Docket No. E-2, Sub 1197
Docket No. E-7, Sub 1195
Initial Comments of EDF
Appendix A - Cadmus Lake City Report

Financial Analysis for Electrification of Lake City's Transit Bus Fleet

March 2018

Prepared for:
Environmental Defense Fund
By Kelly Blynn, Cadmus Group

Table of Contents

Tables

Figures

Executive Summary

Lake City's Transit Authority provides regional bus service with a fleet of over 85 diesel transit buses. Lake City plans to buy 56 new buses between 2020 and 2023, enough to replace the majority of the existing fleet with buses that would operate through at least 2032. As Lake City and its partners consider changing fuel for the new fleet, the forecast total cost of ownership for different fuel types is an important metric for decision-making. Cadmus has undertaken that analysis using data and assumptions selected in consultation with key decision-makers to reflect the current outlook and conditions in Lake City's service area.

One key assumption is that the availability of government grants is highly uncertain. In 2017, Lake City applied jointly with other transit agencies in the region for a $3.3 million Low or No Emission (Low/No) grant from the Federal Transit Administration to purchase electric buses. The Low/No grant program is highly competitive because it is oversubscribed, with nearly 90% of grant funds requested being declined in the prior two years. When their joint grant application was declined in 2017, the agencies expressed confidence in a press release that electric buses would work well for their fleets and that they would "continue to look for additional funding and finance opportunities together to make the technology fiscally possible."

Lake City then engaged a local university to undertake a fleet assessment to inform the development of a technology and financing strategy for fleet transition. Lake City also forged a partnership with Environmental Defense Fund (EDF) to explore financing options that could leverage limited public funds for more benefit, a strategy that would increase the impact of limited grant funds and improve the chances for winning grant funds in the future. EDF engaged Clean Energy Works and Cadmus to complete this financial analysis in time for the 2018 Low/No grant cycle.

This analysis is intended to help understand the costs and benefits of transitioning Lake City's bus fleet, and to explore potential financing strategies to accelerate fleet electrification with less dependence on grant funds. This memo describes analysis that:

- **Compares the projected total cost of ownership over time** for new buses of different fuel types, accounting for anticipated reductions in battery costs and ongoing increases in costs for conventional buses. This analysis also models changes in operating costs from maintenance and fuel over time to inform the subsequent financing analysis.

- **Analyzes the use of an innovative utility financing solution** for the upfront cost premium of the on-board battery and charging station for an all-electric bus that connects it to the grid. This analysis shows results for the transit agency with the benefit of cooperation from a utility that offers tariffed on-bill financing on terms similar to Pay As You Save® (PAYS®) programs for financing building energy upgrades in other parts of the state.

Key findings from this analysis include:

- The total cost of ownership (TCO) analysis shows that battery electric transit buses (BEBs) are competitive with compressed natural gas (CNG) transit buses and diesel transit buses over the anticipated lifetime of the bus.

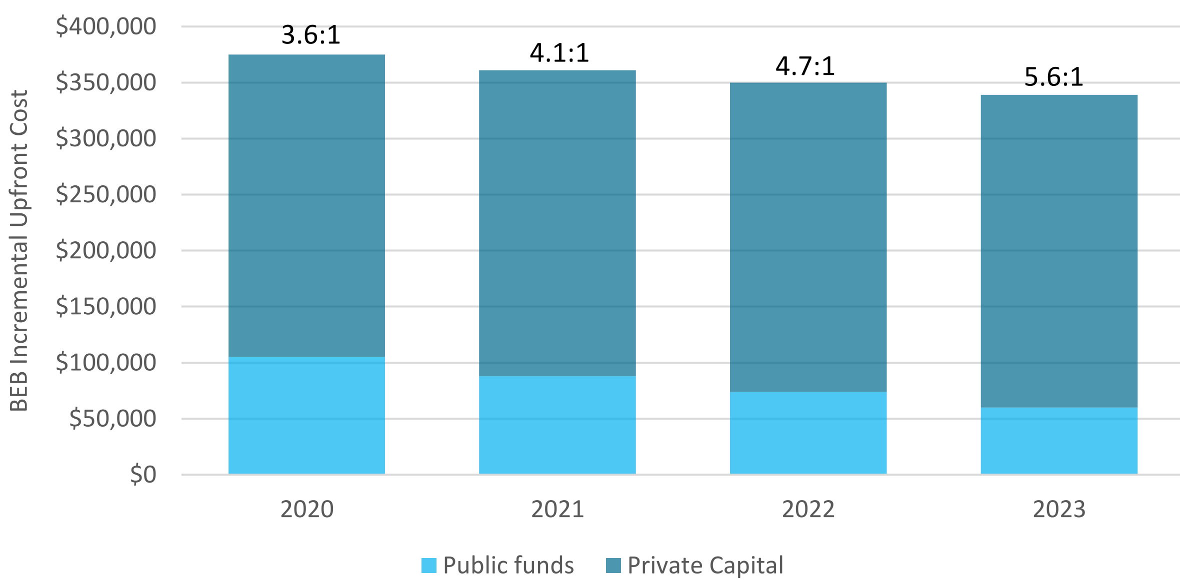
- Utility on-bill investment would triple the number of buses that could be procured in 2020 with a given amount of grant funding from any source. In 2020, a grant of $375,000 could help Lake City afford the incremental cost of one battery-electric bus with the range sought for its fleet, or the same amount of grant money could instead cover the copayments for three electric buses if the utility offers a tariffed on-bill program.

- The multiplier effect resulting from the leverage of public funds increases in subsequent years. By 2023, it's anticipated that the amount of grant funds required to cover the incremental cost of a single electric bus would be could instead cover the copayments for five electric buses.

- If Lake City's utility offered a tariffed on-bill program for on-board batteries and charging stations, a total of $4.7 million to fund copayments would allow Lake City to transform its planned procurement of 56 buses from diesel to all-electric.

- Using VW Settlement or other grants to cover copayments in a tariffed on-bill program over the next five years would leverage more than four times more capital than grant funds alone.

ES 1. Based on the conditions in Lake City, utility on-bill investment in on-board batteries and charging stations for clean transit more than triples the impact of grant funds, and that multiplier effect increases within five years to a ratio of more than 5 to 1.



1 Total Cost of Ownership Analysis

The total cost of ownership (TCO) for transit buses is a financial metric that considers costs over the economic life of the bus, including upfront capital costs as well as operation, maintenance, and fuel costs. Transit bus lifecycle cost models have previously been developed by federal research agencies such as the Transit Cooperative Research Program and by agencies with expertise in electric buses such as the California Air Resources Board through its Innovative Clean Transit initiative. Cadmus has developed a model that estimates the total cost of ownership for electric buses procured over multiple years, informed by these prior models and available data.

The analysis compares **(1) 40’ depot-charge battery electric buses (BEBs)**, **(2) compressed natural gas (CNG) transit buses,** and **(3) diesel transit buses**. BEBs are currently available in two generalized models: an **on-route charge BEB**, or a short-range bus with a smaller on-board battery that requires on-route charging, and a **depot charge BEB**, or an extended range bus with a larger on-board battery that is designed to charge more slowly, typically overnight at a bus depot. Figure 1 summarizes these two general types of BEBs and depicts the types of charging infrastructure. This analysis considers depot charge BEBs given Lake City’s interest in that technology.

Depot charge BEB

In-depot, typically lower capacity (e.g. 50-120kW) charger

Slower charging

Typically charged overnight

Larger on-board battery

On-route charge BEB

Overhead, high capacity (e.g. 300-450kW) charger (can also use wireless charging)

Faster charging

Typically charge during the day

Smaller battery

Figure 1: General Types of Electric Buses and Charging Infrastructure

Section 3 documents the methodology and sources of all inputs to this analysis, many of which are based on a fleet assessment conducted for Lake City. The inputs rely on the best available data about electric bus costs and performance. The results should be read as indicative of relative costs of electric, CNG, and diesel buses, rather than as precise estimates. The actual resulting figures will evolve as Lake City’s vision for electric bus implementation progresses, such as the agency’s choice of charging equipment and management strategy. On a broader industry level, the electric bus market and technology is dynamic, and costs and performance are changing quickly. At a local level, particularities of Lake City’s routes, weather, and other operating context may affect performance and cost estimates, and decisions by the transit agency as the fleet transition advances may also impact the cost assumptions modeled here.

1.1 Total Cost of Ownership in 2019

For procurements in 2019, diesel buses are anticipated to have a slightly lower total cost of ownership over their 12-year anticipated lifetime than electric buses, and then starting in 2020, procurements of battery electric buses are anticipated to have a lower total cost of ownership than both diesel and CNG buses. Any amount of grant funding from federal or state sources for zero emission buses (e.g. Low/No Emission grant or VW Settlement funds) would reduce the total cost of ownership for battery electric buses. The potential for accessing those government resources reinforces the finding that in 2019 the electric bus option would have the lowest estimated total cost of ownership (TCO). The costs in Figure 2 are in net present value terms with a discount rate of 3.5%.

Figure 2: Total Cost of Ownership by Cost Category and Bus Fuel Type in 2019 (Discounted)

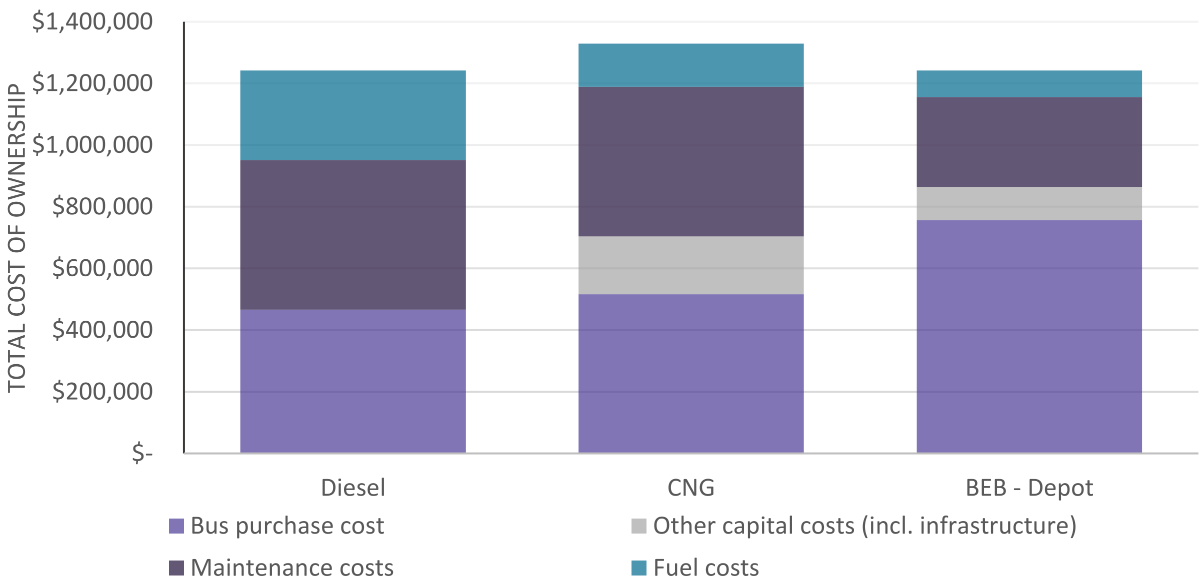


Figure 2 and Table 1 provide a high-level cost comparison for a single bus procured in 2019 for each type of bus technology by cost category. The comparison includes first year capital costs, such as bus purchase costs, charging infrastructure, and a 12-year battery warranty, as well as average annual costs over 12 years, such as fuel and maintenance costs. Compared to diesel transit buses, BEBs are expected to (1) require a greater upfront investment and (2) generate annual savings on maintenance and fuel.

Table 1 highlights a simple comparison for a single bus procured in 2019 for each technology by cost type, including first year capital costs and average annual costs over 12 years. The sources for these costs and underlying assumptions were affirmed by Lake City and are listed in Section 3.

Table 1: Cost Comparison Summary for a Single Bus Procured in 2019

	Diesel	CNG	BEB - Depot
First year costs	**$466,000**	**$703,500**	**$865,000**
Bus purchase cost	$466,000	$516,000	$757,000
Fueling infrastructure and other capital costs	$0	$187,500	$108,000
Average annual costs over life of the bus	**$80,400**	**$64,800**	**$39,100**
Fuel	$30,100	$14,500	$8,900
Maintenance	$50,300	$50,300	$30,200

This analysis considers the cost for a 40' electric bus with a 440-kWh battery that provides an estimated range of 163 miles per charge based on the fleet assessment. For Lake City, electricity costs for battery electric buses under Lake City's utility's Small General Service Time-of-Use tariff would be less than one third of diesel costs, while battery electric buses would see more modest fuel savings relative to CNG buses. It is estimated that Lake City would be able to remain on the lower cost Small General Service Time-of-Use tariff until a substantial share of its fleet is electrified, particularly if the agency utilizes strategic charging management to mitigate peak demands.

Electric buses have lower maintenance costs compared with conventional buses due to having a simpler drive train, fewer parts to maintain, and less brake wear due to regenerative breaking. Empirical studies from the National Renewable Energy Laboratory (NREL) of Foothill Transit's fleet of early model battery electric buses found a 21% cost per mile maintenance savings compared with CNG, while a more recent 2017 NREL study of King County's fleet found a 59% per mile maintenance cost savings compared with diesel buses of the same age[1]. While battery electric buses have significant infrastructure costs, they are estimated by the fleet assessment to be less than the fueling and facility upgrade costs for CNG buses.

1.2 Change in Total Cost of Ownership Over Time

The cost advantage of battery electric buses is expected to increase over the next decade due to trends in both the bus purchase cost as well as fuel cost. The cost of BEBs is anticipated to decline for future procurements, while conventional bus prices are anticipated to rise. The California Air Resources Board's Innovative Clean Transit Initiative has undertaken extensive total cost of ownership modeling for electric buses and other technologies, and has published forecasts of future bus prices by technology, which anticipates the cost of batteries for heavy duty vehicles will fall from $720/kWh in 2016 to $230/kWh by 2030.[2] Using the Consumer Price Index (CPI) to adjust historical American Public Transportation Association (APTA) bus price data, California Air Resource Board (CARB) found conventional bus prices have increased faster than inflation between 2006 and 2015.[3] These forecasts are used in this analysis and described in greater detail in Section 3. In addition to changes in bus prices, volatility and growth in diesel prices is projected to be higher than electricity prices over time. Current diesel, CNG, and electricity fuel costs for Lake City are scaled for future years by the U.S. Energy Information

[1] Eudy, L., & Jeffers, M. (2017). King County Metro Battery Electric Bus Demonstration: Preliminary Project Results, U.S. Department of Transportation, Federal Transit Administration.

Eudy, L., Prohaska, R., Kelly, K., Post, M., Eudy, L., Prohaska, R., … Post, M. (2016). Foothill Transit Battery Electric Bus Demonstration Results. National Renewable Energy Laboratory, (January), 60.

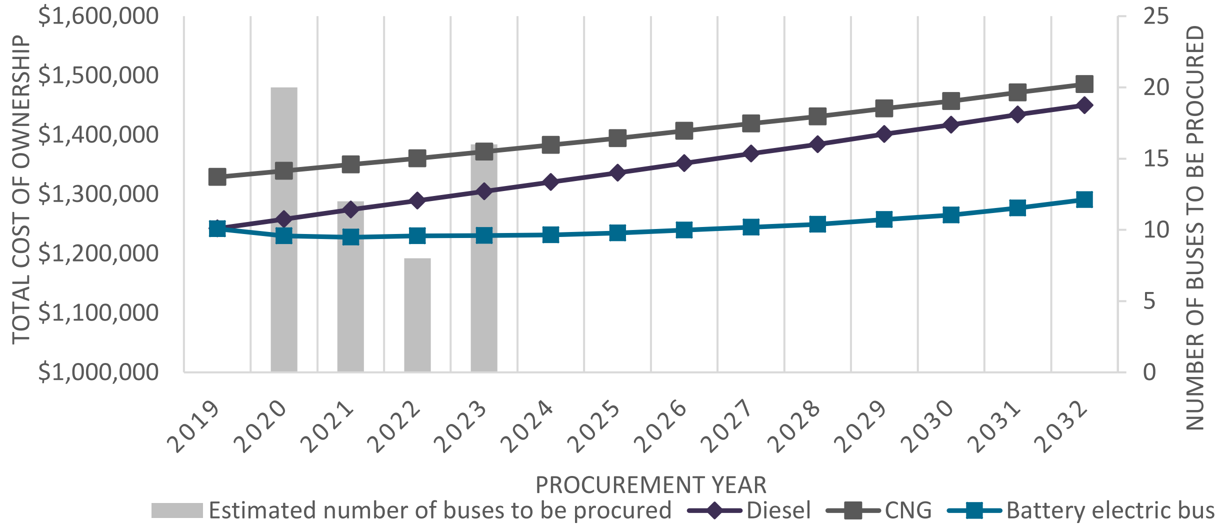
[2] California Air Resources Board Innovative Clean Transit Program. *Battery Cost for Heavy-Duty Electric Vehicles*. 2016.

[3] California Air Resources Board Innovative Clean Transit Working Group. *Cost Data & Sources (6-26-2017)*. 2017.

Administration's (EIA) Annual Energy Outlook Reference Case, which projects higher growth in prices for diesel fuel than electricity.[4]

Projections over the next decade for both bus purchase cost and fuel cost are expected to increase the cost advantage of battery electric buses. Under the referenced inputs and assumptions in Section 3, battery electric buses already have a lower total cost of ownership than CNG buses, and would have a lower total cost of ownership than diesel buses beginning in 2020. Based on the anticipated retirement schedule for Lake City, most procurement would occur in 2020 or after. Figure 3 highlights how the incremental upfront and lifetime costs of a BEB relative to a diesel bus and CNG bus is anticipated to change over time in Lake City's operating context for procurements made between 2019 and 2032.

Figure 3: Total Cost of Ownership per Bus for Procurements Between 2019-2032 (Discounted)



[4] While use of the EIA Reference Case forecasts is a conventional approach for estimating future vehicle fuel costs, it's important to note that fuel prices can be highly volatile, making future forecasts quite uncertain.

2 Utility On-Bill Investment Analysis

With limited funds for grant programs, transit agencies and their partners are exploring financing strategies to be able to afford the higher upfront cost of BEBs by leveraging anticipated operating savings. Multiple electric bus manufacturers offer lease options, particularly battery leases, which reduce the upfront cost for the vehicle to the same level as a diesel bus when accompanied with a long-term operating lease for the on-board battery.[5] Other potential financing strategies have been translated from approaches in the energy efficiency field, such as tariffed on-bill investment by an electricity distribution utility and energy saving performance contracts (ESPC) models.

2.1 Overview of Utility On-Bill Investment for Buildings

Tariffed on-bill investment programs have been implemented both domestically and internationally, primarily to finance building energy efficiency improvements, and many have been based on the Pay As You Save® (PAYS®) system. While most PAYS programs have focused on residential customers, some have financed projects for municipal and other public entities such as lighting improvements and other energy efficient technologies. A sample set of PAYS programs are summarized in Table 2 from a source that includes a more complete account.

Table 2: Example Pay As You Save® (PAYS®) Programs[6]

Program Name	Utility	Types of Customers	Types of Projects
HELP PAYS®	Ouachita Electric Cooperative	Single and multi-family residential customers Public buildings	Heat pumps, insulation, air sealing, and duct sealing
Upgrade to Save	Roanoke Electric	Residential customers	Heat pumps, insulation, air sealing, and duct sealing
Smart Start	New Hampshire Public Service (now Eversource)	Municipal customers	Any cost-effective upgrade, primarily has been lighting or street lighting

A tariffed on-bill program does not involve the utility making a loan to the customer, but it does allow the customer to benefit from upgrades without facing an upfront cost premium that is often a barrier to investment. With utility on-bill investment, the utility can capitalize cost-effective upgrades on the customer's side of the meter at a specific site and recover those costs with a charge on the bill for service at that site.

---

[5] The Financial Accounting Standards Board (FASB) update to accounting standards in 2016 indicates that long-term operating leases will be included among the liabilities on the balance sheet of the lessee, just as capital leases and loans are reported as liabilities on the balance sheet under FASB standards.

[6] Hummel, Holmes and Harlan Lachman. *What is inclusive financing for energy efficiency, and why are some of the largest states in the country calling for it now?* Proceedings of the ACEEE Summer Study. 2018.

Under the terms of a utility on-bill investment, the utility pays some or all of the upfront costs of a cost-effective energy improvement, and it recovers those costs through a fixed tariffed charge that the customer will pay on their monthly energy bill. The service charge for cost recovery is set to be less than the estimated value of energy savings. Once the utility's costs are recovered, the service charge ends and the upgrades belong to the customer. For energy improvements that would still not be cost effective on these terms, the customer may make a co-payment to bring down the upfront cost to a point where the remaining amount would be cost-effective for a utility on-bill investment.

2.2 Utility On-Bill Investment for Battery Electric Buses

In 2018, the Global Innovation Lab for Climate Finance endorsed this approach called PAYS for Clean Transport, starting with electric transit buses, and the analysis in this section explores that option for Lake City and its utility. Specifically, the analysis models cash flows for a utility on-bill investment in the on-board battery and charging station that connects it to the grid. The level of investment per bus is constrained so that cost recovery could be assured under the tariffed terms of the monthly service charge. The service charge is assumed to be capped at 85% of the estimated annual operating savings in the first year, yielding a positive cash flow for the transit agency that is 15% of the estimated savings from switching to an all-electric bus. The period over which the cost recovery charge would apply is also capped so that all costs would be recovered within the duration of the equipment warranty, which is assumed to be 12 years. At that point, the battery and charging station would be owned by the transit agency.

The utility on-bill investment would reduce the amount of additional upfront capital Lake City would be required to pay for each electric bus, yet some copayment would still be needed if the incremental upfront cost of the battery electric bus is greater than the maximum level at which the utility on-bill investment would be cost effective. This analysis calculates the funding that would be needed to make copayments, which would be a lower amount than paying the full incremental upfront cost of an electric bus. For any amount of grant funds available to Lake City for the purchase of battery electric buses, a utility on-bill investment option would multiply the number of buses that could be procured with the same amount of grant funds compared to using grant funds to pay the full incremental upfront cost. This analysis also calculates that multiplier effect and quantifies the leverage on grant funds for both a single bus in the first year and for a fleet transition over multiple years.

2.3 Cash Flow Analysis for a Single Battery Electric Bus

This analysis incorporates the results of the total cost of ownership analysis discussed earlier, and considers the financial terms summarized in Table 3 that are used to model the tariffed on-bill investment program, including the publicly disclosed figure for Lake City's utility's Weighted Average Cost of Capital.

Table 3: Potential Terms for a Tariffed On-bill Investment Program for a 2019 Procurement

Cost of capital – Lake City's utility's Weighted Average Cost of Capital	6.75%
Years of cost recovery on tariffed terms (warranty period)	12
Cap on estimated annual savings committed to cost recovery	85%

For a procurement in 2020, the agency would commit the same amount of capital as it would for a diesel bus, drawing from the combination of federal and local funds typically used to finance new buses, and it would utilize additional discretionary grant funds to afford the incremental cost of a BEB. The amount of grant funds required could be reduced through a utility on-bill investment program. With this option, Lake City's utility would agree to pay the incremental upfront cost of an electric bus that could be recovered through tariffed charges, provided that the agency agrees to pay a fixed tariffed charge for cost recovery that is capped at 85% of the estimated savings in the first year from switching to electricity. The tariffed charge would span the warranty period of the bus (12 years), at which point the agency would own the equipment. The remaining incremental upfront cost for the BEB would be the responsibility of the agency as an upfront copayment, in addition to the base cost of a diesel bus, which could be covered by any source of capital including potential grants from the federal or state government (e.g. Low/No Emissions grant or VW Mitigation funds).

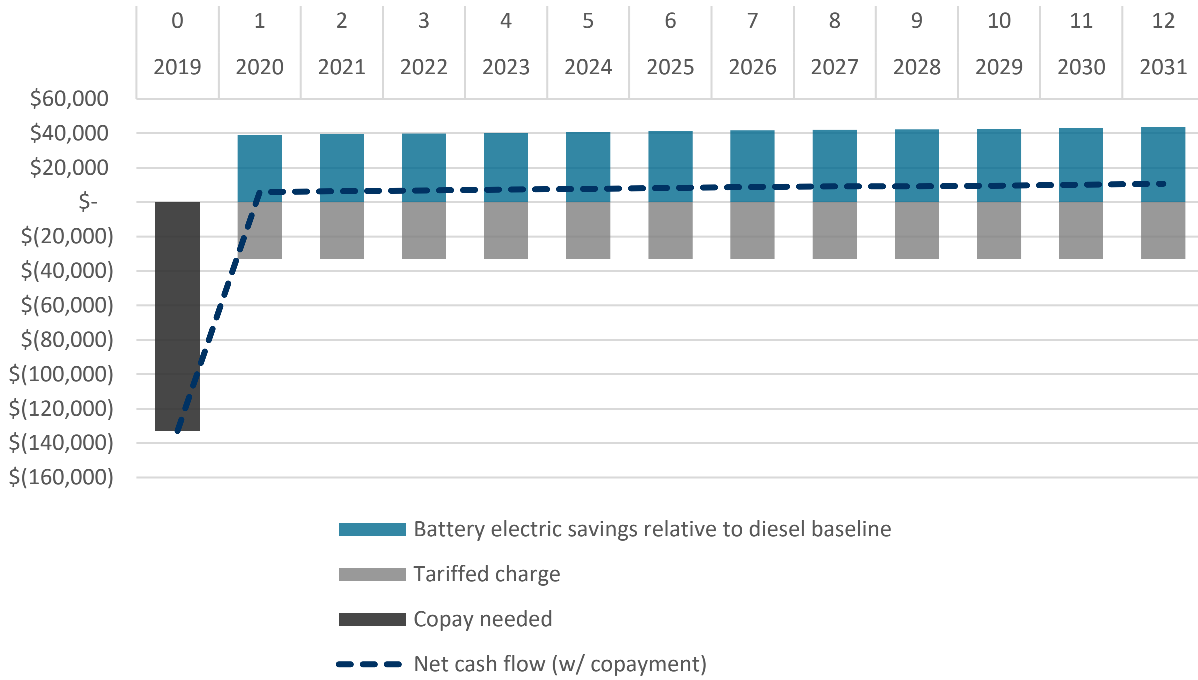
Table 4 illustrates an example of the use of tariffed on-bill investment to procure an electric bus in 2019 from Lake City's perspective. In this sample year, the copayment would leverage enough capital through the terms of the tariff to buy three new battery-electric buses instead of one.

Table 4: Potential terms for a tariffed on-bill investment program for a 2019 procurement

Description	Estimate
Total electric bus capital costs	$865,000
Total diesel bus capital costs	$466,000
- 80% federal match for a diesel bus	*$372,800*
- 20% local match for a diesel bus	*$93,200*
Full incremental upfront cost for an electric bus	$399,000
Estimated annual operating savings in Year 1	$38,900
Estimated annual tariffed cost recovery charge	$33,000
Incremental upfront cost that is cost effective on tariffed terms	-$266,000
Remaining upfront cost covered with a copayment	-$133,000
Ratio of full incremental upfront cost to copayment	3:1

Figure 5 illustrates the cash flows for Lake City for utilizing tariffed on-bill investment to procure an electric bus in 2019.

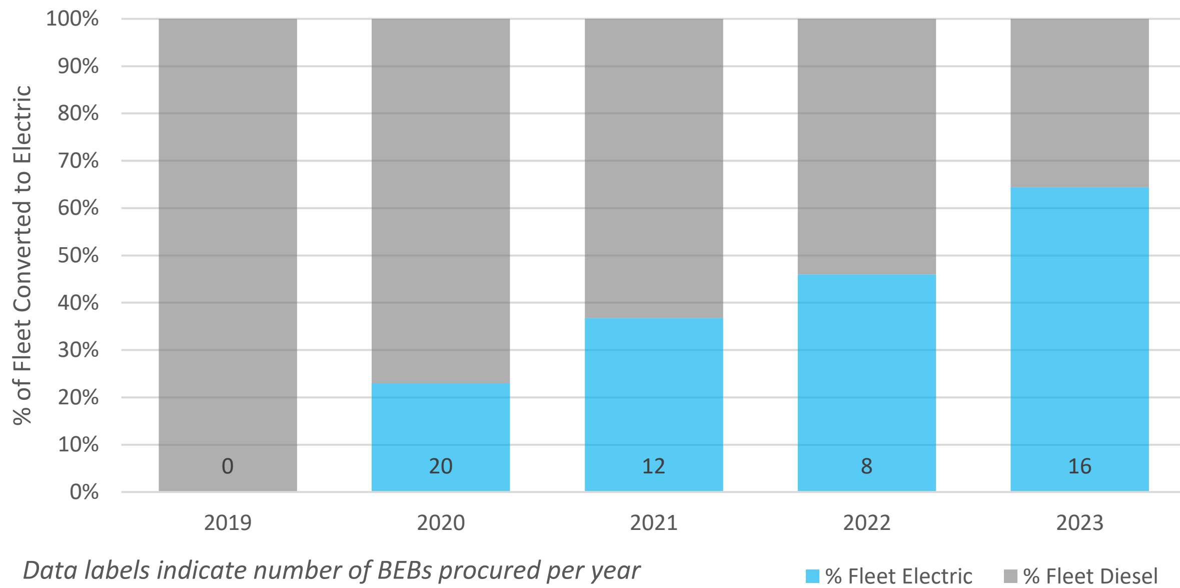
Figure 5: Transit Agency Cash Flow for a Single BEB Procured in 2019 with Utility Tariffed On-bill Investment Program



2.4 Fleet Transition based on 5 Year Outlook

This analysis considers the potential costs to transition Lake City's planned future bus procurements to battery-electric buses. Lake City plans to procure new buses that will replace 60% of its fleet in the next five years. If every new bus procured were to be a battery electric bus, the portion of the fleet that is electric would rise from 0% to 60% within 5 years. (See Figure 6).

Figure 6: Modeled Fleet Transition to Electric Buses for Lake City, 2019-2023



2.5 Analysis of Fleet Transition with Utility On-Bill Investment

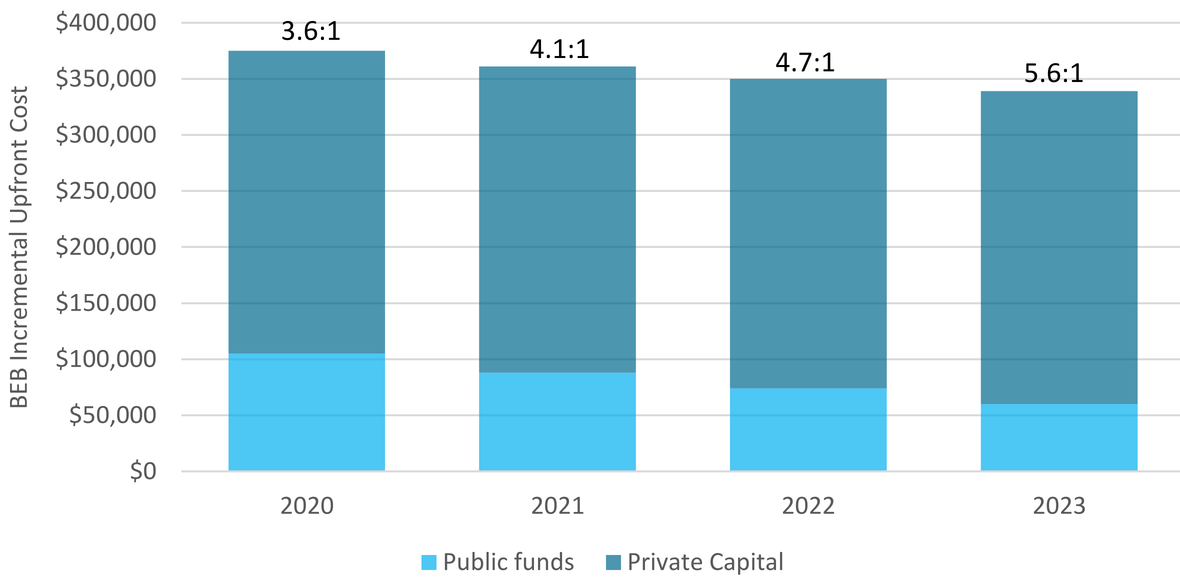
As the incremental upfront cost for battery electric buses decline and estimated operating savings increase over time, the portion of the upfront cost that can be capitalized with a utility on-bill investment (denoted as the incremental upfront cost that meets the PAYS threshold for cost effectiveness in Table 5) is expected to increase. Accordingly, the need for a copayment is expected to decline for all scenarios. Table 5 shows the full incremental upfront cost of a depot charge electric bus relative to a diesel bus, which would be expected to be the same for all scenarios, and it compares that figure with a copayment that would be needed from Lake City. The ratio of the copayment to the incremental cost indicates the extent of leverage that could be achieved with grant funds for procurements between 2019 and 2023 with a utility on-bill investment program.

Figure 7 present the incremental upfront cost per bus for the 56 new buses in the Lake City procurement plan over the next four years if those buses were to be electric buses.

Table 5: Estimated cost per bus for electrification of planned procurements (2020-2023)

	2020	2021	2022	2023
Incremental upfront cost per bus	$375,000	$361,000	$350,000	$339,000
Incremental upfront cost that meets PAYS threshold for cost effectiveness per bus	$270,000	$273,000	$276,000	$279,000
Copayment needed per bus (from VW or other grant funds)	$105,000	$88,000	$74,000	$60,000
Ratio of full incremental cost to copayment	3.6:1	4.1:1	4.7:1	5.6:1

Figure 7: Private Capital and Public Funds Required Per Bus for Lake City Utility On-bill Investment, 2020-2023



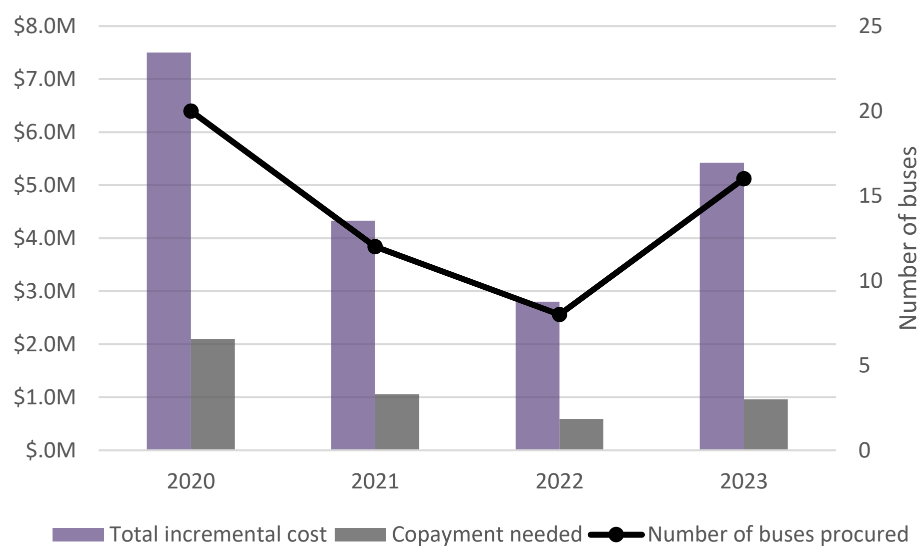
In 2020, a grant of $375,000 could help Lake City afford the incremental cost of one battery-electric bus with the range sought for its fleet, or the same amount of grant money could instead cover the copayments for three electric buses if the utility offers a tariffed on-bill program. By 2023, it's anticipated that the amount of grant funds required to cover the incremental cost of a single electric bus would be could instead cover the copayments for five electric buses.

Table 6 and Figure 8 illustrates the incremental costs, total PAYS investment, and copayments funds needed each year for Lake City planned procurement schedule for the next 56 buses purchased. For the same $1 million in grant funds needed to pay for the full incremental cost of 3 battery electric buses per year in 2020, Lake City would be able to leverage available grant funds 3.6:1 with capital deployed through its utility.

Table 6: Estimated total cost for electrification of planned procurement of 56 buses (2020-2023)

	2020	2021	2022	2023	Total
Estimated number of buses to be procured	20	12	8	16	56
Total Incremental upfront cost ($ million)	**$7.5M**	**$4.3M**	**$2.8M**	**$5.4M**	**$20.1M**
Total Copayment needed ($ million)	**$2.1M**	**$1.1M**	**$.6M**	**$1.0M**	**$4.7M**
Ratio of full incremental cost to copayment	3.6:1	4.1:1	4.7:1	5.6:1	**4.3:1**

Figure 8: Estimated total cost for electrification of planned procurement of 56 buses (2020-2023)



If Lake City's utility offered a tariffed on-bill program for on-board batteries and charging stations, a total of $4.7 million to fund copayments would leverage $15.4 million in utility on-bill investment to transform the transit agency's planned procurement of 56 buses from diesel to all-electric. Using VW

Settlement or other grants to cover copayments in a tariffed on-bill program over the next five years would leverage more than 4 times more capital than grant funds alone.

3 Appendix: Methods, Inputs, and Assumptions

This section describes the methods, inputs, assumptions, and key sources utilized to produce the total cost of ownership analysis and financial analysis. Following a narrative description of the modeling approach and key sources, documents the inputs used specifically for Lake City.

3.1.1 Methods

This analysis compares TCO for 40' diesel transit buses, CNG transit buses, and depot charge BEBs, assessing capital costs, infrastructure costs, and discounted fuel and maintenance costs over a bus's lifetime. The analysis was informed by federal and academic transit bus lifecycle cost models, such as TCRP Report 132 Hybrid-Electric Transit Bus Life Cycle Cost Model,[7] TCRP Report 146 Life Cycle Cost Spreadsheet for Post-2010 Transit Bus Procurements[8] and CARB's Innovative Clean Transit cost model,[9] amongst others. The following sections describe the approach and sources for each model parameter.

Bus purchase costs: Based on rapidly falling battery costs for leading EV manufacturers, CARB predicts battery costs for heavy-duty vehicles will fall from $720 per kWh in 2016 to $230 per kWh by 2030.[10] Using historical bus price data and battery cost reduction trends, CARB's analysts project the battery portion of bus costs will decline 3% per year through 2030, narrowing the premium between BEBs and diesel buses from $288,000 in 2017 to $157,000 in 2030. Base bus price projections produced by CARB are used for this analysis, assuming a 40' bus with a 440-kWh battery.[11]

Charging infrastructure equipment and installation costs: This analysis utilizes the same assumptions as the Lake City fleet assessment, assuming a depot charger cost of $38,000 for equipment and $15,000 for installation. It assumes a 1:1 ratio for buses and depot chargers. For depot charge buses, it may be possible to stagger charging overnight to lessen demand charges.[12] With most agencies having heavily peaked service during the evening rush hour, early pull-ins could likely begin charging by 8pm. This analysis assumes transit agencies can manage depot charging to some degree, with a base case assumption of 75% of buses charging simultaneously.

No costs for diesel fueling infrastructure are included, as it is assumed an agency already has the infrastructure if procuring that technology. Costs for compressed natural gas infrastructure are also from the Lake City fleet assessment.

---

[7] Clark, N. N., F. Zhen, and W. S. Wayne. *TCRP Report 132: Assessment of Hybrid-Electric Transit Bus Technology*.Transit Cooperative Research Program. 2009.

[8] Blaylock, M. et al. *TCRP 146: Guidebook for Evaluating Fuel Choices for Post-2010 Transit Bus Procurements*. 2010.

[9] California Air Resources Board Innovative Clean Transit Working Group. *Transit Fleet Cost Model*. 2017.

[10] California Air Resources Board. *Battery Cost for Heavy-Duty Electric Vehicles*. 2016.

[11] California Air Resources Board Innovative Clean Transit Working Group. *Cost Data & Sources (6-26-2017)*. 2017.

[12] California Air Resources Board Innovative Clean Transit Working Group. *Cost Data & Sources (6-26-2017)*. 2017.

Midlife costs: Although this analysis does not assume any midlife rehabilitation costs for internal combustion engine buses due to typical agency practices, it assumes the agency may purchase an upfront 12-year battery warranty (estimated at $55,000) instead of modeling a midlife battery replacement.

Annual miles driven and bus lifetime: The analysis assumes a bus lifetime of 12 years, based on FTA useful life requirements for a 40' transit bus and typical extended warranty periods for bus manufacturers. The analysis assumes an average annual utilization of 52,500 miles per bus per year, based on inputs from Lake City.

Fuel economy: Lifecycle cost models reviewed analyzed bus fuel economy's relationship with speed and auxiliary loads. TCRP Report 132 utilized field and dynamometer data to estimate a relationship between speed and fuel economy for each bus type.[13] This analysis applies that relationship to estimate diesel bus fuel economy based on the agency's reported average speed to the National Transit Database (NTD), and improves the estimates by 15% to account for advances in fuel economy since that model was developed, informed by EIA's assumptions for heavy-duty fuel economy improvements. For BEBs, this analysis relies on CARB's study of electric bus and truck fuel economy, which found a robust relationship between average speed and energy efficiency ratio (the electric vehicle fuel economy ratio to a comparable diesel vehicle operated at the same speed) that is used to estimate BEB fuel economy at each speed.[14] The model also estimates the impact of auxiliary loads based on the methods in TCRP Report 132's model.

Fuel costs: This analysis uses EIA's Annual Energy Outlook 2017 Reference Case to scale current diesel and commercial electricity prices over time. $2.31 per gallon is assumed to be the starting diesel price in 2018, provided by Lake City. For electricity costs, the analysis models the Small General Service Time-of-Use electricity rate offered by Lake City's utility.

Maintenance costs: Manufacturers of BEBs have claimed substantial maintenance savings due to having a simpler drive train, fewer moving parts for technicians to maintain, and less brake wear due to regenerative braking. While these claims have been difficult to substantiate given that no BEB has been on the road for its full useful life, empirical studies are now beginning to document BEB maintenance savings. Studies from the National Renewable Energy Laboratory (NREL) of Foothill Transit's fleet of early model battery electric buses found a 21% cost per mile maintenance savings compared with CNG, while a more recent 2017 NREL study of King County's fleet found a 59% per mile maintenance cost savings compared with diesel buses of the same age.[15] This analysis assumes the midpoint of that range,

[13] Clark, N. N., F. Zhen, and W. S. Wayne. TCRP Report 132: Assessment of Hybrid-Electric Transit Bus Technology.*Transit Cooperative Research Program*, 2009.

[14] California Air Resources Board. *Battery Electric Truck and Bus Energy Efficiency Compared to Conventional Diesel Vehicles*. 2017.

[15] Eudy, L., & Jeffers, M. (2017). King County Metro Battery Electric Bus Demonstration: Preliminary Project Results, U.S. Department of Transportation, Federal Transit Administration.

40%, as the estimated maintenance savings for BEBs. This analysis uses the average national maintenance cost per mile from NTD data, applies the estimated percent savings, and applies the TCRP Report 132 model methodology, which corrects maintenance costs by warranty years and by average speed, based on much higher maintenance costs found for agencies operating in slow speed conditions.

Financial assumptions: This analysis considers all cost parameters in real dollars, and utilizes a discount rate of 3.5% for the total cost of ownership analysis. For the utility on-bill investment analysis, Lake City's utility's weighted average cost of capital of 7.09% is utilized.

Not included in this analysis: This analysis does not account for every cost in a bus procurement, nor all the potential variability between agency contexts. The analysis does not include, for example, end-of-life costs, for which the main difference with BEBs is their battery packs. These batteries could either require additional costs to recycle, or as some analysts predict, could be sold for reuse as stationary storage to provide ancillary services and other functions after they are no longer fit for vehicle use. Additionally, costs for the fleet as a whole to transition to electric buses, such as maintenance bay upgrades, and maintenance technician and operator training, are also not included in this analysis.

3.1.2 Inputs, Assumptions, and Key Sources

Table 7 documents the inputs, assumptions, and key sources specific to Lake City that informed the total cost of ownership and financial analysis above.

Table 7: Analysis Inputs, Assumptions, and Key Sources

CAPITAL COSTS	INPUTS AND ASSUMPTIONS	SOURCES
Base bus purchase costs (2018)	$456,000 (diesel) $506,000 (CNG) $661,000 (diesel hybrid) $774,000 (440 kWh depot charge 40' bus)	CARB Innovative Clean Transit Cost Data & Sources (2017) (CARB TCO Assumptions) for **2019-2032 forecast costs**
Charging infrastructure equipment cost	$38,000 (depot charger, assumed one bus per charger)	Lake City Fleet Assessment
Charging infrastructure installation cost	$15,000 (depot charger)	Lake City Fleet Assessment
BEB Midlife costs	$55,000 for 12-year battery warranty	Lake City Fleet Assessment
CNG infrastructure costs	$2,500,000 (CNG fueling infrastructure) $1,250,000 (CNG facility upgrades) $125,000 (CNG infrastructure per bus) $62,500 (CNG facility upgrade per bus)	Lake City Fleet Assessment

Eudy, L., Prohaska, R., Kelly, K., Post, M., Eudy, L., Prohaska, R., … Post, M. (2016). Foothill Transit Battery Electric Bus Demonstration Results. National Renewable Energy Laboratory, (January), 60.

OPERATING INPUTS	**INPUTS AND ASSUMPTIONS**	**SOURCES**
Annual miles driven	52,500	County input
Average speed	22 mph	2016 Lake City average speed reported to NTD
Estimated fuel economy (MPDGE)	4.7 (diesel) 4.1 (CNG) 1.93 (battery electric - kwh/mile)	Based on methods and data from TCRP Report 132 and CARB
Fuel costs in 2018	$2.31/gallon (diesel) $1.16/DGE (CNG)	Lake City fuel costs scaled based on EIA Reference Case
Electricity costs	Small General Service TOU **Maximum draw at full electrification would be ~4,400 kw; with multiple depots, may be able to stay on Medium General Service for several years into fleet electrification, and with active charging management, maybe permanently.*	Lake City's utility's electricity costs scaled based on EIA Reference Case
Maintenance costs ($/mile)	$0.96 (diesel) $0.96 (CNG) $0.57 (battery electric)	Based on methodology from TCRP Report 132 that incorporates speed, warranty years. **Assumes 40% maintenance savings for battery electric compared with diesel, based on NREL reports*[16]
Charger assumptions	50 kw	Lake City Fleet Assessment
Charging % of potential peak load	75% of potential peak load	Assumption based on potential to manage/stagger charging overnight
FINANCIAL ASSUMPTIONS	**INPUTS AND ASSUMPTIONS**	**SOURCES**
Discount rate	3.5%	Based on a range from CARB TCO Assumptions and an electric bus feasibility analysis from LA Metro[17]
Interest rate	6.75%	Utility weighted average cost of capital
Savings percentage for PAYS®	15%	Assumption

[16] Eudy, L., & Jeffers, M. (2017). King County Metro Battery Electric Bus Demonstration: Preliminary Project Results, U.S. Department of Transportation, Federal Transit Administration. Retrieved from https://www.afdc.energy.gov/uploads/publication/king_county_be_bus_preliminary.pdf
Eudy, L., Prohaska, R., Kelly, K., Post, M., Eudy, L., Prohaska, R., … Post, M. (2016). Foothill Transit Battery Electric Bus Demonstration Results. *National Renewable Energy Laboratory*, (January), 60.

[17] Ramboll Environ; M.J. Bradley & Associates. (2016). LA Metro Zero Emissions Bus Options. Retrieved from http://metro.legistar1.com/metro/attachments/140a441a-fb64-4fbd-9612-25272b858f07.pdf

Baseline bus	40’ diesel transit bus	Assumption
Bus lifetime/ warranty period	12 years	Assumption based on FTA useful life, bus manufacturer extended warranty period