for petroleum fuels, such as hazardous waste disposal fees, environmental permit or review costs, insurance premiums, etc., are deemed beyond the scope of this paper. Still, when fleets fuel their diesel vehicles at retail pumps, operations and maintenance costs are embedded in the per gallon sale price. For this reason, analysts

Table 14 | **Recommended customer-side construction and installation costs**

STATION ENERGY INSTALLED (KW)	7.7	19.2	50	70	150	300	1,000+
Construction and equipment installation cost ($/station)	$3,487	$6,661	$28,009	$29,386	$60,186	$116,183	$363,527

Notes: The unit "station" encompasses the cumulative electric vehicle supply equipment (EVSE) installed at a site or project; kW = kilowatts.

Source: WRI Authors.

should be diligent when conducting TCO comparisons to ensure the components included in the cost buildup for each vehicle type are appropriately comparable.

When using network-enabled EVSE, additional costs are typically required for maintenance and networking. Maintenance costs are often covered under service agreements with EVSE providers and include any maintenance that needs to be performed on the EVSE. Similarly, networking costs are often covered under contracts with EVSE providers and include costs related to data and connectivity that enable full functionality of the network-enabled EVSE. Table 15 presents recommended values to use for the maintenance and networking costs for EVSE of various sizes and types.

Data Source, Collection Method, and Analysis

The data used to calculate EVSE maintenance and networking costs were collected from seven sources, including studies, analyses, and reports in both peer-reviewed and industry literature, as well as information provided in one expert interview. Four of these sources are relatively recent (Kresge 2022; Nelder and Rogers 2019; PG&E n.d. [a]; VEIC 2018), while the others are quite stale (Snyder et al.; NYC Taxi; and Smith and Castellano from 2012, 2013, and 2015, respectively).

For both maintenance and networking costs, available estimates varied based on EVSE type—some were for Level 2 only, some were for DCFC only, and others did not specify EVSE type. Few of these estimates varied maintenance and networking costs for different EVSE power levels (kW). Level 2 costs are based on the average value of estimates that were specific to Level 2 EVSE, as well as estimates that did not specify EVSE type. In cases where network costs were not provided on a per charger basis but rather per site, an assumption of 10 stations per site was used based on guidance from an expert involved in the projects to generate a per charger cost estimate. Similarly, DCFC costs were based on the average value of estimates that were specific to DCFC or did not specify EVSE type. Maintenance costs between lower- and higher-powered DCFC are differentiated, likely because of the increased complexity of liquid-cooled cabling.

Certain values in the sources were reviewed and set aside due to either a lack of sufficient detail or the presence of more reliable estimates elsewhere in the source. In addition, Snyder et al. (2012) did not provide a maintenance cost estimate in dollars, but instead provided an estimate as a percentage of EVSE costs (10 percent). In this instance, the 10 percent estimate was applied to the recommended EVSE costs (see section "Electric Vehicle Supply Equipment Maintenance and Networking Costs" above).

It is also important to note that some maintenance and networking costs may increase with the number of EVSE purchased (i.e., per station costs), while others may remain the same regardless of the number of EVSE purchased (i.e., flat fees). However, the data currently available are not sufficient to differentiate between per station costs and flat fees.

Table 15 | **Recommended per EVSE costs for annual maintenance and networking**

CHARGING LEVEL	LEVEL 2	LEVEL 2	LEVEL 2	DCFC	DCFC	DCFC
Rated power (kW)	7.7	19.2	19.2	50	70	150
Ports	single	single	dual	dual	dual	dual
Maintenance costs ($/EVSE/year)	$536	$536	$536	$1,704	$1,704	$2,237
Networking costs ($/EVSE/year)	$454	$454	$484	$522	$522	$522

Notes: EVSE = electric vehicle supply equipment; DCFC = Direct Current Fast Charging; kW = kilowatts.

Source: WRI Authors.

LIMITATIONS

There are several limitations to the method and sources presented here:

- While the Electric School Bus Initiative intended to include as many eligible sources of information as possible, the methodology described here is insufficient to ensure that this review was comprehensive. The desktop research presented relies on publications, presentations, webinars, interviews, and similar sources of information.
- TCO analysis is generally conducted before the purchase of a new vehicle, which is likely to be the latest model of that vehicle type; however, the operational parameters used in the analysis must draw on observations from existing models that are already on the road—this approach introduces an unavoidable aspect of approximation.
- Further, there is limited published data available for TCO parameters, especially data that have been collected in a standardized way in real-world settings. Data are particularly limited regarding maintenance and repair costs and insurance costs for school buses of all fuel and size types as well as the costs related to charging infrastructure. Some published data do not outline specific components (e.g., parts and/or labor) that were included in values, and, as such, it was difficult to find sources that had consistent information throughout. Relatedly, much of the published data available for ESBs have been created using modeling scenarios or tools, instead of drawing from real-world data. In other cases, information was collected through interviews and surveys with a few select school districts, rather than in a more systematic fashion.

NEXT STEPS

These significant limitations are not surprising due to the small number of ESBs currently in operation. Capacity constraints and privacy concerns are other meaningful barriers that inhibit fleets from collecting and publicizing robust data on both electric and diesel vehicles. To mitigate these challenges in the future, WRI’s Electric School Bus Initiative plans to establish a mechanism to collect data on transactions, vehicle performance, and other TCO elements as part of its broader engagement with school districts. The authors are glad to provide updates on the status of this ongoing effort upon request. Anticipating better-quality data and larger sample sizes in the future, the data sets included in this Technical Note were designed so that they can easily be added to in the future.

APPENDIX A

Mapping of Reference Sources to Vehicle Parameters

Table A-1 maps the reference sources to the parameter(s) for which they were used.

Table A-1 | **Mapping of reference sources to vehicle parameters**

SOURCE	YEAR	NATURE OF OBSERVATIONS	EXPECTED VEHICLE LIFETIME	ANNUAL VEHICLE MILEAGE	MILES PER GALLON (OR EQUIVALENT)	MAINTENANCE AND REPAIR COSTS	COST OF BATTERY REPLACEMENT	INSURANCE COSTS
BI HQ	n.d.	50 state average						X
BloombergNEF	2021	2 companies' targets					X	
BloombergNEF	2020	Industry average					X	
Burleigh	2020	Model (Blue Bird TCO)				X		
Burnham et al.	2021	Model (AFLEET)				X		X
Burnham	n.d.	Model (AFLEET)			X	X		X
CARB	2018	7 2010 or newer diesel buses			X			
CA HVIP	n.d.	Model (HVIP)			X	X		
CEC	2021	Model					X	
CEC	2020	Model				X		
CEC	2018	Model					X	
Dominion Energy	2022	*Not listed*			X			
Duran and Walkowicz	2013	1,718 route shifts, 212 vehicles, 3 states		X				
Dynamic Specialty	2019	*General assumption*	X					
Energetics Incorporated	2021	Up to 3 buses observed			X			
Eudy et al.	2016	12 transit buses over 16 months			X			
Huntington et al.	2022	18 buses (7 Type A, 5 Type C, 4 Type D)					X	
Laughlin and Burnham	2014	Diesel fleet size unclear				X		
Laver et al.	2007	70,000 transit buses	X					
Metropolitan School	2021	Presumption by 1 school district	X					
Lowell	2013	4 buses (3 diesel, 1 hybrid)			X			
NCES	n.d.	50 states + DC		X				
Newton	2021	53 total, 23 route buses				X		
PG&E	n.d. (a)	Model (PG&E TCO)			X	X		X

Table A-1 | **Mapping of reference sources to vehicle parameters (Cont.)**

SOURCE	YEAR	NATURE OF OBSERVATIONS	EXPECTED VEHICLE LIFETIME	ANNUAL VEHICLE MILEAGE	MILES PER GALLON (OR EQUIVALENT)	MAINTENANCE AND REPAIR COSTS	COST OF BATTERY REPLACEMENT	INSURANCE COSTS
PG&E	n.d. (b)	Model (PG&E TCO)			X	X		X
Roush	n.d.	266 bus mixed-fuel fleet				X		
U.S. EPA	2017	Model (MOVES 2014)		X				
U.S. EPA and DOE	n.d. (a)	5 models (selected from Top 10 list)			X			
U.S. EPA and DOE	n.d. (b)	DOT General Fuel Economy Label			X			
Zic	2019	*General assumption*	X					

Notes: MSRP sources and data presented in Appendix B.; n.d. = no date; TCO = Total cost of ownership; DOT = Department of Transportation.

Source: WRI Authors.

Mapping of Reference Sources to Charging Infrastructure Parameters

Table A-2 maps the reference sources to the parameter(s) for which they were used.

Table A-2 | **Mapping of reference sources to charging infrastructure parameters**

SOURCE	YEAR	ELECTRIC VEHICLE SUPPLY EQUIPMENT COST	CUSTOMER-SIDE CONSTRUCTION AND INSTALLATION COST	UTILITY-SIDE ELECTRICAL UPGRADE COSTS	NETWORK SOFTWARE AND MAINTENANCE COST
Bennett et al.	2022	X	X		
Borlaug et al.	2021	X		X	
HECO	2022		X		
Horowitz	2019, updated 2021			X	
Kresge	2022	X	X		X
Nair et al.	2022	X	X		
Nelder and Rogers	2019	X		X	X
NYC Taxi	2013				X
PG&E	n.d. (a)				X
SDG&E	2020		X	X	
Smith and Castellano	2015	X			X
Snyder et al.	2012				X
VEIC	2018				X
VTO	2016		X		

Source: WRI Authors.

APPENDIX B

Manufacturer's Suggested Retail Price Data and Sources

Table B-1 below shows prices used to inform our MSRP assumptions. All prices represent the 2022 purchase year and are disaggregated by fuel type, size type, battery capacity, MSRP per unit, state, and source type. Prices were drawn from these sources as of August 2022, though available prices are likely to change over time. The table is sorted by fuel type, then vehicle type, then MSRP.

Table B-1 | **MSRP values**

SOURCE	FUEL TYPE	SIZE TYPE	BATTERY CAPACITY (KWH)	MSRP PER UNIT $	STATE	SOURCE TYPE
NY OGS	Electric	Type A	88	$236,390	NY	State Contract
KY DOE	Electric	Type A	88	$246,350	KY	State Contract
KY DOE	Electric	Type A	88	$251,425	KY	State Contract
NY OGS	Electric	Type A	127	$300,785	NY	State Contract
NY OGS	Electric	Type A	127	$322,015	NY	State Contract
KY DOE	Electric	Type C	155	$327,600	KY	State Contract
NC DOA	Electric	Type C	155	$335,481	NC	State Contract
KY DOE	Electric	Type C	226	$346,000	KY	State Contract
NY OGS	Electric	Type C	210	$347,870	NY	State Contract
NY OGS	Electric	Type C	210	$347,870	NY	State Contract
KY DOE	Electric	Type C	226	$348,000	KY	State Contract
NY OGS	Electric	Type C	226	$349,633	NY	State Contract
NY OGS	Electric	Type C	210	$353,219	NY	State Contract
NY OGS	Electric	Type C	155	$355,905	NY	State Contract
NC DOA	Electric	Type C	226	$362,853	NC	State Contract
KY DOE	Electric	Type C	210	$364,123	KY	State Contract
NC DOA	Electric	Type C	210	$385,589	NC	State Contract
KY DOE	Electric	Type D	155	$340,445	KY	State Contract
NY OGS	Electric	Type D	155	$373,239	NY	State Contract
Rembulat	Electric	Type D	193.5	$421,693	CA	News
NY OGS	Diesel	Type A	n/a	$56,637	NY	State Contract
NY OGS	Diesel	Type A	n/a	$58,245	NY	State Contract
NY OGS	Diesel	Type A	n/a	$59,280	NY	State Contract
NY OGS	Diesel	Type A	n/a	$59,775	NY	State Contract
NC DOA	Diesel	Type C	n/a	$92,135	NC	State Contract
KY DOE	Diesel	Type C	n/a	$93,495	KY	State Contract
NC DOA	Diesel	Type C	n/a	$96,290	NC	State Contract
KY DOE	Diesel	Type C	n/a	$97,250	KY	State Contract
NC DOA	Diesel	Type C	n/a	$97,470	NC	State Contract
KY DOE	Diesel	Type C	n/a	$97,850	KY	State Contract

Table B-1 | **MSRP values (Cont.)**

SOURCE	FUEL TYPE	SIZE TYPE	BATTERY CAPACITY (KWH)	MSRP PER UNIT $	STATE	SOURCE TYPE
KY DOE	Diesel	Type C	n/a	$98,560	KY	State Contract
KY DOE	Diesel	Type C	n/a	$100,500	KY	State Contract
KY DOE	Diesel	Type C	n/a	$100,975	KY	State Contract
NY OGS	Diesel	Type C	n/a	$106,484	NY	State Contract
NY OGS	Diesel	Type C	n/a	$107,421	NY	State Contract
NY OGS	Diesel	Type C	n/a	$107,947	NY	State Contract
NY OGS	Diesel	Type C	n/a	$108,051	NY	State Contract
NY OGS	Diesel	Type C	n/a	$108,870	NY	State Contract
NY OGS	Diesel	Type C	n/a	$109,618	NY	State Contract
NY OGS	Diesel	Type C	n/a	$110,732	NY	State Contract
NY OGS	Diesel	Type C	n/a	$111,227	NY	State Contract
NY OGS	Diesel	Type C	n/a	$111,646	NY	State Contract
KY DOE	Diesel	Type D	n/a	$115,850	KY	State Contract
NY OGS	Diesel	Type D	n/a	$125,273	NY	State Contract
NY OGS	Diesel	Type D	n/a	$129,603	NY	State Contract
NY OGS	Diesel	Type D	n/a	$139,696	NY	State Contract

Notes: MSRP = manufacturer's suggested retail price; kWh = kilowatt-hour; n/a = not relevant.

Source: WRI Authors.

MPGe Data and Sources

Table B-2 below shows fuel economy values used to inform our MPGe recommendations. Values are provided in original units of source materials.

Table B-3 below shows city-to-highway ratio values used to inform our MPGe recommendations. Values are provided in original units of source materials.

Table B-2 | **Overall fuel economy**

SOURCE	NATURE OF OBSERVATIONS	TYPE A		TYPE C		TYPE D	
Fuel type		**Electric**	**Diesel**	**Electric**	**Diesel**	**Electric**	**Diesel**
Burnham	n/a (model assumption)	n/a	n/a	24 mpge	8.2 mpg	24 mpge	8.2 mpg
CA HVIP	n/a (model assumption)	1 kWh/mi	15 mpg	1.4 kWh/mi	9	1.4 kWh/mi	7
Dominion Energy	n/a (model assumption)	n/a	n/a	17 mpge	6 mpg	n/a	n/a
Energetics Incorporated	2 buses best observed vs. industry diesel	n/a	n/a	2.54 kWh/mi	7.4 mpg	n/a	n/a
Energetics Incorporated	1–3 buses observed vs. fleet diesel	n/a	n/a	2.96 kWh/mi	5 mpg	n/a	n/a
Eudy et al.	12 transit buses over 16 months	n/a	n/a	n/a	n/a	2.15 kWh/mi	n/a
PG&E n.d. (a)	n/a (model assumption)	n/a	n/a	0.58 kWh/mi	5.5 mpg	n/a	n/a
PG&E n.d. (b)	n/a (model assumption)	0.96 mi/kWh	6 mpg	0.68 mi/kWh	5 mpg	0.74 mi/kWh	4 mpg

Notes: n/a = not relevant; kWH/mi = kilowatt-hour/mile; mpg = miles per gallon; mpge = miles per gallon (or equivalent).

Source: WRI Authors.

Table B-3 | City-to-highway ratios

SOURCE	NATURE OF OBSERVATIONS	SIZE TYPE	FUEL TYPE	MPGE
CARB	1 - test track	Type D	Diesel	4.27/9.27
CARB	1 - test track	Type D	Diesel	4.67/9.03
CARB	1 - chassis dynamometer	Type D	Diesel	3.81/6.89
CARB	1 - chassis dynamometer	Type D	Diesel	4.31/8.05
Lowell	10 months in-service	Type C	Diesel	5.6/9.6
Lowell	10 months in-service	Type C	Hybrid Electric	7/11
Lowell	Controlled testing	Type C	Diesel	5.8/7.2
Lowell	Controlled testing	Type C	Hybrid Electric	7.1/7.5
U.S. EPA and DOE n.d. (a)	EPA testing	LDV: Chevrolet	Electric	131/109
U.S. EPA and DOE n.d. (a)	EPA testing	LDV: Kia	Electric	134/101
U.S. EPA and DOE n.d. (a)	EPA testing	LDV: Hyundai	Electric	132/108
U.S. EPA and DOE n.d. (a)	EPA testing	LDV: Tesla (multiple models)	Electric	138/126; 134/126; 129/116; 127/117; 124/115; 118/107
U.S. EPA and DOE n.d. (a)	EPA testing	LDV: Lucid Motors	Electric	130/132
U.S. EPA and DOE n.d. (b)	EPA city/highway average weighting	n/a	n/a	55%/45%

Notes: MPGe = miles per gallon (or equivalent); EPA = Environmental Protection Agency; LDV = light-duty vehicle; n/a = not relevant.

Source: WRI Authors.

Maintenance and Repair Data and Sources

Table B-4 below shows maintenance and repair values used to inform our recommendations. Values are provided in original units of source materials.

Table B-4 | **Maintenance and repair cost values**

SOURCE	NATURE OF OBSERVATIONS	ELECTRIC	DIESEL	ELECTRIC	DIESEL	ELECTRIC	DIESEL
Fuel type		**Type A**		**Type C**		**Type D**	
Burleigh	OEM pitch deck (model assumption)	n/a	n/a	$0.09/mi	$0.21/mi	n/a	n/a
Burnham	n/a (Volpe DOT model)	n/a	n/a	n/a	$1.00/mi	n/a	n/a
Burnham	Gloucester County, VA School District—no details on observations	n/a	n/a	n/a	$0.50/mi	n/a	n/a
Burnham	Michigan School Bus Officials Template (model assumption)	n/a	n/a	n/a	$1.30/mi	n/a	n/a
Burnham et al.	n/a (model assumption)	40% lower than diesel		40% lower than diesel		40% lower than diesel	
CA HVIP	n/a (model assumption from HDM-III model)	$0.12/mi	$0.23/mi	$0.14/mi	$0.26/mi	$0.16/mi	$0.31/mi
CEC 2020	n/a (model assumption) in 2018 dollars	n/a	n/a	$0.62/mi	$0.88/mi	n/a	n/a
Laughlin and Burnham	Observed in 2010 dollars, diesel fleet size unclear, Alvin ISD	n/a	n/a	n/a	$0.48/mi	n/a	n/a
Laughlin and Burnham	Observed in 2010 dollars, diesel fleet size unclear, Gloucester County Schools	n/a	n/a	n/a	$0.15/mi	n/a	n/a
Newton	Observed, 53 buses represented	n/a	n/a	70% lower than diesel		n/a	n/a
PG&E n.d. (a)	n/a (model assumption)	n/a	n/a	$0.09/mi	$0.21/mi	n/a	n/a
PG&E n.d. (b)	n/a (model assumption), years 1–5 for 7,500 annual miles	$2,215.20 $1,329.10 $1,439.90	$2,848.80	$2,325.80 $1,772.30 $1,772.30	$2,967.50	$2,436.70 $1,772.30 $1,772.30	$3,086.20
PG&E n.d. (b)	n/a (model assumption), years 5+ for 7,500 annual miles	$4,289.60 $2,573.70 $2,788.20	$5,133.50	$4,504.10 $3,431.60 $3,431.60	$5,347.40	$4,718.60 $3,431.60 $3,431.60	$5,561.20
Roush	Observed, 266 school buses in Colorado	n/a	n/a	n/a	$0.67/mi	n/a	n/a

Notes: OEM = original equipment manufacturer; n/a = not relevant; DOT = Department of Transportation; HDM = Highway Design and Maintenance; ISD = Independent School District; mi = miles.

Source: WRI Authors.

2030 Battery Cost Data and Sources

Table B-5 below shows battery cost values used to inform our recommendations. Values are provided in original units of source materials.

Table B-5 | **Battery cost values**

SOURCE	$/KWH IN 2030
CEC 2018 IRP low	120
CEC 2018 IRP Mid	100
CEC 2018 IRP High	89
CEC 2018 IRP Aggre.	73
CEC 2021 IRP low - MHDV	125.16
CEC 2021 IRP Mid - MHDV	111.59
CEC 2021 IRP High - MHDV	112.22
BloombergNEF 2021	80
BloombergNEF 2020	58
Average across	96.55

Notes: $/kWh = dollars per kilowatt-hour; IRP = Integrated Resource Plan; MHDV = medium- and heavy-duty vehicle.

Source: WRI Authors.

ENDNOTES

1. Total cost of ownership of a vehicle includes not only the purchase and finance price of the vehicle itself, but maintenance costs, fuel costs, insurance, and the depreciation that happens over the entire life of the vehicle.
2. One example is Atlas Public Policy's Fleet Procurement Analysis Tool, which can be found at https://atlaspolicy.com/fleet-procurement-analysis-tool/.
3. http://www.atlasevhub.com/materials/medium-and-heavy-duty-vehicle-registrations-dashboard/.
4. https://www.fueleconomy.gov/feg/di_diesels.shtml.
5. https://www.wri.org/insights/where-electric-school-buses-us.
6. https://www.nature.com/articles/s41598-022-14715-8.
7. https://www.nrel.gov/docs/fy22osti/82081.pdf.
8. https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/.
9. https://ww2.arb.ca.gov/sites/default/files/2020-11/appd_hd_invest_strat.pdf#page=84.
10. https://cleantechnica.com/2021/12/28/calstart-study-on-commercial-vehicle-battery-cost-assessment/.
11. https://www.eia.gov/energyexplained/units-and-calculators/energy-conversion-calculators.php.
12. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2018/lcfs18/apph.pdf.
13. https://blogs.edf.org/climate411/files/2022/02/EDF-MDHD-Electrification-v1.6_20220209.pdf.
14. https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-emergency-vehicle-rule-selective-catalytic.
15. https://stnonline.com/multimedia/stn-podcast-e92-conversations-at-stn-expo-reno-twin-rivers-usds-electric-school-bus-journey/.
16. https://publications.anl.gov/anlpubs/2021/05/167399.pdf.
17. https://www.bls.gov/opub/mlr/cwc/bls-introduces-new-employer-costs-for-employee-compensation-data-for-private-industry-workers-in-15-metropolitan-areas.pdf.
18. https://www.osti.gov/biblio/1780970.
19. https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf.
20. https://www.wri.org/research/electric-school-bus-us-market-study-and-buyers-guide-resource-school-bus-operators.
21. https://www.bea.gov/data/prices-inflation/regional-price-parities-state-and-metro-area.
22. https://www.epa.gov/system/files/documents/2022-06/elec-clean-schl-bus-infrastructure-webinar-2022-06-22.pdf.
23. https://www.bea.gov/data/prices-inflation/regional-price-parities-state-and-metro-area.
24. https://www.raponline.org/wp-content/uploads/2020/01/rap-lazar-chernick-marcus-lebel-electric-cost-allocation-new-era-2020-january.pdf.

REFERENCES

Bennett, Jesse, Abby Brown, John Gonzales, and Lauren Lynch. 2022. “EPA’s Clean School Bus Program Webinar: Alternative Fueling Infrastructure.” Presented June 22. https://www.epa.gov/system/files/documents/2022-06/elec-clean-schl-bus-infrastructure-webinar-2022-06-22.pdf.

BI HQ (Bus Insurance HQ). n.d. “Bus Insurance Cost.” Accessed June 2022. https://www.businsurancehq.com/bus-insurance-cost/.

BloombergNEF. 2020. “Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh.” https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/.

BloombergNEF. 2021. “Battery Pack Prices Fall to an Average of $132/kWh, but Rising Commodity Prices Start to Bite.” https://about.bnef.com/blog/battery-pack-prices-fall-to-an-average-of-132-kwh-but-rising-commodity-prices-start-to-bite/#:~:text=For%20battery%20electric%20vehicle%20(BEV,of%20the%20total%20pack%20price.

Borlaug, Brennan, Matteo Muratori, Madeline Gilleran, David Woody, William Muston, Thomas Canada, Andrew Ingram, et al. 2021. “Heavy-Duty Truck Electrification and the Impacts of Depot Charging on Electricity Distribution Systems.” *Nature Energy*, June. https://www.nature.com/articles/s41560-021-00855-0.

Burleigh, Albert. 2020. “Blue Bird Electric School Buses.” Macon, GA: Blue Bird Corporation. https://assets.ctfassets.net/ucu418cgcnau/362sQcGinJzFxVqFh0DBCr/cb2ee507e5c8f646ee133bfdabbccbfb/02_Blue_Bird_Electric_Bus_Presentation_Truck_and_Bus_NOTES_V2.pdf.

Burnham, Andrew. n.d. “AFLEET Tool 2020.” Argonne National Laboratory. Accessed January 2022. https://greet.es.anl.gov/afleet_tool.

Burnham, Andrew, David Gohlke, Luke Rush, Thomas Stephens, Yan Zhou, Mark A. Delucchi, Alicia Birky, et al. 2021. “Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains.” Lemont, IL: Energy Systems Division, Argonne National Laboratory. https://doi.org/10.2172/1780970.

CA HVIP (California’s Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project). n.d. “HVIP TCO Estimator V1.0.” Accessed January 2022. https://californiahvip.org/tco/.

CARB (California Air Resources Board). 2018. “Appendix H: Analyses Supporting the Addition or Revision of Energy Economy Ratio Values for the Proposed LCFS Amendments.” https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2018/lcfs18/apph.pdf.

CEC (California Energy Commission). 2018. “Final 2017 Integrated Energy Policy Report.” Docket Number: 17-IEPR-01. Sacramento, CA. https://efiling.energy.ca.gov/getdocument.aspx?tn=223205 (link to download PDF).

CEC. 2020. “GFO-17-607 Cost Effectiveness Model Battery Electric School Buses.” April. Sacramento, CA. https://www.energy.ca.gov/sites/default/files/2020-04/Cost-Effectiveness_ada.pdf.

CEC. 2021. “ADOPTED Final 2021 Integrated Energy Policy Report Volume IV California Energy Demand Forecast.” Docket Number: 21-IEPR-01. Sacramento, CA. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2021-integrated-energy-policy-report (link to download PDF: https://efiling.energy.ca.gov/GetDocument.aspx?tn=241581).

Dominion Energy. 2022. “Electric School Buses.” Accessed February 2022. https://www.dominionenergy.com/virginia/save-energy/electric-school-buses.

Duran, Adam, and Kevin Walkowicz. 2013. “A Statistical Characterization of School Bus Drive Cycles Collected via Onboard Logging Systems.” Golden, CO: National Renewable Energy Laboratory (NREL). https://www.nrel.gov/docs/fy14osti/60068.pdf.

Dynamic Specialty. 2019. “What’s the Life Expectancy of a School Bus?” https://dynamicspecialty.com/whats-the-life-expectancy-of-a-school-bus/.

Energetics Incorporated. 2021. “Final Evaluation Report: California Investor-Owned Utility Transportation Electrification Priority Review Projects.” https://cadmusgroup.com/wp-content/uploads/2021/06/CA-TE-Priority-Review-Project-Evaluation-Report-Public-Version.pdf.

Eudy, Leslie, Robert Prohaska, Kenneth Kelly, and Matthew Post. 2016. “Foothill Transit Battery Electric Bus Demonstration Results.” Golden, CO: National Renewable Energy Laboratory (NREL). https://www.nrel.gov/docs/fy16osti/65274.pdf.

HECO (Hawaiian Electric Company, Inc.). 2022. “Annual Report on the Progress and Status of the Commercial Public Electric Vehicle Charging Service Pilot Rates.” Docket No. 2018-0135 and Transmittal No. 13-07. https://www.hawaiianelectric.com/documents/products_and_services/electric_vehicles/ev_maui_tariff_2021.pdf.

Horowitz, Kelsey. Updated 2021. “2019 Distribution System Upgrade Unit Cost Database Current Version.” Golden, CO: National Renewable Energy Laboratory (NREL). DOI: 10.7799/1491263. https://data.nrel.gov/submissions/101.

Huntington, Alissa, Jessica Wang, Phillip Burgoyne-Allen, Emmett Werthmann, and Eleanor Jackson. 2022. "Electric School Bus U.S. Market Study and Buyer's Guide: A Resource for School Bus Operators Pursuing Fleet Electrification." Washington, DC: World Resources Institute (WRI). https://files.wri.org/d8/s3fs-public/2022-06/esb-us-market-buyers-guide.pdf?VersionId=9PSSAGGV7siZqfLRTEY91kI5UIChtNcZ.

Kresge, Greggory. 2022. Personal correspondence with Authors, World Resources Institute (WRI), Washington, DC, October 26.

KY DOE (Kentucky Department of Education). n.d. "2022 Kentucky School Bus Purchasing Guide." Accessed August 2022. https://education.ky.gov/districts/trans/Documents/2022%20Purchasing%20Guide%20-%20Complete_rt-returned%20form%20editing-CM.pdf.

Laughlin, Michael, and Andrew Burnham. 2014. "Case Study—Propane School Bus Fleets." Energetics and Argonne National Laboratory for U.S. Department of Energy's Clean Cities Program. ANL Contract No. 2F-32321. https://afdc.energy.gov/files/u/publication/case-study-propane-school-bus-fleets.pdf.

Laver, Richard, Donald Schneck, Douglas Skorupski, Stephen Brady, and Laura Cham (Booz Allen Hamilton). 2007. "Useful Life of Transit Buses and Vans." Report No. FTA VA-26-7229-07.1. Washington, DC: Federal Transit Administration. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/Useful_Life_of_Buses_Final_Report_4-26-07_rv1.pdf.

Lowell, Dana (M. J. Bradley). 2013. "Final Report: NYPA Hybrid Electric School Bus Evaluation Project Phase 2." White Plains: New York Power Authority. https://mjbradley.com/sites/default/files/NYPA%20Hybrid%20School%20Bus%20Phase%202%20FINAL%20REPORT%2011nov13.pdf.

Metropolitan School (Metropolitan School District of Mt. Vernon, Indiana). 2021. "School Bus Replacement Plan for the Years 2022–2033." Department of Local Government Finance. https://www.mvschool.org/msdmv/our-district/budgets/833-2023-2034-bus-replacement-plan/file.

Nair, Vishnu, Sawyer Stone, Gary Rogers, and Sajit Pillai. 2022. "Technical Review of: Medium and Heavy-Duty Electrification Costs for MY 2027–2030." Roush Industries, Inc., and Environmental Defense Fund. https://blogs.edf.org/climate411/files/2022/02/EDF-MDHD-Electrification-v1.6_20220209.pdf.

NC DOA (North Carolina Department of Administration). n.d. "071C - Type C (Conventional) School and Activity Buses." Accessed August 2022. https://ncadmin.nc.gov/071c.

NCES (National Center for Education Statistics). n.d. "Table 1.1. Minimum Number of Instructional Days and Hours in the School Year, Minimum Number of Hours per School Day, and School Start/Finish Dates, by State: 2020." Washington, DC: Institute of Education Sciences. Accessed August 2, 2022. https://nces.ed.gov/programs/statereform/tab1_1-2020.asp.

Nelder, Chris, and Emily Rogers. 2019. "Reducing EV Charging Infrastructure Costs." Basalt, CO: Rocky Mountain Institute (RMI). https://rmi.org/ev-charging-costshttps://rmi.org/ev-charging-costs.

Newton, Claudia. 2021. "(STN Podcast E92) Conversations at STN EXPO Reno: Twin Rivers USD's Electric School Bus Journey." *School Transportation News*. Interview: STN Editor-in-Chief Ryan Gray with Tim Shannon, 10:10. https://stnonline.com/multimedia/stn-podcast-e92-conversations-at-stn-expo-reno-twin-rivers-usds-electric-school-bus-journey/.

NY OGS (New York State Office of General Services). n.d. "40524-2300 School Buses: Award Summary." Accessed August 2022. https://online.ogs.ny.gov/purchase/spg/pdfdocs/4052423000Summary.pdf.

NYC Taxi (NYC Taxi and Limousine Commission). 2013. "Take Charge: A Roadmap to Electric New York City Taxis." https://www1.nyc.gov/assets/tlc/downloads/pdf/electric_taxi_task_force_report_20131231.pdf.

PG&E (Pacific Gas and Electric Company). n.d. (a). "Calculating Total Cost of Ownership (TCO) for your Public School EV Fleet." https://www.pge.com/pge_global/common/pdfs/solar-and-vehicles/your-options/clean-vehicles/charging-stations/ev-fleet-program/public-school-total-cost-of-ownership.pdf.

PG&E. n.d. (b). "Total Cost of Ownership Calculator." Accessed February 2022. https://fleets.pge.com/tco/.

Rembulat, Vince. 2022. "Ripon Unified Buying Four New Electric School Buses." *Manteca/Ripon Bulletin*. https://www.mantecabulletin.com/news/local-news/ripon-unified-buying-four-new-electric-school-buses/.

Roush CleanTech. n.d. "Propane School Buses Reduce Transportation Department Maintenance Costs." Accessed July 2022. https://www.roushcleantech.com/portfolio/propane/.

SDG&E (San Diego Gas and Electric Company). 2020. "Joint IOU Electric Vehicle Charging Infrastructure Cost Report Filed on April 1, 2020." Proceeding Number: R.18-12-006. https://www.sdge.com/sites/default/files/regulatory/IOU%20EV%20Infrastructure%20Cost%20Data%20report.pdf.

Smith, Margaret, and Jonathan Castellano. 2015. “Costs Associated with Non-residential Electric Vehicle Supply Equipment.” Washington, DC: New West Technologies, LLC for United States Department of Energy Vehicle Technologies Office. https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf.

Snyder, Jason, Daniel Chang, Daniel Erstad, Ellen Lin, Alicia Falken Rice, Chia Tzun Goh, and An-An (Angel) Tsao. 2012. “Financial Viability of Non-residential Electric Vehicle Charging Stations.” Los Angeles: UCLA Anderson School of Management. https://luskin.ucla.edu/sites/default/files/Non-Residential%20Charging%20Stations.pdf.

U.S. EPA (United States Environmental Protection Agency). 2017. “Diesel Emissions Quantifier Default Values.” https://cfpub.epa.gov/quantifier/assets/docs/diesel_emission_quantifer_deq_default_values.pdf.

U.S. EPA and DOE (United States Environmental Protection Agency and Department of Energy). n.d. (a). “Fueleconomy.gov Top Ten.” Accessed May 2022. https://www.fueleconomy.gov/feg/topten.jsp?year=2022&action=All.

U.S. EPA and DOE. n.d. (b). “Gasoline Vehicles: Learn More about the Label.” Accessed May 2022. https://www.fueleconomy.gov/feg/label/learn-more-gasoline-label.shtml.

VEIC (Vermont Energy Investment Corporation). 2018. “Electric School Bus Pilot Project Evaluation.” Cambridge: Massachusetts Department of Energy Resources. https://www.mass.gov/files/documents/2018/04/30/Mass%20DOER%20EV%20school%20bus%20pilot%20final%20report_.pdf.

VTO (Vehicle Technologies Office). 2016. “Fact #910: February 1, 2016 Study Shows Average Cost of Electric Vehicle Charger Installations.” Washington, DC: Office of Energy Efficiency and Renewable Energy, United States Department of Energy. https://www.energy.gov/eere/vehicles/fact-910-february-1-2016-study-shows-average-cost-electric-vehicle-charger.

Zic, Ryan. 2019. “Fuel Fact Check: Do Propane School Buses Actually Have a Shorter Lifespan?” *Next-Gen Transportation News*, August 7. https://ngtnews.com/fuel-fact-check-do-propane-school-buses-actually-have-a-shorter-lifespan-2.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals for their thoughtful contributions, insightful comments, and critical reviews, without which this publication would not have been possible: Brittany Barrett, Tim Farquer, Matt Berlin, Andrew Burnham, and Caley Johnson.

ABOUT THE AUTHORS

Michelle Levinson is a Manager with the Electric School Bus Initiative and the US Energy Program at WRI. In this role, she conducts research and serves as a technical expert on financial solutions and energy policy to further electric mobility.
Contact: michelle.levinson@wri.org.

Phillip Burgoyne-Allen is an Associate with the Electric School Bus Initiative in the Ross Center for Sustainable Cities. He works with school districts to help them adopt electric buses and provide transportation that is better for students, communities, and the environment.
Contact: phillip.burgoyne-allen@wri.org.

Alissa Huntington is a Research Analyst for the Electric School Bus Initiative. Through this work, she is partnering with school districts on supporting demand for bus electrification and alleviating barriers to facilitate the transition.

Norma Hutchinson formerly worked as a Research Analyst within the global Energy Program at WRI. In this role, she supported research and analysis on deep decarbonization, innovative utility regulatory policy, and transportation electrification both within the United States and internationally.

ABOUT WRI'S ELECTRIC SCHOOL BUS INITIATIVE

In collaboration with partners and communities, the Electric School Bus Initiative aims to build unstoppable momentum toward an equitable transition of the US school bus fleet to electric by 2030, bringing health, climate, and economic benefits to children and families across the country and normalizing electric mobility for an entire generation. We are working with key stakeholders at all levels and across areas, including school districts, private fleet operators, electric utilities, public and private lenders, manufacturing organizations, policymakers, program administrators, and community members and groups.

Electric
School Bus
INITIATIVE

ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.