ZERO EMISSION BUS FACT SHEET

I. Our State Should Invest EMT Funds in Zero Emission Buses

Our state should use Environmental Mitigation Trust (EMT) funds to invest in zero emission buses and their charging infrastructure. Fleets of school, transit, and shuttle buses are already being converted to these clean, cost-effective, alternatives to traditional diesel power. Transit agencies in Shreveport, Lexington, Louisville, Reno, Columbus, Dallas, Oakland, and the Quad-Cities area of Illinois, are just a handful of those investing in electric and hydrogen fuel cell buses.[1] Outside of the U.S., Tel Aviv,[2] London,[3] Barcelona,[4] and a number of Chinese cities[5] have invested in electric buses and charging stations. As of 2015 there were over 170,000 electric buses on the road worldwide.[6] Navigant Research projects that "the battery EV (BEV) is expected to be the leading type of electric powertrain for buses through 2026."[7]

EMT funds are available to further support the adoption of these highly efficient alternatives to fossil fueled transportation. In addition EMT covers installation of charging infrastructure. As described in greater detail below, the economics already favor widespread investment in zero emission buses and their supporting infrastructure. Investment in these buses today will speed further integration as these technologies come to scale, bringing measurable economic and environmental benefits to the communities they service.

By using EMT funds to procure zero emission buses now, our transit agencies can lock in annual savings on fuel ($40,000-$45,000 per year per bus over diesel) and maintenance. The agencies can then procure additional zero emission buses, which will lock in yet further cost savings going forward for the agency.

A. EV Buses Already Have Lower Comparative Lifetime Costs Than Diesel Buses and CNG Buses--And Costs Continue To Drop Rapidly.

As discussed below, even today the lifetime cost of an electric bus is significantly lower than that of a new diesel or alternative fuel bus, though the upfront cost is higher. The all-in cost of buses--that is, the upfront cost of the bus purchase, fuel costs and maintenance costs--for

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[1] *See* Proterra, *Our Customers*, https://www.proterra.com/our-story/our-customers/, for a full list of just one company's sales.
[2] Sharon Udasin, *Five Electric Buses to Begin Running in Tel Aviv*, Jerusalem Post, Sept. 16, 2016, http://www.jpost.com/Business-and-Innovation/Tech/Five-electric-buses-to-begin-running-in-Tel-Aviv-467873.
[3] *Mayor Unveils First Fully Electric Bus Routes for Central London*, Sept. 9, 2016, https://www.london.gov.uk/press-releases/mayoral/mayor-unveils-first-fully-electric-bus-routes.
[4] Katie Sadler, *Barcelona Unveils Two New Electric Buses and a Rapid-Charging Station*, EuroTransport, Sept. 21, 2016, http://www.eurotransportmagazine.com/20655/news/industry-news/barcelona-electric-buses-rapid-charging-station/.
[5] *See* Lindsay Dodgson, *Buses and Batteries: A Rising Sector*, May 31, 2016, http://www.power-technology.com/features/featurebuses-and-batteries-a-rising-sector-4904956/.
[6] International Energy Agency, *Global EV Outlook 2016*, 24-25 *available at* https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf.
[7] Electric drive buses include hybrid, fuel cell, and all-electric vehicles. Navigant Research, *Electric Drive Buses*, https://www.navigantresearch.com/research/electric-drive-buses (last visited Oct. 10, 2016).

electric buses is around $1,000,000, and around $1,400,000 for diesel and CNG buses.[8] Moreover, as EV bus manufacturing scales up, and as battery costs--the most expensive part of an EV--plummet over time, EV bus prices will fall rapidly as well.

Up Front Costs:

The current sticker price of a new electric bus is about $750,000.[9] A comparable new diesel vehicle costs $480,000 and a compressed natural gas (CNG) bus $490,000, while a Fuel Cell Bus (FCB) costs over $1,000,000.[10] Transitioning to electric technology can also be accomplished through repowering existing diesel vehicles with all-electric components, a process that costs around $500,000.[11]

Government estimates of zero emission bus prices sharply decline as advances in battery manufacturing and increased demand drive down costs. By 2025--within the 10 year timeframe of the VW EMT grant program--an electric bus is expected to cost $480,000, equal to or less than the cost of a new diesel vehicle.[12] Much of this decrease is attributable to projected reductions in battery costs. A California Air Resources Board-conducted literature review concluded that studies consistently place the cost of batteries below $500/kWh by 2020, and approaching $200/kWh by 2030.[13] These estimates are already outdated and clearly understate the rate of reductions in battery costs, which again are the most expensive part of an EV. GM announced that already, even in 2016, it was procuring batteries for its Bolt EV for $145/kWh.[14]

As explained below, even without future reductions in costs, EV buses, with their far lower fuel, operating, and maintenance costs, exhibit lower lifetime costs than diesel and CNG buses.

Fuel Savings:

Electric buses offer tremendous fuel savings. For example, Proterra's all-electric Catalyst bus registers a fuel efficiency averaging 17.48 miles per diesel gallon equivalent (MPDGe) of electric charge.[15] Electric costs vary by market but average $.12/kWh nationally, or about $1.29

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[8] *The Business Case For the Proterra Electric Bus*, Aug. 3, 2015, http://ecomento.com/2015/08/03/business-case-proterra-electric-bus/

[9] Proterra's Catalyst bus cost $749,000 in 2016 while BYD's all-electric bus costs $770,000. Draft, Cost Model Discussion with ACT Cost Subgroup, slides 9-10 (Aug. 23, 2016) *available at* http://cafcp.org/sites/default/files/5_CARB-ACT-Cost-Model-Discussions_CaFCP-Bus-Team-Meeting-Aug2016.pdf (hereinafter "Air Resources Board Cost Model").

[10] *Id.* at slides 9 (CNG), 10 (diesel), 12 (Hydrogen Fuel Cell).

[11] Repowering refers to the removal of the existing motor and drivetrain and replacement with all-electric components. *See* Rich Piellisch, *21 All-Electric ZEPS Buses for IndyGo*, Dec. 8, 2014, http://www.fleetsandfuels.com/fuels/evs/2014/12/21-all-electric-zeps-buses-for-indygo/ (21 rebuilds at a total cost of $12.2 million).

[12] Air Resources Board Cost Model, slide 10 (all values in 2016 dollars).

[13] *Id.* slide 11.

[14] Jay Cole, *GM: Chevrolet Bolt Arrives in 2016, $145/kWh Cell Cost, Volt Margin Improves $3,500*, http://insideevs.com/gm-chevrolet-bolt-for-2016-145kwh-cell-cost-volt-margin-improves-3500/.

[15] NREL, *Foothill Transit Battery Electric Bus Demonstration Results*, vii, Jan. 2016, *available at* http://www.nrel.gov/docs/fy16osti/65274.pdf.

per gallon diesel equivalent.[16] An electric bus will consume about $5,000-$10,000 in electricity annually, far lower than the $50,000/yr spent on diesel or $30,000/yr spent on CNG to fuel a similar vehicle.[17] Notably, long range electric buses are available on the market. Proterra offers electric buses with mileage ranges of 49-350 miles per charge,[18]and BYD sells a bus that goes approximately 155 miles.[19] New Flyer is testing a hydrogen fuel cell bus with 300 miles of range.[20] Companies such as Complete Coach Works offer rebuilt electric buses for lower cost than new buses.[21]

Diesel Buses average 3.26 miles per gallon (MPG)[22] and average fuel prices between $2 and $3 per gallon.[23] This equates to an average consumption of $50,000 of diesel fuel each year.[24] CNG powered buses present a similar scenario. A CNG bus averages 4.51 MPDGe[25] and costs approximately $2.05 per gallon diesel equivalent.[26] A CNG bus consumes an average $30,000 a year for fuel.[27] FCBs are currently more expensive. FCBs are fueled by hydrogen, which costs approximately $8/kg in 2016.[28]

Variability in fuel supply also increases the difficulty of predicting an operating budget for a diesel, or CNG dependent transportation fleet. While long-term fuel contracts can insulate against these fluctuations, shifts in real world prices can still impact operations when negotiating those contracts.

O&M Costs:

Electric buses also have substantially lower operating and maintenance (O&M) expenses as compared to their diesel and CNG alternatives. With an electric or hydrogen fuel cell bus, there are no oil changes or emissions tests, fewer parts that can break, and less wear on braking systems. The average lifetime maintenance cost for an electric bus is just $.60/mile. This is a

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[16] U.S. Department of Transportation, *Zero Emissions Bus Benefits* https://www.transportation.gov/r2ze/benefits-of-ZEBs (last visited Oct. 10, 2016). It is important to consider that, for high power charging, additional costs beyond volumetric electricity use may be incurred depending on the applicable utility rate structure. In particular, demand charges – costs incurred for high rate of power flow – can make a significant difference in determining fuel costs.
[17] California Air Resources Board, *Technology Assessment: Medium and Heavy-Duty Battery Electric Trucks and Buses*, Draft, IV-5 (Oct. 2015).
[18] *See* Proterra Catalyst Bus Specifications, https://www.proterra.com/wp-content/uploads/2016/08/Proterra-Catalyst-Vehicle-Specs.pdf.
[19] BYD, *Electric Bus*, http://www.byd.com/na/old/auto/ElectricBus.html.
[20] Alex Roman, *What's New in Electric Buses?* Metro Magazine *available at* http://www.metro-magazine.com/sustainability/article/711947/what-s-new-in-electric-buses.
[21] Complete Coach Works, *ZEPS Electric Remanufactured Transit Bus* http://completecoach.com/zeps-timelapse/.
[22] U.S. Department of Energy, Alternative Fuels Data Center, *Average Fuel Economy of Major Vehicle Categories*, http://www.afdc.energy.gov/data/10310.
[23] Average national price as of October 3, 2016 was $2.389/gallon, but varies greatly with underlying crude oil prices, *see* http://www.eia.gov/petroleum/gasdiesel/.
[24] California Air Resources Board, *Literature Review on Transit Bus Maintenance Cost (Discussion Draft)* at 7 (Aug. 2016) *available at* https://www.arb.ca.gov/msprog/bus/maintenance_cost.pdf.
[25] *Id.*
[26] U.S. Department of Energy, *Clean Cities Alternative Fuel Price Report* 4, tbl 2 (July 2016) *available at* http://www.afdc.energy.gov/uploads/publication/alternative_fuel_price_report_july_2016.pdf.
[27] California Air Resources Board, *Technology Assessment: Medium and Heavy-Duty Battery Electric Trucks and Buses*, Draft, IV-5 (Oct. 2015).
[28] Air Resources Board Cost Model, slide 20.

significant reduction from the $.85/mile associated with diesel and CNG fueled vehicles.[29] Hydrogen fuel cell buses have an average maintenance cost of $1.00/mile.[30] Proterra estimates that over a 12 year lifetime, an all-electric bus will save its operator $448,000 as compared to a traditional diesel vehicle, $408,000 as compared to a CNG vehicle, and $459,000 as compared to a diesel-hybrid vehicle.[31]

Charging Infrastructure Costs:

There are two options for electric bus charging infrastructure. First, a typical Class 3 slow charger can charge a bus in 3-5 hours. These chargers cost around $65,000 to purchase and install.[32] Again, this cost can be covered by EMT funds. With advances in battery technology increasing bus ranges, new models can achieve up to 350 miles on a single charge, enough to allow an operator to charge its buses overnight and then operate all day without needing to stop to refuel.[33]

Alternatively, fast chargers can provide 30 miles worth of charge in 8-13 minutes.[34] This design allows a bus to charge during the course of its normal route, eliminating the need to come out of circulation to refuel.

B. EMT Funds Can Be Used To Purchase And Install EV Buses And Charging Equipment: Locked In O&M Savings Can Then Be Used To Expand The EV Bus Fleet, Generating Further Savings.[35]

EMT funds are available to meet the higher capital requirements of an electric bus fleet, allowing a transit agency to then lock in the lower lifetime costs of EV buses. The agency can then use the lifetime savings on fuel and maintenance to procure additional EV buses and build on lifetime savings going forward.

Government beneficiaries can receive up to 100% of the cost of repowering or replacing eligible buses with either electric, diesel, or alternative technologies. Non-Government beneficiaries can receive up to 75% of the cost to repower or replace with a new electric motor or bus; but only 40% of the cost of repowering with a new diesel or alternative fuel engine, and only 25% of the cost of a new diesel or alternative bus. But for the reasons discussed above and depicted in the table below, once capital costs are eliminated from the equation, investing in electricity is far preferable to diesel or CNG vehicles.

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[29] Air Resources Board Cost Model, slide 13.
[30] Air Resources Board Cost Model, slide 16.
[31] Proterra, *The Proterra Catalyst 35-Foot Transit Vehicle*, https://www.proterra.com/products/35-foot-catalyst/ (last visited Oct. 11, 2016).
[32] Air Resources Board Cost Model, slide 24.
[33] *See* Proterra Catalyst Bus Specifications, https://www.proterra.com/wp-content/uploads/2016/08/Proterra-Catalyst-Vehicle-Specs.pdf. *See also* Aarian Marshall, *This New Electric Bus Can Drive 350 Miles on One Charge*, Wired, Sept. 12, 2016, https://www.wired.com/2016/09/new-electric-bus-can-drive-350-miles-one-charge/.
[34] NREL, *Foothill Transit Battery Electric Bus Demonstration Results*, 13, Jan. 2016, *available at* http://www.nrel.gov/docs/fy16osti/65274.pdf.; *see also* Proterra Catalyst Bus Specifications, https://www.proterra.com/wp-content/uploads/2016/08/Proterra-Catalyst-Vehicle-Specs.pdf.
[35] *See* Partial Consent Decree, *In re: Volkswagen "Clean Diesel" Marketing, Sales, Practices, and Products Liability Litigation*, Case No.: MDL No. 2672 CRB (JSC) at 2-3 (N.D. Cal. June 28, 2016).

Costs (Capital + O&M) for Diesel, CNG, Electric Buses

	Diesel	CNG	Electric
Purchase Price	$480,000	$490,000	$750,000
Fuel Cost (DGe)	$2-3	$2.05	$1.29
Fuel Cost (annual)	$50,000	$30,000	$5,000-$10,000
Fuel Efficiency(MPDGe)	3.26	4.51	17.48
O&M cost ($/mile)	$.85	$.85	$.60
Additional Lifetime O&M (compared to electric)[36]	$448,000	$408,000	--
Approximate Lifetime Cost	$1,348,000[37]	--	$1,180,000[38]

These savings are not exclusive to transit buses. Electric School Buses are in use by a number of municipalities throughout the country.[39] School buses are ideal fits for electrification. Buses typically operate two shifts each day, once in the morning and again in the afternoon. Down time between shifts allows buses to fully recharge. In King County, California, two electric school buses were estimated to save roughly 16 gallons of fuel per bus per day. This amounted to an annual fuel saving of over $11,000 per bus.[40]

[36] Includes savings from fuel and maintenance, *see* Proterra, *The Proterra Catalyst 35-Foot Transit Vehicle*, https://www.proterra.com/products/35-foot-catalyst/ (last visited Oct. 11, 2016).
[37] Judah Aber, *Electric Bus Analysis for New York City Transit*, Columbia University, May 2016, 16 fig 7, http://www.columbia.edu/~ja3041/Electric%20Bus%20Analysis%20for%20NYC%20Transit%20by%20J%20Aber%20Columbia%20University%20-%20May%202016.pdf.
[38] *Id.*
[39] *See e.g.*, James Ayre, *Massachusetts Puts $1.4 Million into Electric School Bus Pilot Program*, Aug. 16, 2016, https://cleantechnica.com/2016/08/16/massachusetts-puts-1-4-million-electric-school-bus-pilot-project/; Nicole Schlosser, *Can Electric School Buses Go the Distance?* May 23, 2016, http://www.schoolbusfleet.com/article/713421/can-electric-school-buses-go-the-distance (providing an overview of state and local pilot projects); Larry Hall, *Tech: The Yellow School Bus Is Going All Electric*, Clean Fleet Report, Mar. 26, 2016, http://www.cleanfleetreport.com/tech-yellow-school-bus-going-electric/.
[40] Larry Hall, *Tech: The Yellow School Bus Is Going All Electric*, Clean Fleet Report, Mar. 26, 2016, http://www.cleanfleetreport.com/tech-yellow-school-bus-going-electric/.

C. EV Buses Provide Significant Reductions in Tailpipe and Greenhouse Gas Emissions

As shown in the below table, emission reductions vary depending on the model year of the bus being replaced.

Tailpipe Emissions from Existing Buses[41]

	NOx (kg/yr)	PM (kg/yr)	Carbon Monoxide (kg/yr)	Hydrocarbons (kg/yr)
MY 2010 Diesel	527.6	28.0	299.6	47.1
MY 2012 Diesel	32.4	.5	26.6	5.0
MY 2012 CNG	107.9	.1	360.4	0
Electric	0	0	0	0

To be sure, NOx reductions can also be achieved by replacing existing diesel buses with new diesel buses or CNG buses. However, the NOx reductions are not as significant. Nor do they provide as meaningful of reductions in other pollutants such as greenhouse gases ("GHG"), Carbon Monoxide, and black carbon. **On a well to wheels basis, a new diesel bus contributes roughly 3,000 grams of CO_2 equivalent per mile (gCO_2e/mile), a new CNG vehicle 2,800 gCO_2e/mile, and a full-electric bus 650 gCO_2e/mile.**[42] When choosing which technologies to focus EMT funds on, our state should be mindful of the additional reductions in these other pollutants that adhere only to electric buses.

Tailpipe Emissions from New Transit Buses[43]

	Well-to-Wheel GHGs (gCO_2e/mile)[44]	NOx (lbs/yr)	Black Carbon (lbs/yr)	Carbon Monoxide (lbs/yr)
Diesel	3,000	59	891	59
CNG	2,800	237	178	793
Electric	650	0	0	0

It is also important to consider where these emission reductions will occur. Transit buses tend to operate in heavily populated urban areas and suburban corridors. Pollution from these sources falls directly upon the surrounding communities and commuters. When we consider emissions from electric school buses, it is important to remember that the population most exposed to diesel school bus emissions are children. Children are especially vulnerable to the health effects of air pollution.[45] By relying on electric vehicles we can reduce pollution from the same vehicles we trust to bring them safely to and from school.

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[41] Memorandum from Dana Lowell to Conrad Schneider, *Clean Diesel v. CNG Buses: Cost, Air Quality, & Climate Impacts*, M.J. Bradley & Associates, Feb. 22, 2012, 9 t. 1, *available at* http://www.catf.us/resources/publications/files/20120227-Diesel_vs_CNG_FINAL_MJBA.pdf.

[42] *See* "Urban Bus GHG Emission Comparison," *Advanced Clean Transit*, California Air Resources Board, May 2015 http://www.arb.ca.gov/msprog/bus/workshoppresentation.pdf.

[43] Proterra, *Sustainability*, https://www.proterra.com/performance/sustainability/ (last visited Oct. 11, 2016).

[44] *See* "Urban Bus GHG Emission Comparison," *Advanced Clean Transit*, California Air Resources Board, May 2015 http://www.arb.ca.gov/msprog/bus/workshoppresentation.pdf.

[45] Larry Hall, *Tech: The Yellow School Bus Is Going All Electric*, Clean Fleet Report, Mar. 26, 2016, http://www.cleanfleetreport.com/tech-yellow-school-bus-going-electric/.