POLICY BRIEF

Public Transit Leading in Transition to Clean Technology

Key Takeaways

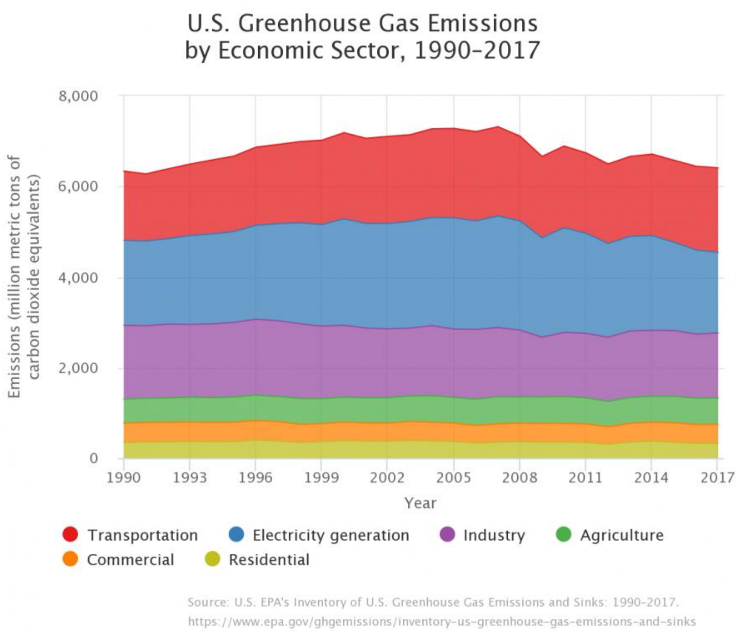
1. **The transportation sector is the largest greenhouse-gas-emitting sector.** Transitioning to cleaner fuel sources can help reduce emissions and can be a key component of a region's Climate Action Plan. In addition, alternative fuels that reduce or eliminate harmful emissions have health benefits for these regions.

2. **Public transit bus fleets are undergoing a dramatic shift in their makeup.** Today, more than 21 percent of fleet vehicles are hybrid-electric. Moreover, public transit agencies are beginning to integrate zero-emission buses into their fleets and are setting goals for 100 percent zero-emission bus fleets in future years.

3. **While capital costs for zero-emission buses remain higher than those of conventional buses, the lifetime costs of zero-emission buses are projected to be competitive with conventional buses**. Hurdles to adoption include the complexity of integrating charging and refueling infrastructure with existing public transit facilities and reconciling the range of current battery-electric buses with route operations.

4. **Federal grant programs have been vital resources** for public transit agencies nationwide in acquiring new zero-emission vehicles. Continued assistance from states implementing zero-emission mandates will be critical for these agencies.

Although the United States is no longer leading at a federal level with respect to climate initiatives and goals, cities around the country are stepping up and are pledging to curb emissions. Transportation will be a critical part of these efforts because it currently accounts for 29.5 percent of total U.S. greenhouse gas (GHG) emissions and is the largest emitting sector [Ref. 1].



More than 36 U.S. mayors have now signed the Chicago Climate Charter, an agreement that lays out each city's goals to reduce GHG emissions and monitor progress [Ref. 2]. The city of Chicago's press release specifies a pledge of "investing in public transit systems to reduce the carbon footprint; providing safe public transportation and accessible land use and accelerating affordable renewable energy access." [Ref. 3]

Many public transportation agencies are already doing their part in advancing sustainability, especially regarding bus fleets. As new and cleaner technologies become available, the public transit industry is poised to lead in adaptation. In developing a Climate Action Plan, cities and municipalities of all sizes should partner with their local public transit agencies as central players in reducing transportation emissions.[1]

Propulsion Types

Diesel. Diesel has been the traditional propulsion type for the U.S. bus fleet. Significant progress has been made in producing engines that emit fewer nitrogen compounds (NOx) and particulate matter, thanks to use of advanced engines, emission controls and ultra-low-sulfur diesel fuel.

Biofuels. Fuels like ethanol and biodiesel are made from biomass materials and are usually blended with traditional petroleum fuels. Most ethanol is derived from corn and most biodiesel is made from vegetable oils and greases. While they emit slightly less air pollution than petroleum fuels, they also are less efficient per gallon. The primary environmental benefits of biofuels are in the "upstream" cycle, when the biofuel plants absorb carbon dioxide from the atmosphere.

Compressed natural gas (CNG). CNG is a mature technology widely used in U.S. transit fleets as the natural gas supply has skyrocketed from modern shale extraction techniques. CNG has been shown to burn cleaner than other fossil fuels by emitting lower NOx, lower carbon dioxide and virtually no particulate matter. However, CNG results in greater emissions of methane, which is a potent greenhouse gas. CNG also requires significant investments in fueling infrastructure.

Hybrid. Hybrid-electric vehicles rely on a traditional combustion engine and an electric propulsion system. As a fairly mature technology, hybrid-drive buses offer greater efficiency than conventional buses and have the advantage of requiring limited new infrastructure. Batteries recharge through regenerative braking [Ref. 4].

Battery-electric. Battery-electric buses (BEBs) run solely on electric power and have no tailpipe emissions. They also offer the benefit of low exterior and interior noise levels. BEBs are a relatively new technology; advancements have occurred rapidly and are expected to continue. Foothill Transit in West Covina, CA, found that BEBs averaged four times the fuel efficiency of diesel and CNG buses [Ref. 5]. On certain routes, that fuel efficiency advantage increased to eight times that of diesel and CNG buses. Range varies depending on the battery size. Typical manufacturer-advertised ranges are 155 to 225 miles,[2] with some advertising more than 300 miles for new models. Some public transit agencies have not had their expectations met regarding manufacturers' range estimates, as range is significantly impacted by climate,[3] topography, ridership loads and driving behavior [Ref. 6]. Finally, BEBs require notable

[1] This paper serves as an update to APTA's 2012 "Transit on the Cutting Edge of Clean Technology." It provides a layout of where the industry is with regard to electrification and how agencies are planning for the future, with reference to TCRP Synthesis 130, "Battery Electric Buses – State of the Practice" (2018).

[2] Based on standard bus procurement guidelines, conventional buses are expected to have a minimum tested range of 350 miles. According to the National Transit Database, the average distance a bus traveled per day was 117 miles.

[3] The New York Power Authority has found that BEBs use approximately 2.5 times more energy on cold days because of interior heating.

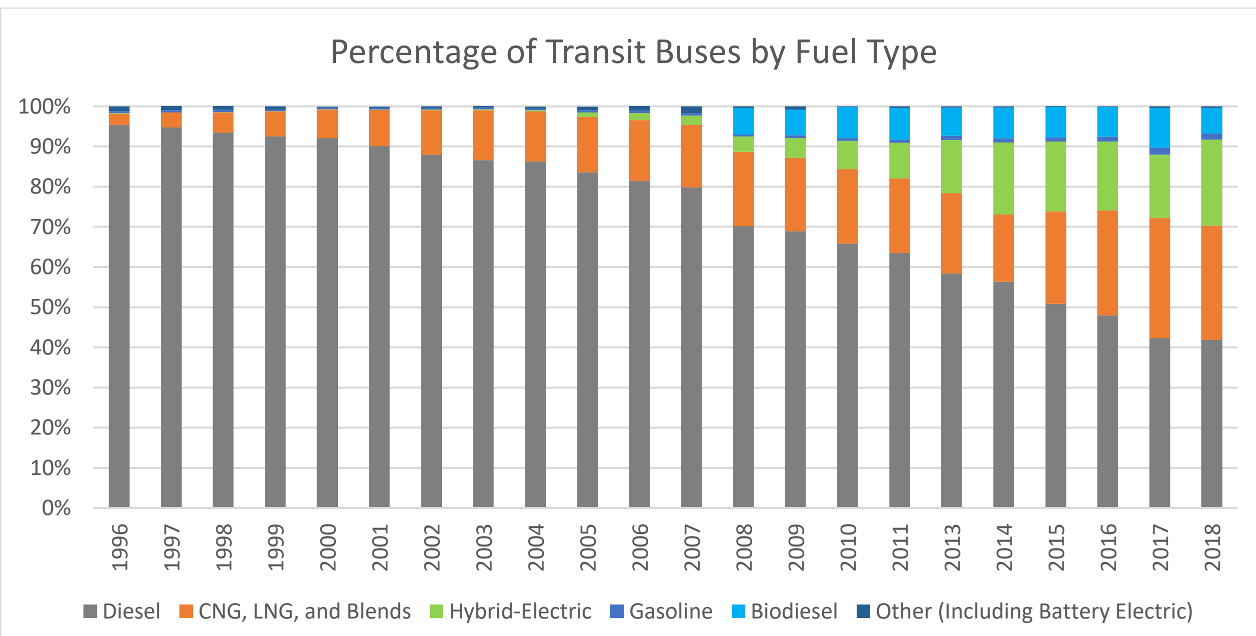
investments in charging infrastructure and have longer refueling (charging) times compared to other propulsion types.

Hydrogen fuel cell electric. Fuel cell electric buses (FCEBs) are electric vehicles powered by hydrogen fuel cells and an electric battery. FCEBs have no tailpipe emissions and have a higher fuel economy compared with conventional buses. These vehicles have a reported range of approximately 250 miles and offer fueling times similar to CNG [Ref. 7]. FCEBs are still a new technology with ongoing development to improve the fuel cell system and lower costs. Hydrogen is not readily available as a vehicle fuel and must be processed in one of several manners in an energy-intensive process. This process contributes to substantial new fueling infrastructure needs at a significant cost to transit agencies.

Breakdown of the Existing Public Transit Bus Fleet

Over the past two decades, a remarkable shift toward alternative fuels in the U.S. public transit bus fleet has occurred. In 1998, fewer than 7 percent of buses were powered by fuels other than pure diesel. In 2018, that number is close to 60 percent as diesel-electric hybrids and cleaner burning CNG buses have picked up significant market share. In 1998, only 5 percent of the bus fleet was estimated to be CNG-powered. Today, that figure exceeds 28 percent. Throughout this period, biodiesel buses have consistently achieved a share of approximately 7 percent of the total fleet.

In 2018, APTA estimated that more than 21 percent of the bus fleet was either hybrid-electric (primarily diesel-electric) or solely electric, compared to only 4 percent a decade ago. Moreover, this percentage of hybrid and electric buses is sizably larger than the 2 percent of automobiles that are hybrid or pure electric [Ref. 8]. In terms of fleet numbers, APTA's 2019 Vehicle Database report recorded 6,256 diesel-electric hybrids and 269 battery-electric buses in active service. External estimates report more than 300 BEBs and approximately 40 FCEBs.

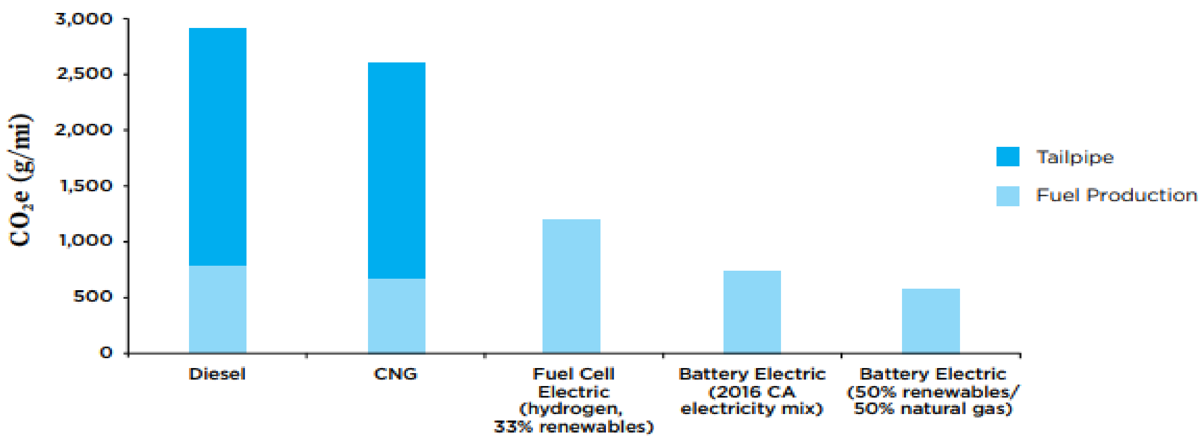


Source: APTA Fact Book Appendix A

Sustainability Benefits of Zero-Emission Buses

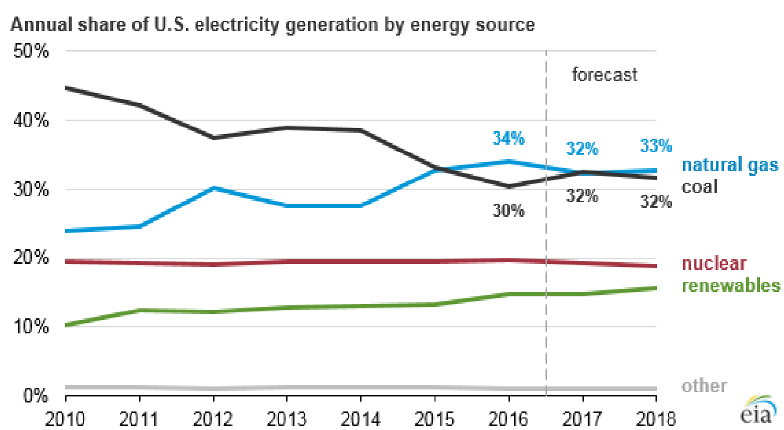
The major driver behind zero-emission buses is sustainability. Electric buses have no tailpipe emissions, resulting in cleaner air for the neighborhoods in which they operate. This factor is important from an equity perspective, as studies have shown that lower-income neighborhoods and communities of color experience higher particulate matter concentrations [Ref. 9]. Higher particulate matter concentrations result in increased asthma rates and other negative health impacts for those areas. Electric buses also result in less noise pollution because they are quieter than buses with combustion engines.

While electric buses have no tailpipe emissions, they can have larger "upstream" impacts (the carbon emissions generated from making electricity) than generated from formulating CNG or diesel fuel. The following chart [Ref. 10] details the life-cycle emissions comparison for different bus fuel options based on two different upstream calculations.[4] The Union of Concerned Scientists notes that, nationally, BEBs can emit 20 to 85 percent less GHGs than conventional buses based on different state electricity formulations.



Source: Chandler et al.

Furthermore, as the United States' electricity generation continues transitioning to renewable sources, battery-electric buses will become more environmentally friendly in the upstream cycle. The chart below shows the substantial decline in electricity generated by coal and growth compared with renewables.



Source: Energy Information Administration.

[4] The 2016 California mix was 45 percent renewable, 36 percent natural gas and 19 percent other.

Capital Costs for BEBs

The upfront price point of electric buses is a current barrier to widespread adoption. A 2018 report found 40 to 50 percent greater capital costs for BEBs than for diesel or CNG buses (i.e., $200,000 - $300,000 more per bus) [Ref. 11]. According to data reported by agencies in APTA's 2019 Vehicle Database, the average capital costs of a BEB delivered in 2018 was approximately $930,000.[5] Some manufacturers are responding by offering leasing programs that enable agencies to buy the vehicle with the same upfront cost as a conventional bus, with annual payments throughout its lifecycle [Ref. 12]. As more electric bus orders are placed, marginal costs should continue to decrease for manufacturers because of economies of scale, leading to further price reductions.

Another major cost factor is the need to install depot plug-in charging stations or high-speed chargers that can be used on-route. The National Academy of Sciences State of Practice listed typical costs as noted in the table, although agencies have found depot charging costs to be higher than those listed here. High-speed on-route chargers reportedly can cost up to $600,000 to install, and location restrictions can complicate implementation on certain routes [Ref. 13]. While depot charging is less expensive than on-route charging, charging is slower and can require overnight docking. In addition, public transit agencies must factor in electrical upgrades to accommodate charging infrastructure especially at large scale deployments.

Deployment Costs	Average
Buses (average per bus)	$887,308
Depot Charging Equipment (per charger)	$50,000
Depot Charging Installation (per charger)	$17,050
On-Route Charging Equipment (per charger)	$495,636
On-Route Charging Installation (per charger)	$202,811

Source: Center for Transportation and the Environment.

Fuel and Maintenance Costs for BEBs

Analysis from the California Air Resources Board indicates that an electric bus can save as much as $458,000 in fuel and maintenance costs compared with a diesel bus over its life cycle (or $336,000 in savings compared with a CNG bus) [Ref. 14].

Maintenance savings can be realized with BEBs because they don't require oil changes, they don't have transmissions and their brakes are expected to last longer. The National Renewable Energy Laboratory (NREL) reported that BEBs can travel more than twice the distance of natural gas buses before needing to be serviced [Ref. 15].

However, some public transit agencies are not realizing projected fuel and maintenance cost savings. While Foothill Transit previously projected a $135,000 reduction in maintenance costs and $225,000 in fuel savings over the lifecycle of one BEB [Ref. 16], the agency is currently experiencing greater costs compared to its CNG buses [Ref. 17]. The current limited supply chain for BEB parts is one factor limiting the ability of agencies to achieve these savings. Major contributors to Foothill Transit's BEB costs include higher part costs after the warranty period, unscheduled labor costs and low-voltage battery replacements.

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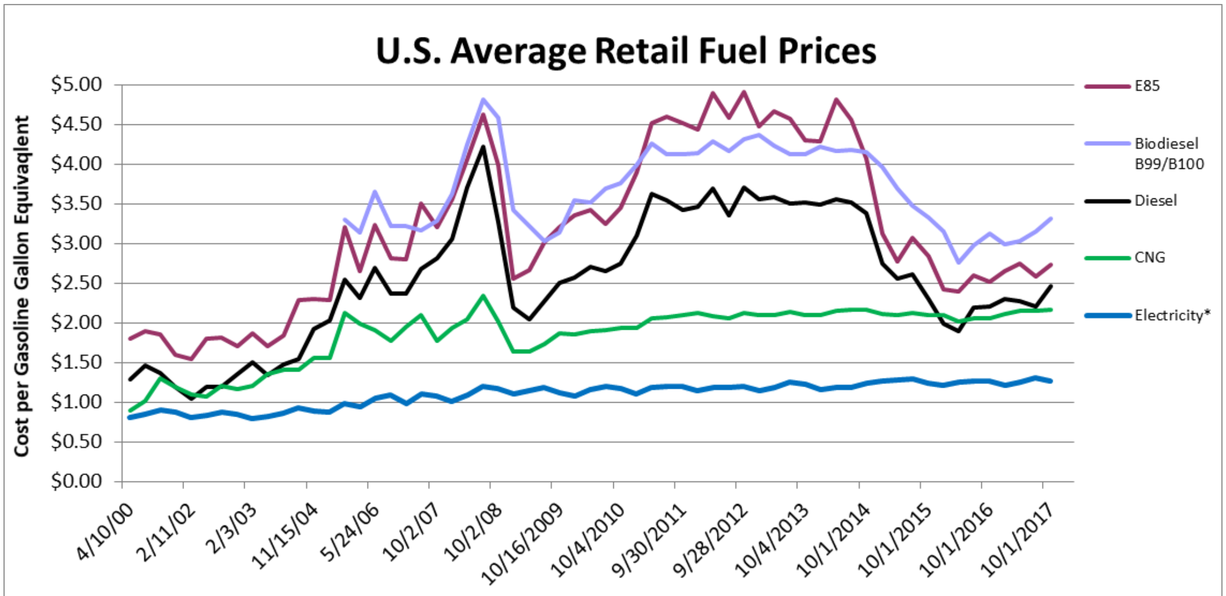
[5] Sample size of 10 agencies, 72 buses.

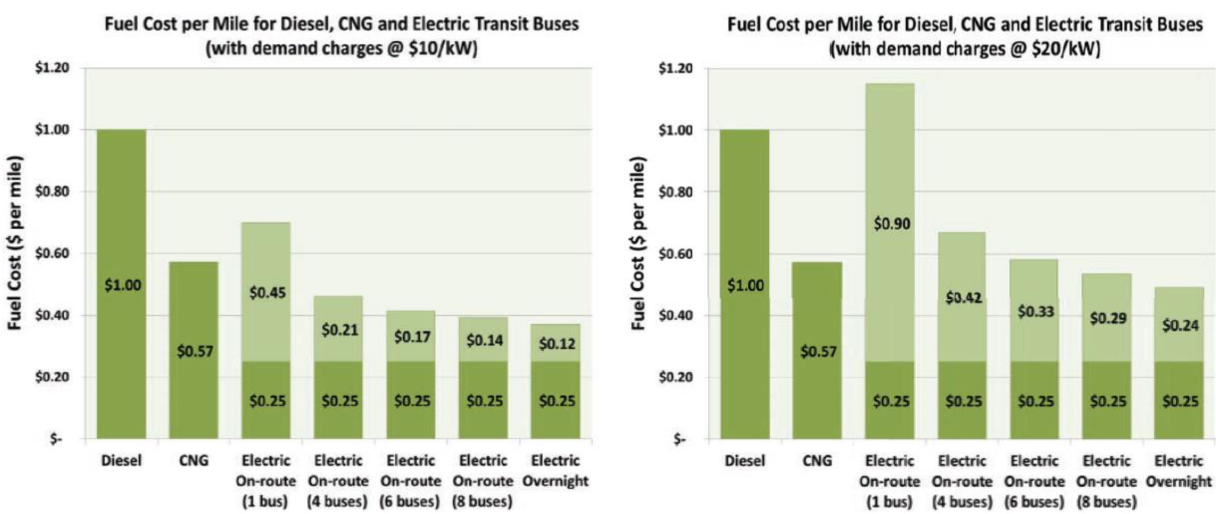


*Electricity prices are reduced by a factor of 3.4 because electric motors are approximately 3.4 times as efficient as internal combustion engines. FTA's bus testing of New Flyer buses confirms these estimates.

Source: U.S. Department of Energy, www.afdc.energy.gov/data/

Electricity can be a less expensive source of fuel on a per-mile basis than diesel. As the chart above shows, U.S. electricity prices have been consistently lower than other fuels; they are also more stable than conventional fuels, which can have significant spikes in short periods. Over time, this could appeal to transit agencies, which value cost stability. However, to realize this benefit, agencies must manage and optimize their electricity use carefully with BEB deployments. Unlike conventional fuels, electricity rates fluctuate depending on location, time of usage and demand charges (fees based on the rate of electricity drawn [kWh/h]). These different rates can create complexity for public transit agencies when identifying how and when to charge their BEBs. Agencies need to work closely with their utilities to manage these costs.

The following figure contains average per-mile costs for different fueling options and different demand charges for electricity, assuming a diesel price of $4 per gallon. According to the National Academy of Sciences survey, $0.36 was the average per-mile electricity cost experienced by agencies [Ref. 18].

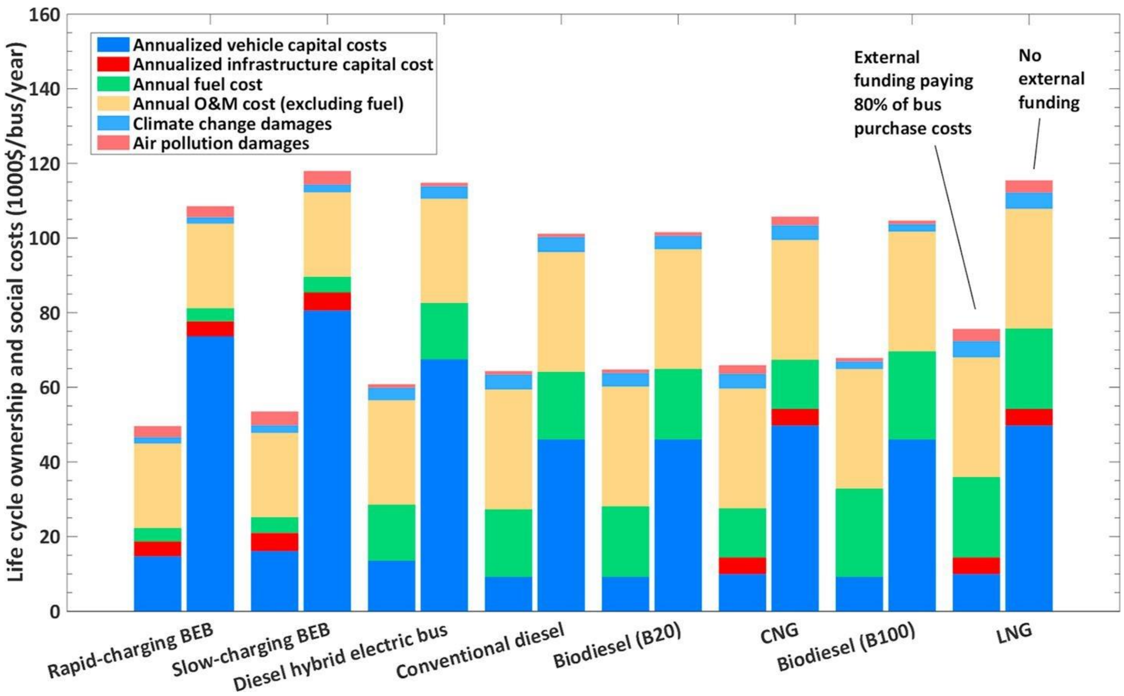


Source: National Academies of Sciences, Engineering, and Medicine

The Economics of BEBs: Life-Cycle Costs

The overall economics of BEBs are intriguing public transit agencies and municipalities and will be a major factor in determining how quickly these organizations will be able to adopt the vehicles. While BEBs have higher upfront costs and require infrastructure investments, transit agencies are interested in the potential for lower operating and maintenance costs. Since BEBs are still in early stages of deployment, agencies are assessing these claims in practice and are working in collaboration with manufacturers, utilities and other stakeholders to minimize costs.

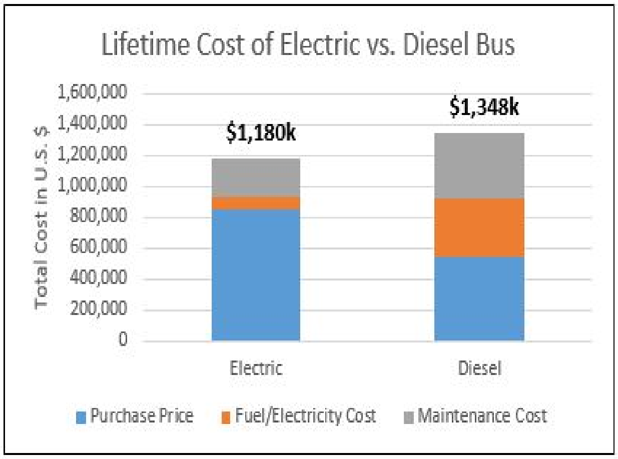
Research conducted by Carnegie Mellon University in 2017 indicates that, with external funding of bus capital costs, BEBs have a significant advantage when it comes to overall life-cycle costs [Ref. 19]. Note that social costs such as air pollution and climate change damages are estimated for each fuel type and included in the chart below.

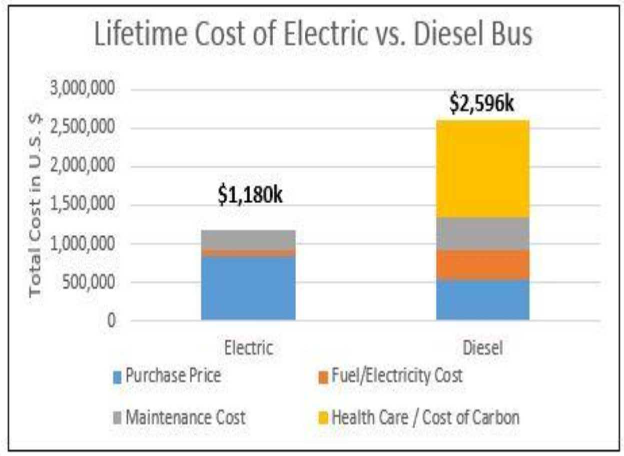


Source: https://www.sciencedirect.com/science/article/pii/S136192091630476X#f0025

A 2016 Columbia University analysis sponsored by MTA New York City Transit also found a clear, long-term cost incentive for electric buses compared to conventional fuel buses when the estimated health and sustainability benefits are included. Decreased particulate emissions reduce the prevalence of heart and lung diseases and provide significant health care savings. These benefits explain why many policy leaders are advocating for BEBs as better for public transit agencies and communities. These early estimates provide helpful information on potential cost incentives for adopting BEBs, although transit agencies are still evaluating lifetime costs based on actual experience.

Estimated Lifetime Costs for BEBs





Analysis depicting the estimated lifetime costs of electric buses with associated health benefits (right) and without (left)

Source: Judah Aber, Electric Bus Analysis for MTA New York City Transit, Columbia University, May 2016. *http://www.columbia.edu/~ja3041/*

Hydrogen FCEBs Providing Zero-Emission Alternative for Agencies

While more expensive than BEBs, FCEBs are experiencing increased interest from the public transit industry, providing agencies with another zero-emission alternative. NREL reports that FCEB prices average around $1.3 million, approximately $900,000 less than in 2008, and they are projected to drop by an additional $400,000 over the next several years [Ref. 20]. According to NREL, there were 35 active FCEBs in 2018, with an additional 39 in planned development [Ref. 21].

Public transit agencies that own FCEBs appreciate their quick refueling times, reportedly around 10 minutes, and longer range compared to BEBs. These characteristics enable agencies to operate FCEBs similarly to conventional buses, meaning that agencies are more likely to be able to replace vehicles on a 1:1 ratio. It also means that agencies can increase the scale of FCEBs without the compromises to route planning. FCEBs experience limited disruption in cold weather (which differs from the BEB experience to date) because one of the byproducts of the fuel cell process is heat [Ref. 22]. This heat can be directed toward the interior and eliminate the need for onboard auxiliary heaters. From a sustainability perspective, FCEB proponents tout that the buses produce less battery waste compared to BEBs, since fuel cells can be refurbished several times before the end of their useful life, whereas the batteries in BEBs cannot.[6]

While there is no need for charging infrastructure with FCEBs, they do typically require the agency to install hydrogen fueling infrastructure on-site. The Orange County Transportation Authority (OCTA) in Orange, CA, found that building an on-site hydrogen station would save costs long-term over buying hydrogen on the open market. This finding is attributable to the higher price of hydrogen per kilogram on the open market and the increased labor costs involved with transporting hydrogen from an off-site station [Ref. 23]. Other agencies operating FCEBs have come to this realization as well, causing them to plan diligently ahead of deployment. The Champaign-Urbana (IL) Mass Transit District has reported that its infrastructure investment was $8 million, which will fuel the system's first two 60-foot FCEBs in 2020. Even with on-site infrastructure, the current costs of hydrogen exceed that of traditional fuels, although Shell International

[6] Both FCEBs and BEBs incur midlife replacement costs.

believes parity with diesel is possible with economies of scale and sustained hydrogen infrastructure investments [Ref. 24].

Policy Drivers

A variety of federal and state policies have been, and will continue to be, major drivers in the conversion to zero-emission vehicle fleets at public transit agencies. The federal Clean Fuels Grant program, established by the Transportation Equity Act for the 21st Century, and the Transit Investments for Greenhouse Gas and Energy Reduction Grant program, created in the American Recovery and Reinvestment Act of 2009, jump-started clean energy technology adoption for many transit agencies over the past 15 years. This section briefly lists current federal, state and private incentives for zero-emission buses.

Low or No Emission Grants (Low-No)

The central federal policy driver[7] for clean public transit technology has been the $55 million annual Low-No grants (49 U.S.C § 5339(c)) funded under the FAST Act through FY 2020 [Ref. 25]. Pursuant to the Transportation, Housing and Urban Development, and Related Agencies Act, 2019 (P.L. 116-9), the program received an additional $30 million for a total of $85 million in FY 2019. These grants can support transit agencies with the cost differential between a zero-emission bus and a conventional bus, as well as with acquiring relevant charging and electric infrastructure. Additional federal funding could enhance testing and infrastructure buildout to further facilitate the transition to a zero-emission bus fleet.

Buses and Bus Facilities Formula and Competitive Grants

This program provides grant money (through formula allocations and competitive grants) to states and public transit agencies to replace, rehabilitate and purchase buses and bus-related facilities or equipment [Ref. 26]. While the formula component is an extension of the general formula bus program, the competitive program is based on asset age and condition. Note that the Low-No grants are a sub-program of the Bus and Bus Facilities competitive program, which received $423.3 million in FY 2019. However, transit agencies may use other funds from the Buses and Bus Facilities program, both formula and competitive, for low/zero-emission buses and infrastructure, even if they do not come from the Low-No program.

Capital Investment Grants (CIG) and Better Utilizing Investments to Leverage Development (BUILD) Grants

Several Bus Rapid Transit (BRT) projects in the CIG program include the purchase of electric buses for corridor operations. In 2018, the Indianapolis Public Transportation Corporation (IndyGo) received a $75 million Small Starts Grant Agreement that included the purchase of 13 60-foot BEBs; operations began in September 2019. Currently, IndyGo, the Urban Redevelopment Authority of Pittsburgh and the Spokane (WA) Transit Authority are all in the project development phase with BRT projects that include BEB purchases.

BUILD grants are another resource for public transit agencies seeking to acquire zero-emission buses. In the FY 2019 awards, the Antelope Valley Transit Authority, Lancaster, CA, was awarded $8.7 million to purchase BEBs and corresponding chargers. The Brazos (TX) Transit District was awarded a $14 million grant in the FY 2018 awards for a similar bus replacement.

Volkswagen Clean Air Act Civil Settlement

[7] Public transit agencies may also use transit formula, Federal-Aid Highway Congestion Mitigation and Air Quality Improvement, and other funds to acquire zero-emission buses.

Volkswagen's 2016 settlement for violating the Clean Air Act is providing $2.8 billion to states for diesel emissions reduction. States are already taking advantage of the funds by investing in zero-emission buses. For example, Rhode Island will invest the majority of its $14.4 million on electric buses and charging stations [Ref. 27]. Colorado announced in 2019 that it would be awarding nearly $14 million of its settlement funds to six public transit agencies for alternative fuel vehicles, including 24 BEBs [ref. 28]. Finally, New York State will devote $52.4 million, or 40 percent, of its settlement funds to purchase approximately 100 BEBs [Ref. 29].

State Mandates and Incentives

Many state programs are also encouraging the transition to cleaner power sources. For example, California's cap-and-trade program provides funding to the California Air Resources Board (CARB), which has distributed grants to several public transit agencies for zero-emission buses.[8] In December 2018, CARB unanimously approved a statewide mandate for transit agencies to transition to electric fleets by 2040 [Ref. 30]. After 2029, agencies will be prohibited from purchasing diesel- or gas-powered buses. The mandate will require the purchase of more than 12,000 zero-emission buses and it is estimated that full implementation of the regulation will reduce GHGs by 19 million metric tons from 2020 to 2050 and reduce maintenance, fuel and other costs by $1.5 billion. Many California public transit agencies have already begun purchasing zero-emission buses and made significant electrification pledges. Other states in addition to California are also adopting zero-emission vehicle goals for passenger and transit vehicles. For instance, in July 2019, New York passed the Climate Leadership and Community Protection Act, which aims to transition to carbon-free electricity by 2040 and have net-zero carbon emissions by 2050 [Ref. 31].

Utility Partnerships

Public transit agencies pursuing BEBs are encouraged to have conversations early on with their utility providers. Utilities have an interest in supporting BEBs and are critical to helping transit agencies understand and manage electricity costs, which can vary widely depending on the BEB charging strategy. In some cases, utility companies are subsidizing, building out or operating charging infrastructure for BEBs. For example, the Portland General Electric Company is installing and managing six bus charging stations to support an electric bus route for TriMet in Beaverton, OR [Ref. 32]. This assistance is particularly valuable for public transit agencies if it enables them to avoid the procurement process for charging infrastructure. Utilities may also develop unique rate structures for transit agencies that can help them avoid perilous demand charge fees. Not all utilities are able to take on this role, but they will remain key partners in planning and running a successful BEB fleet expansion.

Notable Electric Bus Leaders and Significant Transition Announcements

This section is an overview of public transit agencies that have been begun adopting zero-emission buses as well as setting larger policy goals for fleet electrification and sustainability. It should be noted that many of these agencies, such as Foothill Transit and Los Angeles Metro, have already made the transition from diesel to CNG for their fleets.

Alameda-Contra Costa Transit District (AC Transit), Oakland, CA

After receiving an $8.5 million CARB grant, AC Transit will acquire 10 FCEBs, nearly doubling the size of its FCEB fleet [Ref. 33]. The agency aims to have all zero-emission buses by 2040. AC Transit began testing FCEBs in 2006 and currently has 13 FCEBs with two hydrogen fueling facilities. It recently recorded a record 32,000 hours of continuous operation of an FCEBs (surpassing the 25,000-hour target), noting a reliability performance at or above conventional buses. In addition, the agency is doing a direct side-by-side

[8] The California Energy Commission's Clean Transportation Program is also investing in electric charging and hydrogen infrastructure.

comparison of FCEBs and BEBs on the same routes, which will provide invaluable information for the rest of the industry. The agency is currently seeking to replace 20 to 40 diesel buses with BEBs [Ref. 34].

Chicago Transit Authority (CTA)
After experiencing success with two battery-electric buses in 2014 and 2015 (funded by a $2.5 million Federal Transit Administration (FTA) grant), CTA will purchase 20 additional electric buses by 2020, to be used on several high-ridership routes [Ref. 35]. This $32 million investment also includes necessary charging infrastructure. CTA reports that its two electric buses have saved more than $54,000 annually in fuel and maintenance costs compared with diesel buses [Ref. 36]. In April 2019, the Chicago City Council approved a resolution to transition the CTA fleet to 100 percent electric by 2040 [Ref. 37].

Foothill Transit
Foothill Transit is committed to an all-electric bus fleet of more than 300 vehicles [Ref. 38]. The agency began acquiring BEBs in 2010 and currently operates 30 BEBs. The BEB fleet includes quick-charge buses with a range of 35 miles and a recharging time of 10 minutes as well as longer-range models that can travel approximately 250 miles on one charge. Foothill Transit recently announced plans to acquire an all-electric double-decker bus in 2019, which can carry more than twice as many customers as its 40-foot buses [Ref. 39]. Finally, the agency estimates a 2,616-ton reduction in GHG emissions over the last six years because of its BEBs.

IndyGo, Indianapolis
For its new BRT line, IndyGo bought 31 60-foot electric buses with contractually obligated ranges of 275 miles. (The manufacturer is required to install and pay for wireless charging pads to meet this contract requirement.) IndyGo already had 21 BEBs in its fleet since 2016 (facilitated by a $10 million U.S. DOT TIGER grant), with a range of 130 miles and operating costs one-fourth the amount of conventional diesel buses [Ref. 40]. The agency plans to operate a 100 percent electric bus fleet by 2035 [Ref. 41].

King County Metro Transit
King County Metro in Seattle was the first public transit agency to adopt 60-foot diesel-electric hybrids and now has the largest fleet order of battery-electric buses. By 2020, it will have acquired 120 all-electric buses, 73 of which are to cost approximately $754,000 each [Ref. 42]. The agency's reported charging station infrastructure costs range between $5.5 million and $6.6 million. In 2016, King County Metro received a $3.3 million FTA grant for existing BEBs and charging infrastructure.

Los Angeles County Metropolitan Transportation Authority (LACMTA)
In 2017, the LACMTA board adopted a policy of converting its entire fleet to zero-emission vehicles by 2030, contingent on continuous BEB technology advancement and future price decreases. As a first step, the agency has purchased 40 60-foot articulated electric buses and associated charging infrastructure for $80 million, to be used on its Orange Line BRT line. The agency also has an approved contract for 60 new 40-foot BEBs that will help convert the Silver Line to all-electric by 2021 [Ref. 43]. It has said that on-route chargers will be needed as part of their electrification rollout.

Metro Transit, Madison, WI
The city of Madison has announced a goal to convert its bus fleet to 50 percent electric by 2035. A $1.3 million FTA grant will help the city purchase three electric buses in 2020 at a price of $667,000 per bus [Ref. 44].

MTA New York City Transit (NYCT)

NYCT was the first public transit agency to adopt 40-foot, diesel-electric hybrid buses and now plans to have an all-electric fleet at least by 2040 [Ref. 45]. NYCT operates the largest bus fleet in the country with more than 5,700 buses and currently is leasing 10 BEBs. Earlier this year, NYCT placed an order for 15 60-foot BEBs, with plans to add another 45 buses by 2020 [Ref. 46].

San Francisco Municipal Transportation Agency (SFMTA)

SFMTA has announced that it will purchase only all-electric buses by 2025 to have a completely all-electric fleet by 2035 [Ref. 47]. The agency is currently testing BEBs from different manufacturers to see how the buses handle the city's heavy ridership and challenging topography. Muni already operates the largest fleet of zero-emission electric trolleybuses (250 buses), with electricity provided from GHG-free hydropower. This move is crucial to the city of San Francisco's commitment to a net-zero carbon footprint by 2050. Finally, SFMTA's ongoing transition to diesel-electric hybrid buses has already reduced fuel consumption by 5.4 million gallons over 12 years. This new "green zone" initiative enables these hybrids to switch to battery mode in neighborhoods with high concentrations of low-income households to reduce their exposure to vehicle emissions [Ref. 48].

Stark Area Regional Transit Authority (SARTA), Canton, OH

SARTA currently has 13 hydrogen FCEBs and a hydrogen refueling system. Each bus cost approximately $1.4 million and was funded by different federal grant programs [Ref. 49]. The agency has recorded a 50 percent increase in fuel efficiency over diesel buses.

Transit Authority of River City (TARC), Louisville, KY

TARC operates 15 all-electric buses on downtown circulator routes and a branch of its busiest route [Ref. 50]. The electric buses constitute approximately 7 percent of its total fleet. In April 2019, TARC received $1.56 million in federal Congestion Mitigation and Air Quality Improvement funds to add two additional electric buses to its fleet [Ref. 51].

In the Future: Public Transit Leads the Automobile Industry

Several key indicators point to the continued adoption of electrified vehicles in both public transit and the passenger automobile sector. To make electric vehicles more competitive and accessible, it will be critical to lower the cost of batteries and their key elements, particularly cobalt, as well as to ensure the continued proliferation of charging infrastructure. Since 2010, the price of lithium-ion batteries has decreased from $1,000/kWh to $200/kWh and is projected to further decrease to $62/kWh by 2030, which will further narrow the price gap between electric powertrains and combustion engines [Ref. 52]. Foothill Transit noted that the capital costs of its electric bus orders fell by 21 percent from 2009 to 2015 [Ref. 53]. Bloomberg New Energy Finance analysts predict that BEB upfront costs will be cheaper than diesel buses in most countries by 2030 [Ref. 54].

While significant attention is given to electrification in the auto market, public transit is already leading the way in terms of electric vehicle implementation. Although current U.S. BEB sales are only 5 percent of the market, forecasts for the electric bus share of the market range from 27 percent of new U.S. sales (Navigant Research) to 50 to 60 percent (CALSTART) by 2030 [Ref. 55]. For comparison, EVs currently make up around 2 percent of car sales. A Bloomberg New Energy Finance report forecasts that 84 percent of global bus sales will be electric by 2030, reflecting an incredible acquisition of BEBs in Asia [Ref. 56]. Meanwhile, forecasts for light-duty vehicles in the U.S. project a slower adoption, with just 60 percent of new car sales being electric by 2040 [Ref. 57].[9]

As the swift transformation of the U.S. public transit fleet to CNG, hybrid and biodiesel demonstrates, public transit has the potential to shift rapidly toward new fuels when the industry makes a commitment. Existing and future fleet electrification commitments by transit agencies could lead to 75 percent of transit buses being zero-emission by 2040 [Ref. 58]. The promise of further technological innovations in producing lighter, cheaper and more efficient buses gives transit agencies optimism that they will be able to completely transition to zero-emission buses in the next few decades. This bold transformation will result in significantly reduced fossil fuel consumption and emissions. The adoption of zero-emission buses also brings the benefits of electrification to a wider range of communities than the automotive market.

Conclusion

Although the federal government is no longer setting climate goals to reduce GHG emissions, cities and municipalities are increasingly stepping up to set specific goals and curb these emissions. The transportation sector is now the largest greenhouse-gas-emitting sector. Public transit agencies are natural allies in this fight for a cleaner environment. As part of that fight, the transition to a cleaner and more efficient vehicle fleet will be central to achieving sustainability goals.

Fortunately, the public transit bus fleet has already made substantial improvement in adopting cleaner vehicles, with hybrid-electric buses representing more than 21 percent of the fleet. Transit agencies are now targeting zero-emission buses as the next phase in this progression. Market forces will help to decrease the costs of these technologies and enhance their effectiveness. However, the sustainability benefits of zero-emission buses are already apparent, with significant reductions in greenhouse gases and particulate matter.

While it appears as if battery-electric buses will be the choice for most agencies, fuel cell electric buses provide an alternative for agencies in transitioning to zero emissions. As public transit agencies set targets for electric fleets, continued support from federal and state governments will ensure that the technology further proliferates. They will also help develop solutions to workforce transition challenges, infrastructure design and facility retrofitting. Finally, strong partnerships and clear targets will be essential as public transit continues to pioneer the transition to new technologies.

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