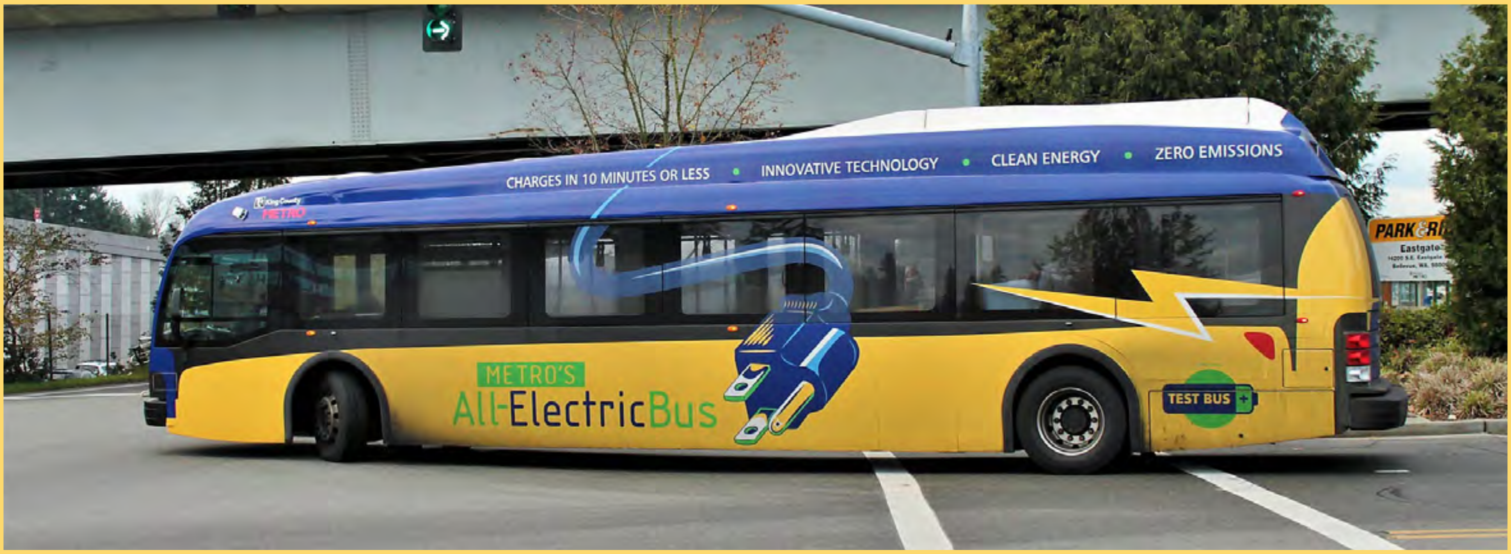

Electric Buses

Clean Transportation for Healthier Neighborhoods and Cleaner Air

FRONTIER GROUP

TexPIRG Education Fund

ENVIRONMENT TEXAS RESEARCH & POLICY CENTER

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Executive Summary

Buses play a key role in in our nation's transportation system, carrying millions of children daily to and from school and moving millions of Americans each day around our cities. Buses reduce the number of individual cars on our roads, make our communities more livable and sustainable, and provide transportation options for people of all ages and abilities.

Yet, the **majority of America's buses remain dirty** – burning fossil fuels like diesel that put the health of our children and communities at risk and contribute to global warming:

- Approximately 95 percent of America's school buses, carrying some of the most vulnerable passengers, run on diesel.[1]

- More than 60 percent of the nation's nearly 70,000 transit buses run on diesel, and another 18 percent run on natural gas, while just 0.2 percent of buses are all-electric.[2]

Numerous studies have shown that inhaling diesel exhaust can cause respiratory diseases and worsen existing conditions like asthma. The negative effects are especially pronounced in children.

- **Diesel exhaust is internationally recognized as a cancer-causing agent** and classified as a likely carcinogen by the U.S. Environmental Protection Agency.[3]

- In a study of 61 million people in 2015, researchers found that exposure to diesel soot and ground-level ozone created by **diesel exhaust was linked to higher rates of mortality**.[4]

Diesel exhaust from buses poses a particular risk to health. Buses primarily travel where there are lots of people, including in the more densely-crowded areas of cities, on the busiest roads, and near schools. They also circulate continuously and make many trips, and therefore risk exposing many people to emissions.

The good news is that America can clean up its buses by making them electric. **All-electric buses are here, and they're cleaner, healthier and often cheaper** for transit agencies, school districts and bus contractors to run in the long-term.

To clear our air and protect our health, policymakers should accelerate the replacement of diesel and other fossil fuel-powered buses with clean, electric buses.

- Replacing all of America's school buses with electric buses could avoid an average of 5.3 million tons of greenhouse gas emissions each year.[5]

- Replacing all of the diesel-powered transit buses with electric buses in the United States could save more than 2 million tons of greenhouse gas emissions each year.[6]

Dramatic declines in battery costs and improvements in performance, including expanded driving range, have made electric buses a viable alternative to diesel-powered and other fossil fuel buses.

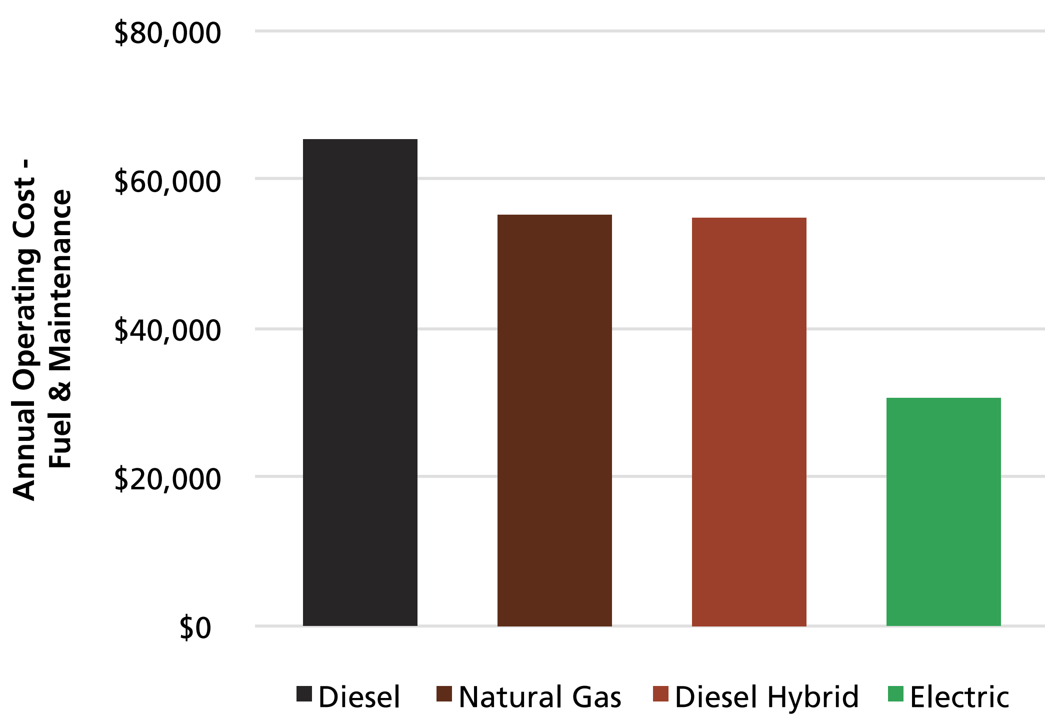
- Each electric school bus can save districts nearly $2,000 a year in fuel and $4,400 a year in reduced maintenance costs, saving tens of thousands of dollars over the lifetime of a bus.[7]

- The Chicago Transit Authority estimates that each electric transit bus in its fleet saves the city $25,000 in fuel costs every year.[8]

Cities in the United States and around the world are taking the lead, committing to transition to cleaner, quieter and more efficient electric bus fleets.

- The idea of all-electric school buses is spreading across the country and pilot programs are now underway in states including California, Massachusetts and Minnesota.

Figure ES-1. Estimated Annual Operating Costs of Transit Buses, by Fuel Type[9]



- The mayors of Los Angeles and Seattle have joined a pact with 10 other mayors around the world to purchase only electric transit buses after 2025.[10] Los Angeles County's transit agency, Metro, committed to go all-electric by 2030, while Shenzhen, China, transitioned its 16,000 buses to electric in December 2017.[11]

With reduced operating costs and no tailpipe emissions, all-electric buses and charging stations can be a smart infrastructure investment for school districts and transit providers across the country.

Electrifying buses is also an important first step towards broader adoption of heavy-duty electric vehicles, like trucks. While buses themselves account for a relatively small percentage of vehicle emissions, heavy duty vehicles as a whole are responsible for over a quarter of climate emissions from on-road transportation in the U.S.[12]

To support more widespread adoption, state governments should:

- Allocate settlement money from Volkswagen's "Dieselgate" settlement to subsidize the purchase of electric school and transit buses, as well as charging infrastructure.

- Create incentive programs and grants for transit agencies, school districts and bus contractors to help finance the upfront cost of electric buses and charging infrastructure.

- Facilitate the installation of charging infrastructure through programs that help cover the costs.

- Encourage utilities to design their rates in ways that support electric buses.

- Consider low-cost financing programs that help agencies, districts and bus contractors leverage other sources of funding, like Volkswagen settlement money.

- Identify other ways to ensure successful electrification of buses, including technical assistance and research, as well as the publication of data and lessons learned.

Transit agencies, school districts and bus contractors should:

- Replace buses powered by fossil fuels with the cleanest possible technology for the health of future generations: all-electric.

- Consider adopting goals to repower the entire fleet with electric buses over one replacement cycle.

- Ask state governments and beneficiary agencies to dedicate funds from the Volkswagen settlement to electric buses.

- Prepare for future adoption of electric buses by running electrical conduits necessary for charging infrastructure during any new construction or reconstruction of depots and parking lots.

Introduction

Buses are the workhorses of America's transportation system, carrying millions of Americans of all ages to school, work, shopping, recreation and other places they need to go. Buses travel on city streets and rural roads, serving every kind of community – and delivering benefits across the country.

Though the humble school bus isn't the first thing that pops to mind when it comes to public transit, the quintessential yellow bus is what half of all American kids take to public school each day.[13] With 480,000 school buses carrying up to 26 million children to school each day, school buses are the largest form of mass transportation in the country.[14] The American School Bus Council found that in 2010, school buses saved parents $6 billion in fuel costs and prevented 2.3 billion gallons of gasoline from being burned.[15]

Trips on transit buses account for nearly half of all public transit use in the U.S. – more than 3.5 billion rides were taken in the first three quarters of 2017, according to the American Public Transportation Association.[16] Public transit saves an estimated 37 million metric tons of carbon emissions and 4.2 billion gallons of gasoline each year.[17]

Energy savings and reduced emissions of greenhouse gases aren't the only benefits of buses. Buses provide a critical form of transportation to those who cannot or do not wish to drive – including children, the elderly and disabled people. Reliance on buses and other forms of public transportation can free households of the burden of owning a car (or owning an additional car), saving thousands of dollars each year.

Buses are also safe. Traditional school buses are designed with high-backed cushioned seats, crush-resistant roofs, and rollover protection to keep children from major harm.[18] According to the National Highway Traffic Safety Administration (NHTSA), riding a school bus to school is 70 times safer than traveling by car.[19] Transit buses are also safe, with much lower crash rates and fatality rates 60 times lower than cars, per million miles traveled.[20]

However, buses have traditionally had a major flaw that reduces the benefits they deliver to Americans and our communities: pollution. Numerous scientific studies have shown that diesel exhaust isn't just smelly, but is also dangerous, with links to lung cancer, asthma and even autism.[21] Children – including children riding on school buses – are among the most vulnerable to the health effects of diesel pollution.

As research began to pile up on the dangers of diesel soot, government and industry worked together to make diesel buses cleaner and introduce newer fuels that produce less tailpipe pollution. In spite of these efforts, more than half of America's transit buses continue to run on diesel fuel.[22] And though less-polluting models of diesel buses were a welcome improvement, technology now exists that can dramatically reduce the remaining health threats posed by diesel buses: the all-electric, battery-powered bus.

In this report, we review the exciting advances in electric bus technology, highlight the cities that are pioneering the use of electric buses in schools and transit agencies, and demonstrate why the transition to electric buses is needed to protect public health and reduce emissions of the pollutants that cause global warming. Some transit and school buses are publicly owned and operated, while others are owned or operated by private contractors. Public policy can play an important role in moving both of these models toward electric buses.

By transitioning from dirty fossil fuels to clean electricity, the humble bus can fully deliver on its potential to offer clean, accessible, convenient and low-carbon transportation across America.

Pollution from Transportation Threatens Public Health

Transportation produces more greenhouse gas emissions than any other sector in the United States and diesel buses are highly polluting vehicles. For example, in California, transportation contributes nearly 40 percent of the state's greenhouse gas emissions, with heavy-duty vehicles responsible for nearly a fifth of those emissions.[23] Heavy-duty vehicles like buses also produce large quantities of air pollution, impacting the health of residents and school children in the populous areas they serve.

Diesel exhaust from tailpipes is a dangerous pollutant – one that is common in the air in urban areas and places with frequent truck and bus traffic, including the schools where our children learn and play. The main pollutants emitted by diesel vehicles are particulate matter (very fine particles that can be harmful when inhaled), nitrogen oxides (which contribute to smog and ground-level ozone), hydrocarbons (which can cause cancer) and carbon monoxide (which can be dangerous in high concentrations).[24] These pollutants contribute to a variety of known health impacts, including:

Mortality risk: A 2017 study in the *New England Journal of Medicine* estimated the levels of air pollution experienced by 61 million Medicare beneficiaries between 2000 and 2012, based on their zip codes.[25] The researchers linked exposure to fine particulate matter and ground-level ozone to higher rates of mortality.[26] The study concluded that exposure to particulate matter and ozone, even at levels below national standards, contributes to adverse health impacts.[27]

Cancer rates: Diesel soot contains more than 40 toxic chemicals, including known or suspected carcinogens such as benzene, arsenic and formaldehyde.[28] Diesel exhaust itself is classified as a potential cancer agent by the U.S. EPA, and at least 19 of the hydrocarbons it contains are known to or suspected to cause cancer.[29] In 2012, the International Agency for Research on Cancer elevated the risk of diesel exhaust from "potentially carcinogenic" to "carcinogenic with sufficient evidence."[30] Specifically, exposure to diesel exhaust has been linked to higher rates of lung cancer and greater risk for bladder cancer.[31]

Respiratory concerns: Diesel pollution can also lead to decreased lung function, respiratory tract inflammation and irritation, persistent wheezing, and aggravated asthma symptoms.[32] Tiny particles of diesel soot (fine particulate matter, referred to as $PM_{2.5}$ for the maximum size of the particles, 2.5 micrometers) are especially hazardous because they can enter deep into lower airways, carrying toxic chemicals such as polycyclic aromatic hydrocarbons (PAHs) that irritate the respiratory tract.[33] Diesel exhaust also contains ultrafine particulate matter (the smallest airborne particles, measuring from nanometers to a few micrometers), which is unregulated and may pose an even greater health threat, since the small size of the particles allows them to travel deeper into people's lungs and bloodstream.[34]

Other impacts: Also present in diesel soot are tiny particles of carbon, metal oxides and heavy metals that have been linked to negative health impacts.[35] Diesel pollution contributes to other environmental and public health problems, including smog, acid rain and global warming. Though transit systems using diesel buses avert emissions when compared to driving single-occupancy vehicles, buses in the United States produced 19.8 million metric tons of greenhouse gases in 2015.[36]

Limits of "Clean" Diesel Technology

Increased awareness about the public health threats from diesel pollution has led environmental agencies and industry to limit emissions from diesel engines. While these efforts have reduced the dangers posed by diesel, none have been entirely successful in providing adequate protection for the environment and public health.

The EPA adopted more stringent diesel pollution standards in 2000, limiting the amount of sulfur allowed in diesel fuel, and the amount of particulate matter and nitrogen oxides that could be emitted from diesel vehicles. Specifically, the regulation required that:

- Starting in 2006 and phasing in through 2009, diesel fuel for vehicles had to be low sulfur. Ultra-low sulfur diesel produces 10 to 50 percent less soot when burned compared to traditional diesel.[37]

- Starting in 2007, diesel vehicles manufactured had to emit 90 percent less particulate matter than previous models.[38]

- Half of diesel vehicles sold between 2007 and 2009 had to emit 95 percent less nitrogen oxides and reduce emissions of harmful hydrocarbons.[39] By 2010, all diesel engines sold were to comply.[40]

However, despite these efforts, burning diesel for transportation remains dirty. Even in lower concentrations, the soot, chemicals and other emissions from diesel exhaust are potent public health threats. Some components of diesel exhaust, like ultrafine particles, pose health threats but remain unregulated.

Furthermore, regulations on diesel exhaust often fail to protect public health, as illustrated by recent scandals in which diesel vehicles were found to emit much higher levels of pollution during real-world driving than during required testing. In 2015, Volkswagen admitted it had intentionally manufactured diesel vehicles that only used pollution controls during laboratory tests, emitting up to 40 times more nitrogen oxide pollution while driving.[41] Eleven million Volkswagen cars were affected, while other major car companies have been accused of using similar devices, including Chrysler and Mitsubishi.[42]

The technology available today to limit air pollution from diesel engines remains inadequate, especially when compared to zero-emission electric buses that are already on the market and are increasingly affordable and reliable. Moreover, electric buses will get cleaner as our electricity grid is increasingly powered by renewable energy.

Children Are Especially Vulnerable to Exhaust Pollution

Children are most vulnerable to the negative health effects caused by air pollution; their respiratory systems are still developing and they inhale more air per pound of body weight than adults.[43] Diesel pollution is especially dangerous – for children, there is no established safe level of exposure to diesel exhaust pollutants.[44]

Credit: ThoseGuys119 via Flickr, CC BY 2.0.

Numerous studies have found that air pollution harms a child's lungs, especially if the child already suffers from asthma. A 2010 study conducted by researchers at Stanford University and the University of California, Berkeley, linked exposure to air pollution with altered gene expression among asthmatic children in California.[45]

Other studies have concluded that exposure to hydrocarbons from diesel exhaust in early childhood could increase the likelihood of developing asthma.[46] In 2013, another set of researchers looked specifically at the impact of diesel exhaust particles on children in Cincinnati and concluded the diesel exhaust made the children more susceptible to asthma by turning off certain genes.[47] Most recently, a 2017 Rutgers University study on asthmatic children living near an industrial New Jersey seaport with heavy diesel truck traffic found that greater exposure to carbon soot coincided with markers for lung inflammation.[48]

Air pollution found in diesel exhaust – particulate matter and metals like nickel and manganese – can also be harmful to developing fetuses. Researchers found a significant relationship between a pregnant mother's exposure to diesel soot and the chances her child could develop autism, adding to the body of evidence that air pollution, as early as in utero, is harmful for child development.[49]

Concerns about the effects of diesel exhaust on children's health are particularly troubling since millions of children spend considerable time each day on diesel buses – and many more attend schools where diesel buses pick up and drop off passengers and often idle with their engines running. Studies, such as the ones described above, looking specifically at emissions from diesel buses have verified those concerns.

Dirty Buses Expose Children and Neighborhoods to Dangerous Pollution

Air pollution from buses is a particular threat since buses transport large numbers of people and make many trips through densely populated areas. There are a number of ways that people are exposed to dangerous pollution from buses:

At School: Buses idling in front of schools are one way that children (along with their guardians and teachers) may be exposed to toxic diesel fumes. According to the EPA, air pollution at schools, including concentrations of benzene and formaldehyde, is higher during the hour when children are being picked up.[50] A

2013 study by researchers in Cincinnati found that concentrations of particulate matter and carbon at a school with many idling buses significantly decreased after a campaign to stop idling.[51]

While Riding the Bus: A real-time analysis in 2005 found that air quality inside a vehicle's cabin worsened when following a diesel bus – a troubling fact given that school bus caravans are common, especially on field trips or for sports events, and also an indicator of the sheer volume of pollution produced by buses, especially older ones.[52] The study found that the level of soot, hydrocarbons and nitrogen oxides to which passengers were exposed was 11 times higher when following a diesel bus compared to following no vehicle, and eight times higher than when trailing a gasoline vehicle.[53]

A number of studies have indicated that diesel fumes from school buses, particularly older ones, may "self-pollute," or cause air pollution within the bus itself. A 2001 study by NRDC and the Coalition for Clean Air found that diesel pollution inside school buses was up to four times higher than levels of pollution in cars driving in front of the buses.[54] A 2008 study of air pollution in diesel school buses in Austin, Texas also found higher concentrations of ultrafine particulate matter inside buses.[55] Higher levels of fine particulate matter and carbon were also found in school buses compared to air pollution in vehicles driving in front of the buses during a 2010 study in Seattle.[56]

In the Community: Another way people are exposed to dirty diesel pollution from buses is simply by living or working near the busy roads on which buses and other vehicles travel. More than 45 million Americans live within 300 feet of busy roads or other major transportation infrastructure, according to the U.S. EPA, and are at risk of exposure to dangerous pollutants in exhaust.[57] Pollution from traffic is highest near roads and can harm lung function, induce asthma in children, and increase the risk of death from heart disease.[58] Studies have also linked air pollution to problems with cognition. A 2017 cohort study of 2.2 million people in Ontario, Canada, found that residents living closer to busy roads had higher rates of dementia.[59] Reducing the number of cars on the road by expanding transit and other options, and electrifying vehicles, particularly the most-polluting like buses, can help reduce the health threats posed by busy roads.

Natural Gas Buses Contribute to Global Warming

Natural gas buses are often touted as a cleaner alternative to diesel and it was once thought that they would offer a climate benefit. While they can offer reduced nitrogen oxide emissions, natural gas buses may emit more greenhouse gas emissions than their diesel equivalents, largely due to low fuel economy.

The primary component of natural gas is methane, which is a powerful global warming pollutant. Over 20 years, methane traps 86 to 105 times more heat in the atmosphere than does the same amount of carbon dioxide.[60] As a result, even small methane leaks during the production, processing, storage and transportation of natural gas negate its lower emissions of carbon dioxide during combustion. Considering emissions produced outside of the bus's operation, natural gas-powered buses likely create *more* global warming pollution than diesel-powered buses.

A study by the environmental consulting firm M.J. Bradley & Associates compared tailpipe emissions of compressed natural gas transit buses and diesel transit buses, finding that carbon dioxide emissions were similar for the two types of buses.[61] However, in a lifecycle analysis (well-to-wheels, accounting for emissions from fuel production and driving), the natural gas buses were responsible for more greenhouse gas emissions than the diesel buses – contributing up to 13.3 additional tons of carbon dioxide-equivalent greenhouse gas emissions each year.[62]

Another study, by the international consulting firm Ricardo, concluded that greenhouse gas emissions are higher for natural gas buses compared to diesel buses.[63] In a lifecycle well-to-wheels analysis, the study found that natural gas-powered buses emitted 6 percent more annual greenhouse gas emissions than diesel buses.[64] A 2015 study by researchers from Carnegie Mellon University also found that, compared to conventional diesel transit buses, natural gas buses are responsible for 6 percent more lifetime greenhouse gas emissions.[65]

The extraction and production of natural gas can also cause air pollution and health impacts near gas operations. For example:

- In Northeastern Colorado, a study by researchers from the National Oceanic and Atmospheric Administration and the University of Colorado traced high levels of volatile organic compounds, precursors to ground level ozone, back to oil and gas operations.[66]

- In 2011, ozone levels in rural Wyoming exceeded the worst air pollution days in Los Angeles. [67] The worst days exceeded the EPA's healthy limit, prompting the Wyoming Department of Environmental Quality to urge the elderly and children to stay indoors.[68]

- A 2014 study in Utah linked oil and gas operations to the accumulation of air pollution and production of ground level ozone.[69]

Even in a best-case scenario, with near-zero emissions emitted from the buses themselves, reliance on natural gas cannot achieve deep reductions in greenhouse gas emissions, and worsens air pollution and health impacts where it is being extracted. Transitioning America's electricity grid to renewable energy and switching to electric transportation is the cleanest and safest option.

Most of America's Buses Still Run on Dirty Fuels

Today, most of the nation's public bus fleet continues to run on diesel, though all-electric models are becoming a viable and permanent solution to diesel pollution.

School Buses

Nearly a half-million school buses were on the roads in 2017, outnumbering transit buses roughly 12 to 1.[70] School buses come in a variety of sizes – some seat 20 children, while others can seat up to 90.[71] Around 25 million students ride school buses each day.[72]

Many of the school buses that children ride each day are old enough to predate the EPA's latest diesel emission standards.[73] According to a 2015 survey, the average age of a school bus in operation was 9.3 years, and school buses can operate for up to 16 years, suggesting that many school buses on America's streets were likely purchased before the 2007 clean diesel rules took place.[74] One estimate puts the number of pre-2007 school buses still on America's streets at 250,000.[75] Even newer buses likely run on diesel, with an estimated 95 percent of school buses in the country using diesel.[76]

The fuel efficiency of traditional diesel-powered school buses that fit 40 to 50 students is 7 miles per gallon (mpg), while hybrids average 9 mpg.[77] This puts a heavy cost burden on school districts: according to the American School Bus Council, districts pay an average of $6,600 each year in diesel fuel costs for every school bus in operation.[78] This also results in a significant amount of emissions, since school buses collectively traveled an estimated 3.3 billion miles in 2017.[79]

Switching to electric school buses offers the greatest opportunity to reduce emissions and schools' fuel costs. Electric school buses can get the equivalent of 17 miles per diesel gallon equivalent, and as America's electricity grid shifts to renewable energy, the buses will increasingly run on clean energy.[80] Replacing all of America's school buses with electric buses could avoid more than 5.3 million tons of greenhouse gas emissions each year and save more than $3 billion in diesel costs for school districts.[81]

Transit Buses

Though public buses help reduce overall transportation emissions by keeping individual cars off the road, all-electric fleets could yield even cleaner air. The transportation sector is responsible for 27 percent of total greenhouse gas emissions in the U.S., and public transportation buses on American streets collectively burned over 430 million gallons of diesel in 2014.[82]

According to the 2016 National Transit Database compiled by the Department of Transportation, 60 percent of transit buses active in the U.S. – more than 40,000 of 67,000 total – were conventional buses running on diesel.[83] Hybrid diesel buses made up another 12 percent of transit buses, while nearly 18 percent were powered by compressed natural gas.[84] Less than 1 percent of transit buses were powered entirely by electricity. (See Figure 1.)[85]

It is possible that more than half of buses on the road predate the latest EPA standard on diesel pollution. According to the 2016 National Transit Database, nearly 38 percent of the nation's active diesel bus fleet was manufactured prior to 2007 (the year that more stringent diesel standards went into effect) and have not been rebuilt.[87] An additional 7,400 buses, or 18 percent of the current fleet, were manufactured between 2007 and 2010, and haven't been rebuilt, so they may not meet current standards for nitrogen oxide and hydrocarbon pollution.[88]

Diesel buses average an estimated 4 miles per gallon; natural gas-powered buses don't fare much better, averaging just 4.5 miles per gallon (in diesel-equivalent mileage), while diesel hybrid buses average 5 miles per gallon.[89] Electric buses, on the other hand, are four times more energy efficient than diesel or natural gas buses, averaging over 17 miles per diesel gallon equivalent. (See Figure 2.)[90]

Replacing polluting diesel transit buses with electric buses could greatly reduce greenhouse gas emissions in the United States and benefits would continue to grow as America transitions to clean, renewable energy. Replacing all of the diesel-powered transit buses with electric buses in the United States could save more than 2 million tons of greenhouse gas emissions each year.[91]

Figure 1. Percent of Active Transit Buses in the U.S. by Fuel Type[86]

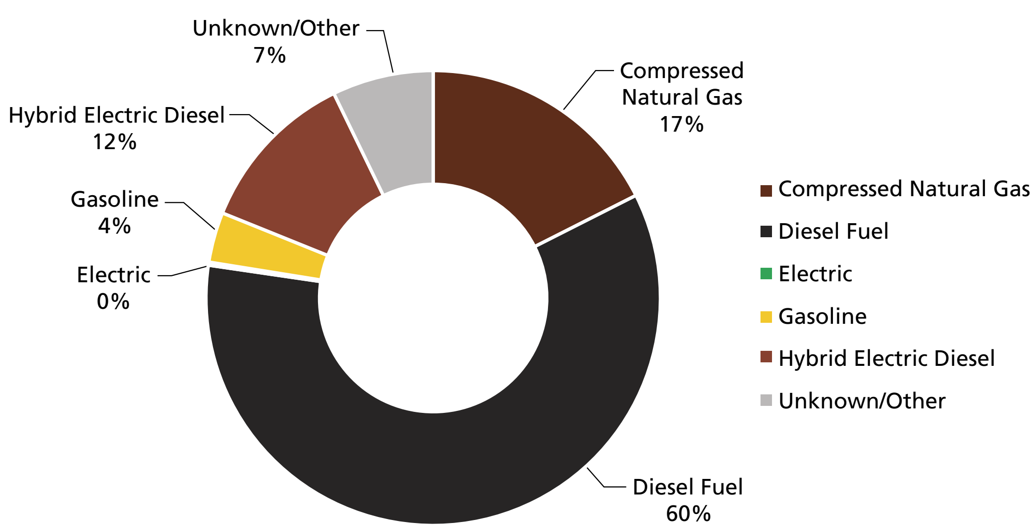
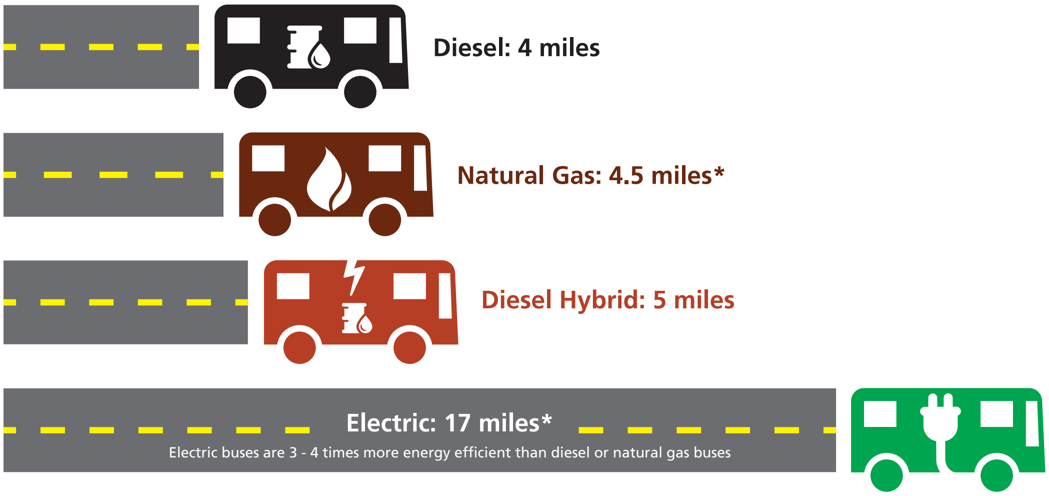


Figure 2. Distance Traveled per Gallon of Diesel (*or Diesel-Equivalent)



On a local level, transit agencies can help cities reduce their contribution to global warming by switching to electric buses. For instance, if Chicago Transit Authority replaced its 1,653 diesel buses with electric buses, it would save nearly 55,000 tons of greenhouse gases each year, equivalent to taking more than 10,000 cars off the roads. The transit agency serving Philadelphia, the Southeastern Pennsylvania Transportation Authority, could avert 22,000 tons of greenhouse gas emissions every year, akin to taking more than 4,000 cars off the road; replacing Denver's 828 diesel buses would save nearly 47,000 tons of global warming emissions each year, equivalent to removing more than 9,000 personal vehicles. (See Table 1. See Appendix A for a full list of America's 50 largest transit agencies.)[92]

By expanding transit options and improving bus service, while switching to clean electric buses, cities and towns across the country can help reduce global warming emissions and local air pollution.

Table 1. Potential Emissions Savings from Electric Buses for Select Transit Agencies

Agency	Major City Served	State	Annual Emissions Averted by Switching to Electric Buses (Short Tons)	Equivalent Number of Cars Taken Off the Road
City of Phoenix Public Transit Department (Valley Metro)	Phoenix	AZ	9,075	1,752
San Francisco Municipal Railway	San Francisco	CA	32,049	6,187
Denver Regional Transportation District	Denver	CO	46,967	9,067
Metropolitan Atlanta Rapid Transit Authority	Atlanta	GA	10,889	2,102
Chicago Transit Authority	Chicago	IL	54,993	10,616
Massachusetts Bay Transportation Authority	Boston	MA	55,071	10,631
Southeastern Pennsylvania Transportation Authority*	Philadelphia	PA	22,256	4,297
Metropolitan Transit Authority of Harris County	Houston	TX	21,715	4,192

Clean, All-Electric Buses Make Economic Sense for America's Schools and Cities

Until recently, significant barriers stood in the way of electric bus adoption: electric buses had limited range, were costly, and faced reliability challenges. Few were available on the market at all. But technological innovations and sharp declines in battery costs are solving many of these issues and manufacturers are producing high-quality, increasingly affordable, all-electric buses for use by school districts and transit agencies. These improvements are helping spur a boom in electric buses across the country.

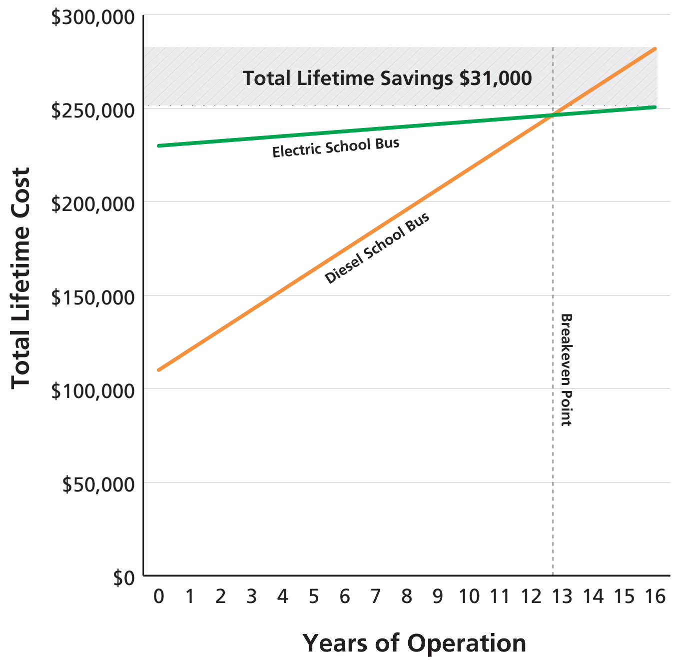
Long-Term Affordability

Savings for School Districts

All-electric school buses can save school districts money in annual operating costs from reduced maintenance and fuel costs, while also providing more predictability in costs each year since electricity prices are relatively stable compared to fuel prices. The fledgling electric school bus market is growing as more manufacturers begin offering options; for instance, school bus manufacturer Blue Bird started rolling out electric buses in 2018, while Thomas will follow in 2019.[93]

Initial results from a six-vehicle electric school bus pilot program funded by the Clinton Global Initiative illustrate how schools can potentially save money with electric buses. Their analysis found that an electric bus saves nearly $2,000 a year in fuel and $4,400 a year in reduced maintenance costs.[94] If the bus is equipped to send stored energy back to the electricity grid (see text box "Linking Electric Buses to the Electrical Grid Provides Greater Benefits," page 16), an electric school bus could potentially generate up to $6,000 in revenue each year, depending on their utility's rates. While a diesel school bus

Figure 3. Lifetime Cost of Electric and Diesel School Buses, Including Purchase Price, Operating Costs, and Vehicle-to-Grid Revenue[97]



costs $110,000 upfront and an electric school bus today costs $230,000 (including charging infrastructure), reduced operating costs for the electric bus more than make up the difference.[95] Factoring in other costs, like replacing the electric bus's battery, the study estimates that an electric school bus equipped with vehicle-to-grid capabilities makes up for its higher purchasing costs within 13 years of operation, saving more than $31,000 over the bus's lifetime. (School buses operate for up to 16 years. See Figure 3.)[96]

Government funding and other incentives can make school buses even more affordable (see section "Opportunities to Shift to Electric Buses," page 23.) For instance, California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) offers up to $220,000 for electric school buses sold in the state (the voucher amounts increased in December 2017, up from $110,000 previously).[98] An analysis by industry experts compared lifecycle costs of an all-electric school bus to a conventional diesel bus, using the old voucher amounts. The electric school bus used in the analysis originally cost $348,000, while the diesel bus cost $139,000 up front.[99] With California's voucher program and other incentives, the purchase price of the electric bus dropped to $218,000, or $79,000 more than the diesel bus.[100] However, the electric school bus saved $10,500 each year over the course of its 16-year lifespan, paying back the extra upfront cost in less than eight years, and continuing to offer savings for years to come.[101] With California's newly increased voucher amount of $220,000, the upfront cost of the electric bus would actually be lower than the upfront cost of the diesel bus, and would still offer fuel and maintenance savings each year. Finally, costs of electric school buses are expected to fall in coming years as more manufacturers, like Thomas and Blue Bird, enter the market and technologies improve.[102]

Linking Electric Buses to the Electrical Grid Provides Greater Benefits

Electric buses are powered by taking energy from the electricity grid; when they are plugged in, their large batteries charge and buses use that stored energy to travel on their routes. By managing when the vehicles are charging, electric buses can help support the electrical grid by charging at off-peak times. With appropriate pricing mechanisms and agreements with utilities, electric bus operators can benefit from financial incentives that support charging when demand is low. (See page 25 for more on agreements with utilities.) Used electric bus batteries could also be repurposed for energy storage at the end of the buses' useful lives, which can help support the electrical grid.

Finally, new technology allows buses to send stored energy back to the grid. When equipped with vehicle-to-grid technology, electric buses can use their batteries for energy storage, providing a service to the grid by reserving and selling electricity back at times of high demand. This is particularly valuable for school buses, which typically charge overnight when electricity demand is lower; are parked during the middle of day and evening, when demand is highest; and often aren't in use during the summer when air conditioning use peaks. For example, if a school bus had extra juice after driving children home in the afternoon, it could connect to the grid and sell excess energy back to the grid during the early evening hours when demand is still high.

Vehicle-to-grid features could help school districts make the finances of electric buses pencil out more easily. A 2014 analysis from researchers at the University of Delaware estimated that a school bus could generate more than $15,000 from selling energy back to the grid, providing net benefits after five years of operation.[103] Early pilot projects with electric school buses in three school districts in California found each bus could generate more than $6,000 each year by sending extra electricity back to the grid during periods of high demand.[104]

By providing a source of energy storage, electric buses could support a transition toward a grid powered by renewable energy – helping to incorporate variable sources of renewable energy like wind and solar into the grid. School buses may be particularly important for helping to integrate solar energy, since they are typically parked and can charge during peak solar production at mid-day.

Savings for Transit Agencies

Electric buses can be more affordable than fossil fuel buses in the long run, since they have 30 percent fewer parts, no exhaust systems, their braking systems last longer, and they don't require oil changes or fossil fuels.[105] According to studies of electric buses currently in operation, electric buses save at least $0.19 per mile in lower maintenance costs.[106] Over the lifetime of the bus, an electric transit bus can avoid hundreds of thousands of dollars in operating costs over an equivalent diesel or natural gas bus, from lower fuel and maintenance costs. According to an analysis by the California Air Resources Board, an electric bus purchased in 2016 can save $458,000 in fuel and maintenance costs compared to a diesel bus, $336,000 compared to a natural gas bus and $331,000 compared to a diesel hybrid bus. (See Figure 4.)[107]

Even though electric buses today are still more expensive upfront than their diesel or natural gas-powered counterparts, electric transit buses can pay for themselves within 10 years of operation through fuel savings and reduced maintenance costs. (See Figure 5.)[109]

New Flyer, the largest transit bus manufacturer in North America, says that its natural gas-powered buses start around $450,000 while their electric version starts at $700,000.[111] Over the lifetime of the bus, however, the company estimates the electric bus saves $400,000 in fuel expenses and $125,000 in averted maintenance costs, making up for the upfront cost differential.[112]

Proterra says its standard electric transit bus costs $750,000, compared to $500,000 for a conventional diesel bus.[113] The company estimates that its electric buses offer fuel and maintenance savings of up to $50,000 a year over fossil fuel-powered buses, meaning transit agencies can recoup the extra cost in five to seven years (depending on the bus's purchase price and operational cost variables), continu-

Figure 4. Estimated Lifetime Fuel and Maintenance Costs of Transit Buses, by Fuel Type[108]

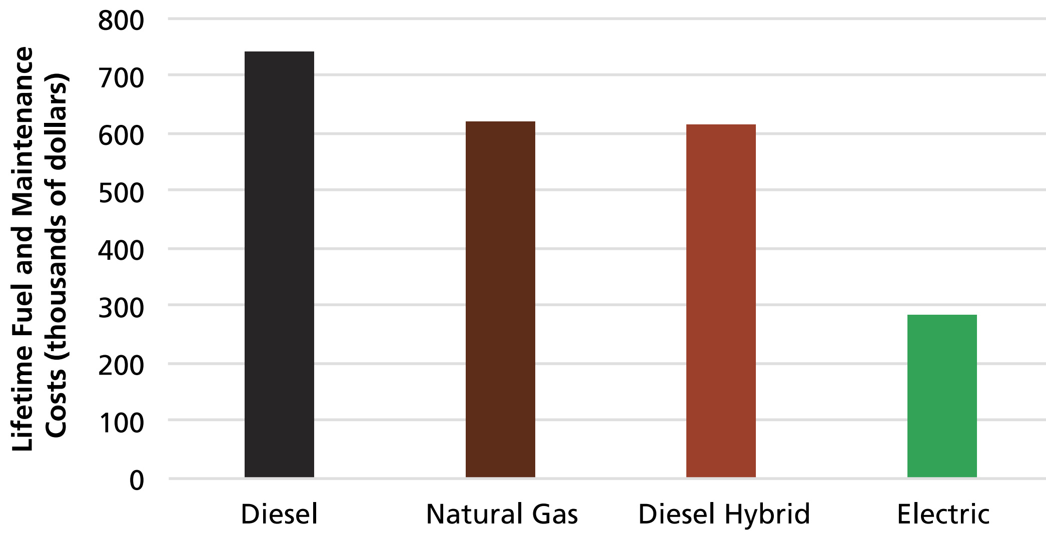


Figure 5. Cumulative Cost of Transit Buses, by Type, Including Purchase Price and Operations[110]

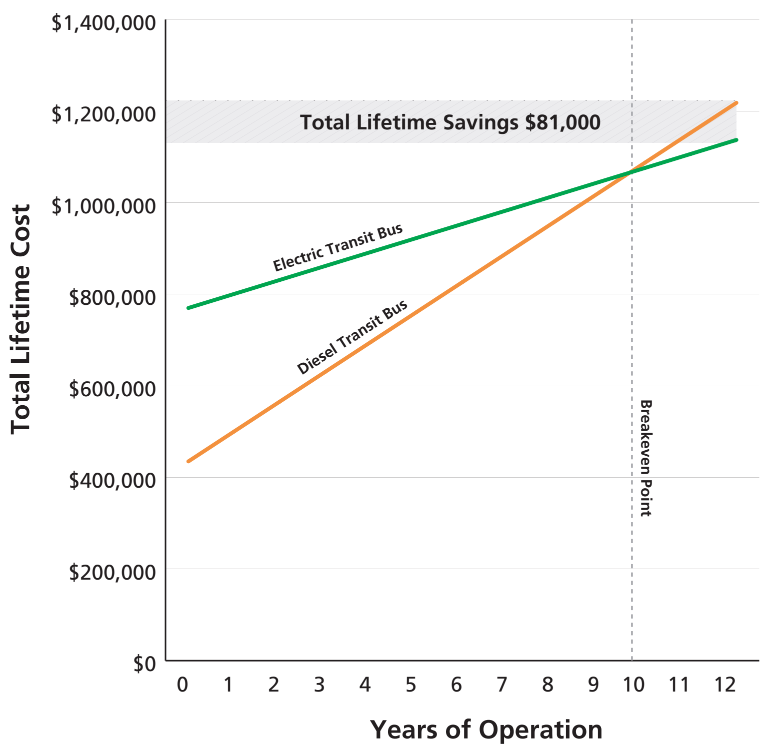
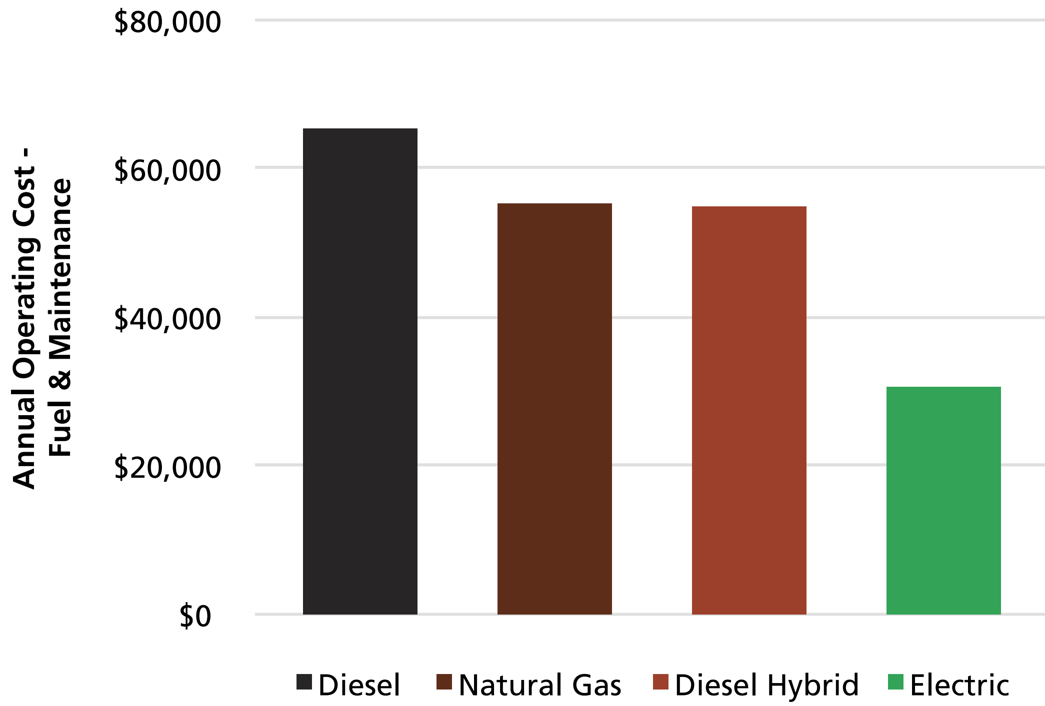


Figure 6. Estimated Annual Operating Costs, for Fuel and Maintenance, of Transit Buses, by Fuel Type[115]



ing to save money every year over the lifespan of the bus.[114]

Those savings don't account for the benefits of electric buses to the environment and public health, like cleaner air and less pollution. The Chicago Transit Authority (which in 2014 became the first major transportation agency in the U.S. to run an electric bus) estimates that a single electric bus saves the city nearly $80,000 per year: $25,000 in fuel and $55,000 in avoided healthcare expenses resulting from cleaner air.[116]

Because transit agencies can utilize federal assistance for capital costs, but not operating costs (through the Urbanized Area Formula Funding program), purchasing a bus with higher upfront costs but lower operating expenses may be a better value for agencies in the long run. Transit agencies in the U.S. can use federal money to pay for up to 80 percent of the purchase price of a bus (or other capital investment for transit).[117] A 2017 study from Carnegie Mellon University found that, with federal funding to help purchase the buses, all-electric buses had the lowest lifetime costs when compared with all other buses on the market, including hybrid, diesel, biodiesel or natural gas vehicles.[118] The study concluded that all-electric buses are the best option available to transit agencies because of their low lifetime costs and their environmental and public health benefits.[119]

The upfront cost of electric buses is falling, too. For example, in 2017, bus manufacturer BYD won a bid with LA Metro for 60 all-electric buses, with an estimated pre-tax price around $686,000 per bus, competitive with bids for low-NO_X natural gas buses priced around $620,000 before taxes.[120]

Increasing Range

Electric School Buses Get Kids to School and Back Home Again

Electric school buses today have ranges long enough to cover most school bus routes. For instance, Blue Bird has come out with two electric school buses, one small and one large, both of which can drive 100 miles on one charge. The company estimates that the 100-mile range can cover 80 percent of school bus routes with just an overnight charge, and up to 90 percent of school bus routes in the county if the bus can charge mid-day.[121] The full-size model will have a 150 kWh battery pack; both models will have vehicle-to-grid capability, allowing them to store energy for the grid when plugged in.[122] Production is slated for 2018.[123]

The Canadian company Lion is already selling the first all-electric medium-sized school bus built in North America.[124] The batteries of the "eLion" bus can store 130 kWh of electricity, providing range of 50 to 100 miles on a single charge, depending on the model.[125] It has an estimated battery life of 15 years and fully charges in four to six hours, though fast-charging development is already underway and is expected to be released soon.[126] GreenPower also offers a 72-person school bus that can travel 75 to 140 miles.[127]

A contactless electric bus charging station in Washington state. Credit: Creative Commons/SounderBruce, CC BY-SA 2.0

Electric Transit Buses Can Serve Urban Transportation Needs

Recent advances in the range capabilities of transit buses make them an increasingly feasible option for transit agencies. Hyundai's new electric bus can travel 180 miles on a single charge, New Flyer has a bus with a 200-mile range, and Proterra's electric bus models can travel 200 to 350 miles.[128] Typical bus routes in urban and rural areas are shorter than 200 miles a day, meaning that electric buses could serve most routes in the country with today's technology.[129] For longer routes, fast-charging options are available, whereby buses can charge for a few minutes periodically throughout their route, using technologies such as overhead contactless chargers. [130] (See photo on page 19.)

BYD has a 60-foot articulated electric bus ,the first of its kind, available in the U.S. today that can travel 200 miles with one charge.[131] One model in development from Proterra can store 660 kWh of energy in its battery and holds the world record for electric vehicle range after traveling 1,100 miles on a single charge in September 2017.[132] Connected to a high-speed charging system, the bus only takes one hour to be fully charged.[133]

Improved Reliability

Electric buses require less maintenance than other types of alternative-fuel buses, in part because they have 30 percent fewer parts than diesel buses and no exhaust systems.[134] A 2016 report from the National Renewable Energy Laboratory found electric transit buses required maintenance just once every 133,000 miles driven, while natural gas buses needed on average to be serviced every 45,000 miles.[135]

One concern with electric buses historically had been their ability to perform well in cold or wintery weather. Quebec, Canada, is operating 60 electric school buses while electric school buses are also on the road in Minnesota and Massachusetts, demonstrating the capability of electric buses to function in all kinds of weather. As transit operators and manufacturers gain more experience working in difficult environments, such as extreme cold, they learn solutions that improve reliability. For example, in 2015, Worcester, MA, experienced its greatest snowfall of all time, with a January blizzard dropping 34 inches of snow and February setting the record for coldest month ever. The agency had been operating six electric buses and identified the need to be able to heat the areas around fast chargers to clear ice and snow, as well as the charging section on the top of the bus.[136]

Major Cities and States Take the Lead on Bus Electrification

The market for electric buses is changing rapidly as technology improves and prices continue to fall. A 2018 study by Bloomberg New Energy Finance projected that the number of electric buses in the world will triple by 2025, a span of just seven years.[137] Driven by a need to combat air pollution, particularly in China, electric buses will become more popular and more affordable in a short amount of time.[138] Bloomberg notes that by 2026, the purchase price for some electric models will likely be cost competitive with diesel versions because of falling battery prices.[139]

At the end of 2016, there were roughly 300 zero-emission transit buses operating around the country, but hundreds more are on their way.[140] In a February 2017 interview, the CEO of Proterra said that by 2020, a third of all new buses sold in the country could be electric, jumping to 100 percent of sales by 2030.[141]

Demand for electric buses is high across the country. (See Appendix B for more transit agencies' electric bus plans.) For instance:

- In July 2017, the Los Angeles County Metropolitan Transportation Authority announced its transit fleet would be emission-free by 2030, requiring at least 2,300 electric buses.[142] In the agency's announcement, Metro Chairman and Los Angeles Mayor Eric Garcetti said, "We can wait for others, and follow – at the expense of residents' health – or lead and innovate, and reduce emissions as quickly as possible. I'd much rather do the latter."[143]

- Mayors of 16 cities in California, representing nearly 8 million people, submitted a letter in January 2018 in support of state proposal that would require all fleets in California to be 100 percent electric by 2029.[144]

- King County Metro Transit, which serves the Seattle area, will acquire 120 all-electric buses by 2020.[145]

- MTA New York City Transit, the country's largest transit network, started testing five New Flyer electric buses across its system in February 2018, and similar tests are planned for Boston, Los Angeles, Portland and Salt Lake City in 2018.[146] The buses will have access to rapid charging at the beginning and end of their routes and will enable the transit agencies to better define their needs, helping to inform the electric bus market.[147]

- Since 2016, seven agencies in California, making up one-third of the state's transit buses, have committed to all-electric fleets by 2040.[148] For example, Antelope Valley Transit Authority in southern California plans to convert all of its 85 buses to electric by 2021, saving an estimated $46 million over the lifetime of the buses.[149]

- In January 2018, the Chicago Transit Authority requested proposals for 45 new all-electric buses.[150]

Outside the U.S., other cities are leading the way. In December 2017, Shenzhen, China, became the first city in the world to exclusively operate all-electric buses.[151] The city currently owns more electric buses than any other city, operating more than 16,000 buses – about three times the size of New York City's bus fleet, the largest in the U.S.[152] The transition in Shenzhen illustrates the technological readiness of electric buses and the immediate feasibility of large-scale transitions.

Investment and interest from manufacturers is growing as well, thereby expanding the number of options available and reducing costs. For instance, in May 2017, Hyundai unveiled its first electric bus.[153] In October 2017, Volkswagen announced plans for a $1.7 billion investment in electric vehicles including buses and trucks.[154] Volvo has also been developing new models of electric buses, expanding their range and improving battery and charging technology.[155]

School districts are also starting to electrify their buses. The largest pilot program is underway in California, providing three school districts with 29 electric buses from the manufacturers Lion, TransTech and Motiv Power Systems.[156] In 2016, four school districts in Massachusetts became the first outside of California to purchase electric school buses – four in total, made by Lion.[157] In the fall of 2017, the first electric school bus (also manufactured by Lion) arrived in the Midwest in the suburbs of Minneapolis-St. Paul, Minnesota.[158]

Opportunities to Shift to Electric Buses

America's fossil fuel buses produce large quantities of greenhouse gas emissions and air pollution, contributing to climate change and public health problems. Any new diesel buses purchased now will continue polluting for years to come since transit and school buses have lifespans longer than a decade. Fortunately, electric buses produce far fewer carbon emissions over their lifetime and eliminate localized air pollution from fossil fuel burning on city streets. As America transitions to an electrical grid powered by renewable energy, electric buses will offer even greater environmental benefits. Considering all of America's nearly 70,000 transit buses and 480,000 school buses will have to be replaced in the next 15 to 20 years, there is room for large-scale adoption of electric buses.

The time is right for state and local officials to begin making the shift to all-electric public transportation. The falling costs of electric buses, coupled with the availability of new funds to support the transition, provide an opportunity for school districts, transit agencies, cities and others to accelerate the transition to clean electric buses. Opportunities for funding electric buses include:

Volkswagen Settlement Money: The recent settlement in the "Dieselgate" case, which resulted from Volkswagen's (VW) deliberate violation of clean air standards, awarded billions of dollars for state and local officials to invest in zero-emission transportation.[159] Of the settlement, $2.7 billion created a Mitigation Trust that allocates funds to states to replace heavy-duty vehicles including school buses and transit buses and charging infrastructure.[160]

In states across the country, there has been interest in spending the settlement money on replacing diesel buses with all-electric alternatives. For example:

- Major utilities, including Duke Energy and Indianapolis Power & Light Company, voiced support for using the VW funds to buy electric school buses.[161] Transit agencies are also eager for the funding to switch to electric buses – from Lane County, OR, to Colorado Springs, CO, transit agencies are asking for portions of the settlement money to purchase electric buses.[162]

- Colorado plans to spend $18 million, or a quarter of its allocated Volkswagen settlement money, to help pay for cleaner transit buses – including an estimated 30 electric buses – and another $18 million can be used for electric school buses.[163]

- In Ohio's first round of public comments, the most common requests were for settlement money to go towards school and transit bus replacements.[164] The state's draft plan from December 2017 allocates $3 million for electric school bus technology.[165]

- The state of Washington is devoting up to 45 percent of its VW funding to electrification of buses and trucks.[166]

State Programs: There are several existing programs at the state level that could help transit agencies finance a transition to clean buses. One example is California's voucher program, the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), which is funded by the state's cap-and-trade carbon reduction system and run by the California Air Resources Board.[167] The program provides funds to help fleets purchase lower emission vehicles, with the goal of improving the state's air quality and combating global warming.[168] Fleet operators can apply for vouchers, worth between $80,000 to $175,000 for one electric transit bus and $25,000 to $220,000 for electric school buses depending on the size, and up to $20,000 to invest in inductive (contactless) charging systems.[169] For fiscal year 2018, $180 million has been budgeted for bus and truck vouchers, with at least $35 million supporting the purchase of zero-emission buses.[170] In Colorado, fleets in areas of the state with air pollution concerns can apply for funding to help purchase electric buses, including up to $35,000 per bus for public bus fleets and $22,000 per bus for private bus fleets.[171]

Federal Funding: A number of programs exist at the federal level that may help states, transit agencies and local officials purchase electric buses, such as:

- The U.S. Department of Transportation's Low or No Emission Vehicle Competitive Program makes $55 million in grants available each year, through 2020, to purchase or lease electric buses.[172] In 2017, transit agencies in 38 states were granted up to $1.75 million through the program to finance the purchase of electric buses and supporting charging infrastructure.[173]

- The federal Congestion Mitigation and Air Quality (CMAQ) Improvement Program provides flexible funding for state and local governments for projects that help reduce air pollution in areas that exceed clean air standards. Funding of more than $2 billion a year is available through CMAQ through 2020.[174] Chicago's transit agency, for example, will use funding from this program to purchase 10 electric buses and two charging stations.[175]

- Cities with populations of more than 50,000 may be able to use funds from the Urbanized Area Formula Funding program, which will cover up to 80 percent of a project, and can be used to replace or rebuild buses.[176] The program offers more than $5 billion each year, through 2020.[177]

- For school buses, the Clean School Bus Act of 2010 also made funding available to help districts pay for buses that operate on alternative fuels.[178] The School Bus Rebate Program, for instance, provided more than $7 million to replace and retrofit old school buses in 2017.[179]

Utilities: Utilities could play a major role in supporting the transition to electric buses. By providing beneficial rate structures for electric bus charging, and supporting charging infrastructure, utilities can help speed the adoption of electric buses. Utilities can also benefit from electricity sales to electric bus fleets. There are a number of ways for utilities to engage with electric buses, including:

- Investing in the electrical infrastructure needed for bus charging at bus depots and on routes.

- Developing specific rate structures for transit agencies and school buses in order to help make charging electric buses more economical.

- Helping to finance the additional upfront cost of electric buses by entering agreements with transit agencies to help finance charging infrastructure and bus batteries. For example, in some agreements, utilities pay for electric bus batteries and charging infrastructure upfront and allow transit agencies to pay monthly, at an amount no greater than the fuel savings the agency is reaping from avoided diesel costs.[180]

- Introducing smart charging systems to help maximize integration of renewable energy.

A number of utilities have begun small scale programs, which could provide the model for larger-scale investment going forwards. For example, Southern California Edison received approval from the California Public Utilities Commission for a pilot program in which the utility will invest in the infrastructure needed to install 20 electric bus charging ports, while providing rebates to the transit agencies for the costs of the actual charging equipment.[181] Pacific Gas and Electric has also received approval for a school bus and renewable energy integration pilot.[182] The utility will invest in electrical infrastructure for electric bus charging and will work with school districts to ensure the buses are charging during times of peak solar production.[183] Portland General Electric will partner with the transit agency Tri-Met to enable Oregon's first all-electric bus route.[184] The utility will install and operate six electric bus charging stations and help Tri-Met purchase an additional electric bus.[185]

Another way utilities can help facilitate electric bus adoption is by developing more appropriate rate structures for electric bus charging. For typical electricity use, utilities charge for the total amount of energy consumed and charge for usage during peak times. Since buses use significant amounts of electricity, additional charges can be a financial hurdle. By offering rate structures that work better for bus charging, and by using energy storage and incentivizing charging during non-peak times, utilities and agencies operating buses can support one another. For example, Foothill Transit in California negotiated with its utility for lower demand charges during its electric bus pilot.[186]

Other Programs: Other programs may also be available to help offset the initial investment in purchasing an electric school or transit bus. For instance, in June 2017, the pollution control agency for parts of southern California, the South Coast Air Quality Management District, awarded nearly $9 million total for a number of school districts to purchase electric school buses and charging infrastructure.[187]

Chicago's Drive Clean program provided $14 million through the city's Department of Transportation to help fleets buy electric and alternative fuel vehicles. The program provided $10 million for electric buses and trucks.[188]

Using funds from a regional greenhouse gas cap-and-trade system, Massachusetts funded a pilot program that awarded grants to four school districts to purchase vehicle-to-grid electric school buses and chargers.[189]

Transit agencies can also utilize financing and leasing programs through bus manufacturers themselves. For instance, since the highest incremental cost for electric buses is the battery, Proterra has started a battery leasing program. This system allows customers to purchase an electric bus at the same cost of a diesel bus, while Proterra retains ownership over the battery.[190] Customers then pay for the usage of the battery each year, over a 12-year agreement, thereby reducing the barrier of higher upfront capital costs.[191] Used electric bus batteries could also be sold for a second life as energy storage systems, which could also help support the grid's transition to renewable energy.[192]

Finally, a report by Bloomberg New Energy Finance notes that agencies can partner with other cities to create a bigger agreement with private bus contractors in order to secure better rates on electric buses.[193]

Future Changes: Incentives like those outlined above can help offset the higher purchase price of electric buses today. However, experts like the California Air Resources Board predict that the cost of electric buses will continue to decline and soon incentives will no longer be necessary.[194] The commitment by cities such as Seattle and Los Angeles to embrace the electric bus revolution and electrify their entire fleets can help push the electric bus market to develop more efficient and cheaper technology. This kind of innovation would put the zero-emission transition within closer reach much sooner for all cities.

Industry experts predict that production and sale of all-electric buses will skyrocket in the next decade.[195] That would be good news for transportation that's cleaner, healthier and cheaper in the long run. With measurable benefits to public health and long-term savings on fuel and maintenance costs, zero-emission buses are a smart transportation investment.

But the widespread adoption of electric buses is not inevitable. And, to get the greatest health and environmental benefits out of electric buses, we need to start now. With the right government policies, the upfront costs of all-electric buses and charging stations can be made affordable for every transit provider and school district in the country.

Recommendations

To speed the adoption of all-electric buses as the new norm in American public transit, state governments should:

- Allocate settlement money from Volkswagen's "Dieselgate" settlement to subsidize the purchase of electric school and transit buses, as well as charging infrastructure.

- Create incentive programs and grants for transit agencies, school districts and bus contractors to help finance the upfront cost of electric buses and charging infrastructure.

- Facilitate the installation of charging infrastructure through programs that help cover the costs.

- Encourage utilities to design their rates in ways that support electric buses.

- Consider low-cost financing programs that help agencies, districts and contractors leverage other sources of funding, like Volkswagen settlement money.

- Identify other ways to ensure successful electrification of buses, including technical assistance and research, as well as the publication of data and lessons learned.

Transit agencies, school districts and bus contractors should:

- Replace buses powered by fossil fuels with the cleanest possible technology for the health of future generations: all-electric.

- Consider adopting goals to repower the entire fleet with electric buses over one replacement cycle.

- Ask state governments and beneficiary agencies to dedicate funds from the Volkswagen settlement to electric buses.

- Prepare for future adoption of electric buses by running electrical conduits necessary for charging infrastructure during any new construction or reconstruction of depots and parking lots.

Methodology

Emissions Averted by Replacing Diesel Buses

We used Argonne National Laboratory's Heavy-Duty Vehicle Emissions Calculator to estimate the lifecycle well-to-wheels greenhouse gas emissions that would be averted by converting all of the country's diesel transit buses and diesel school buses to electric buses, as well as the savings from individual transit agencies switching their diesel buses to electric buses.

Transit Buses, Nationally: According to the 2016 National Transit Database, the United States has 40,105 active diesel transit buses and we used Argonne's emissions calculator to estimate emissions savings from replacing all of them with electric buses.[196] We assumed a new electric transit bus would have a lifespan of 12 years.[197] We used Argonne's default estimate for the annual miles traveled by new transit buses – 35,000. Finally, we applied the calculator's "diesel in-use multiplier," which accounts for real-world inefficiencies in diesel buses, instead of relying on laboratory results.

To estimate the emissions resulting from charging electric buses that accounts for states' varying electricity grids, we calculated emissions savings in the calculator using Florida's electricity grid, which has around the median level of carbon dioxide equivalents per megawatt hour for states in the country, according to the EPA's eGRID database.[198]

This results in a lifetime savings of approximately 24,541,000 short tons of greenhouse gas emissions (over 12 years), or an average of 2,045,000 short tons each year.

Transit Buses, By Agency: We followed the same steps for the 50 largest transit agencies in the country (by number of active buses in their fleet according to the 2016 National Transit Database). However, the electricity grid selected for the analysis in the Argonne tool was changed to reflect the state where each transit agency is located, therefore states with less carbon-intensive fuel sources see a greater reduction in emissions by switching to electric buses.[199]

The 2016 National Transit Database doesn't reflect recent updates from transit agencies, so in Appendix B we included updates from some of America's biggest transit agencies that are running electric buses now or have plans to acquire electric buses in coming years.

School Buses, Nationally: There are approximately 480,000 school buses on American streets, according to the American School Bus Council.[200] The industry publication, *School Transportation News*, estimates that 5 percent of those buses are powered by non-diesel fuels like natural gas, propane or electricity.[201] We assumed the other 95 percent of school buses ran on diesel, so 456,000 diesel buses would be replaced with electric buses, and used a lifespan of 16 years for the new school bus.[202] We used Argonne's default estimate for the annual miles traveled by new school buses – 15,000. We again applied the calculator's "diesel in-use multiplier" and used Florida to reflect an average electricity grid.

This results in a lifetime savings of 84,902,000 short tons of greenhouse gas emissions (over 16 years), or an average of 5,306,000 tons each year.

Appendix A: **Bus Fleets of America's 50 Largest Transit Agencies (by Number of Active Buses), 2016**

Agency	Major City or Area Served	State	Average Annual Greenhouse Gas Emissions Averted By Switching All Diesel Buses in Fleet to Electric (Short Tons)	Equivalent Number of Cars Taken Off The Road	Diesel Buses	Compressed Natural Gas	All-Electric	Hybrid Diesel	Gasoline	Other/ Unknown	Total Active Buses
CITY OF PHOENIX PUBLIC TRANSIT DEPARTMENT (VALLEY METRO)	Phoenix	AZ	9,075	1,752	160	173	0	0	0	174	507
REGIONAL PUBLIC TRANSPORTATION AUTHORITY	Phoenix	AZ	3,516	679	62	243	0	17	11	7	340
ORANGE COUNTY TRANSPORTATION AUTHORITY	Anaheim	CA	1,531	296	27	367	0	0	314	174	882
LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY (METRO)*	Los Angeles	CA	3,516	679	62	2,448	0	0	0	0	2,510
FOOTHILL TRANSIT	Los Angeles	CA	NA	NA	0	353	17	0	0	0	370
ALAMEDA-CONTRA COSTA TRANSIT DISTRICT	Oakland	CA	32,049	6,187	565	0	0	0	10	13	588
SAN DIEGO METROPOLITAN TRANSIT SYSTEM	San Diego	CA	2,098	405	37	510	0	0	0	12	559
SAN FRANCISCO MUNICIPAL RAILWAY	San Francisco	CA	32,049	6,187	565	0	0	19	4	0	588
SANTA CLARA VALLEY TRANSPORTATION AUTHORITY	San Jose	CA	20,420	3,942	360	0	0	134	0	11	505
DENVER REGIONAL TRANSPORTATION DISTRICT*	Denver	CO	46,967	9,067	828	33	2	11	0	0	874
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY*	Washington, D.C.	D.C.	9,215	1,779	277	482	0	864	0	0	1,623
BROWARD COUNTY TRANSIT DIVISION	Fort Lauderdale	FL	12,799	2,471	251	0	0	86	0	0	337
MIAMI-DADE TRANSIT	Miami	FL	36,307	7,009	712	0	0	121	0	0	833
CENTRAL FLORIDA REGIONAL TRANSPORTATION AUTHORITY	Orlando	FL	14,839	2,865	291	4	0	46	20	0	361
PINELLAS SUNCOAST TRANSIT AUTHORITY	St. Petersburg	FL	19,326	3,731	379	1	0	21	9	0	410

Appendix A: **Bus Fleets of America's 50 Largest Transit Agencies (by Number of Active Buses), 2016**

Agency	Major City or Area Served	State	Average Annual Greenhouse Gas Emissions Averted By Switching All Diesel Buses in Fleet to Electric (Short Tons)	Equivalent Number of Cars Taken Off The Road	Diesel Buses	Compressed Natural Gas	All-Electric	Hybrid Diesel	Gasoline	Other/ Unknown	Total Active Buses
METROPOLITAN ATLANTA RAPID TRANSIT AUTHORITY	Atlanta	GA	10,889	2,102	242	424	0	0	0	0	666
CITY AND COUNTY OF HONOLULU DEPARTMENT OF TRANSPORTATION SERVICES**	Honolulu	HI	-1,440	-278	449	0	0	92	0	0	541
CHICAGO TRANSIT AUTHORITY*	Chicago	IL	54,993	10,616	1653	0	2	214	0	0	1,869
PACE - SUBURBAN BUS DIVISION	Chicago	IL	31,971	6,172	961	20	0	2	158	0	1,141
PACE-SUBURBAN BUS DIVISION, ADA PARATRANSIT SERVICES	Chicago	IL	6,986	1,349	210	0	0	0	156	0	366
MASSACHUSETTS BAY TRANSPORTATION AUTHORITY	Boston	MA	55,071	10,631	695	314	0	0	3	53	1,065
MARYLAND TRANSIT ADMINISTRATION*	Baltimore	MD	10,912	2,107	328	0	0	404	0	0	732
RIDE-ON MONTGOMERY COUNTY TRANSIT	Montgomery County	MD	5,722	1,105	172	102	0	64	0	0	338
CITY OF DETROIT DEPARTMENT OF TRANSPORTATION	Detroit	MI	11,012	2,126	331	0	0	0	0	0	331
METRO TRANSIT*	Minneapolis	MN	20,785	4,013	833	0	0	5	0	0	838
BI-STATE DEVELOPMENT AGENCY OF THE MISSOURI-ILLINOIS METROPOLITAN DISTRICT, (ST. LOUIS METRO)	St. Louis	MO	18,584	3,588	413	0	0	0	0	0	413
CHARLOTTE AREA TRANSIT SYSTEM	Charlotte	NC	29,023	5,603	645	0	0	50	0	0	695
NEW JERSEY TRANSIT CORPORATION*	Newark	NJ	43,948	8,484	1321	0	0	0	0	0	1,321
REGIONAL TRANSPORTATION COMMISSION OF SOUTHERN NEVADA	Las Vegas	NV	15,145	2,924	267	202	0	188	0	0	657

Appendix A: **Bus Fleets of America's 50 Largest Transit Agencies (by Number of Active Buses), 2016**

Agency	Major City or Area Served	State	Average Annual Greenhouse Gas Emissions Averted By Switching All Diesel Buses in Fleet to Electric (Short Tons)	Equivalent Number of Cars Taken Off The Road	Diesel Buses	Compressed Natural Gas	All-Electric	Hybrid Diesel	Gasoline	Other/ Unknown	Total Active Buses
NIAGARA FRONTIER TRANSPORTATION AUTHORITY	Buffalo	NY	24,247	4,681	306	9	0	0	0	0	315
NASSAU INTER COUNTY EXPRESS	Nassau County	NY	633	122	8	307	0	0	0	0	315
METROPOLITAN TRANSIT AUTHORITY (MTA) NEW YORK CITY TRANSIT*	New York City	NY	167,037	32,247	2,108	532	0	1,285	0	0	3,925
MTA BUS COMPANY	New York City	NY	43,740	8,444	552	213	0	0	0	0	765
METROPOLITAN TRANSIT AUTHORITY	New York City	NY	21,711	4,191	274	0	9	46	0	0	329
WESTCHESTER COUNTY BEE-LINE SYSTEM	Westchester County	NY	18,225	3,518	230	0	0	99	0	0	329
SOUTHWEST OHIO REGIONAL TRANSIT AUTHORITY	Cincinnati	OH	12,742	2,460	383	0	0	27	0	0	410
THE GREATER CLEVELAND REGIONAL TRANSIT AUTHORITY	Cleveland	OH	10,379	2,004	312	90	0	21	24	20	467
CENTRAL OHIO TRANSIT AUTHORITY	Columbus	OH	8,949	1,728	269	124	0	6	0	0	399
TRI-COUNTY METROPOLITAN TRANSPORTATION DISTRICT OF OREGON	Portland	OR	39,990	7,720	705	0	0	0	0	0	705
SOUTHEASTERN PENNSYLVANIA TRANSPORTATION AUTHORITY*	Philadelphia	PA	22,256	4,297	669	0	0	747	0	0	1,416
PORT AUTHORITY OF ALLEGHENY COUNTY*	Pittsburgh	PA	23,121	4,464	695	0	0	32	0	0	727
CAPITAL METROPOLITAN TRANSPORTATION AUTHORITY	Austin	TX	22,644	4,371	512	0	0	0	0	0	512
DALLAS AREA RAPID TRANSIT	Dallas	TX	2,786	538	63	477	0	0	0	0	540

Appendix A: Bus Fleets of America's 50 Largest Transit Agencies (by Number of Active Buses), 2016

Agency	Major City or Area Served	State	Average Annual Greenhouse Gas Emissions Averted By Switching All Diesel Buses in Fleet to Electric (Short Tons)	Equivalent Number of Cars Taken Off The Road	Diesel Buses	Compressed Natural Gas	All-Electric	Hybrid Diesel	Gasoline	Other/ Unknown	Total Active Buses
METROPOLITAN TRANSIT AUTHORITY OF HARRIS COUNTY, TEXAS	Houston	TX	21,715	4,192	491	7	0	316	40	0	854
VIA METROPOLITAN TRANSIT	San Antonio	TX	16,717	3,227	378	38	3	30	0	14	463
UTAH TRANSIT AUTHORITY	Salt Lake City	UT	22,746	4,391	401	47	0	31	10	0	489
TRANSPORTATION DISTRICT COMMISSION OF HAMPTON ROADS	Virginia Beach	VA	8,749	1,689	263	0	0	29	76	0	368
KING COUNTY DEPARTMENT OF TRANSPORTATION*	Seattle	WA	30,007	5,793	529	0	3	724	137	30	1,423
SNOHOMISH COUNTY PUBLIC TRANSPORTATION BENEFIT AREA CORPORATION	Snohomish County	WA	14,578	2,814	257	0	0	30	41	0	328
MILWAUKEE COUNTY TRANSIT SYSTEM	Milwaukee	WI	10,080	1,946	404	0	0	0	0	0	404

* For an update on this transit agency's plans for electric vehicles, please see Appendix B.

** Hawaii: Because Hawaii's primary source of electricity is petroleum, the benefits of switching to all-electric buses are limited right now. However, the state has plans to switch to 100 percent renewable energy by 2040, which means electric buses will continue getting cleaner as they run on electricity powered by more renewable energy.[203]

Appendix B: **Proposed Electric Bus Plans for Some of America's Largest Transit Agencies**

Agency	Major City or Area Served	State	Total Active Buses	Proposed Electric Bus Plans
MTA NEW YORK CITY TRANSIT	New York City	NY	3,925	In January 2018, MTA started a 3-year pilot running 10 electric transit buses throughout New York City.
LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY	Los Angeles	CA	2,510	In July 2017, Metro approved the purchase of 95 new electric buses, which will be rolled out in coming years.
CHICAGO TRANSIT AUTHORITY	Chicago	IL	1,869	Between October 2017 and January 2018, the agency was accepting proposals for up to 45 electric buses. In February 2018, CTA received $400,000 from the U.S. EPA for electric buses; the agency will contribute an additional $490,000.
WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY	Washington, D.C.	D.C.	1,623	D.C. will be bringing 14 all-electric buses online in 2018.
KING COUNTY DEPARTMENT OF TRANSPORTATION	Seattle	WA	1423	By the middle of 2018, the agency will roll out another 10 all-electric buses and has purchased 120.
SOUTHEASTERN PENNSYLVANIA TRANSPORTATION AUTHORITY	Philadelphia	PA	1416	SEPTA is rolling out 25 all-electric buses in 2018.
NEW JERSEY TRANSIT CORPORATION	Newark	NJ	1321	In October 2017, NJ Transit announced it would use funds from a Federal Transit Administration grant for the state's first electric buses in Camden, NJ.
DENVER REGIONAL TRANSPORTATION DISTRICT	Denver	CO	874	Starting in the fall of 2016, RTD made all of the 36 free shuttle buses that run on a main street through downtown Denver into electric buses.
METRO TRANSIT	Minneapolis	MN	838	In 2019, Metro Transit will use $1.75 million in federal funding to purchase six all-electric buses.
MARYLAND TRANSIT ADMINISTRATION	Baltimore	MD	732	In 2017, three all-electric buses rolled out in Howard County.
PORT AUTHORITY OF ALLEGHENY COUNTY	Pittsburgh	PA	727	In 2019, Port Authority plans to have one all-electric bus in operation, ahead of a proposed Bus Rapid Transit system with 25 all-electric buses.

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