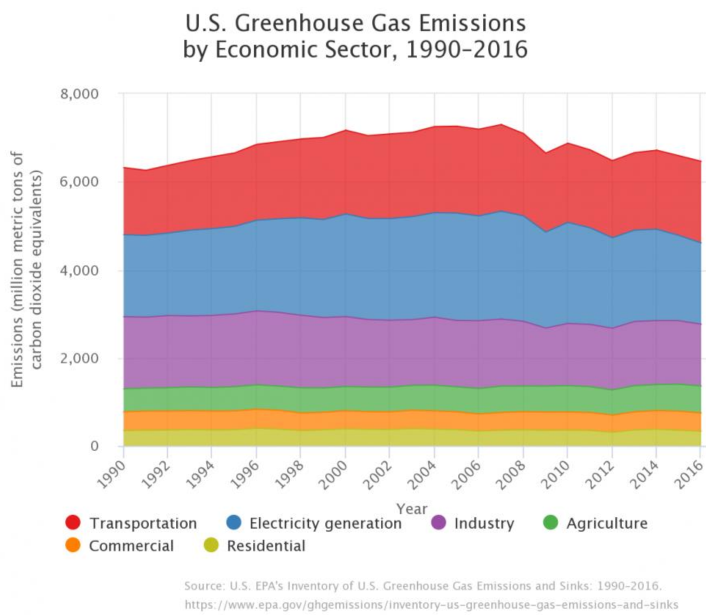
POLICY BRIEF

Public Transit Leading in Transition to Clean Technology

Key Takeaways

- → The transportation sector is the largest greenhouse-gas-emitting sector. Moving to cleaner fuel sources can help reduce emissions and can be a key component of a region's Climate Action Plan
- → Transit bus fleets are undergoing a dramatic shift in their makeup, with more than 21 percent of the vehicles being hybrid-electric in 2018 and with transit agencies testing pure electric buses
- → While capital costs for battery electric buses remain higher than those of traditional buses, lifetime costs of battery electric buses have been shown to be lower and have additional positive externalities compared with traditional buses
- → Federal and state grant programs have been vital resources for public transit agencies nationwide in acquiring new electric vehicles

Although the United States is no longer a leader at a federal level with respect to climate initiatives, cities around the country are pledging to curb emissions. Transportation will be a critical part in this, as it currently accounts for 28.5 percent of total U.S. greenhouse gas (GHG) emissions and is the largest emitting sector [Ref. 1]. Furthermore, advancing alternative fuel sources that reduce or eliminate nitrogen oxides and particulate matter emissions has been shown to have health benefits.



Many public transportation agencies are already moving forward, especially with regard to bus fleets. As new and cleaner technologies continue to be made available, the transit industry is poised to lead in adaptation. In developing a Climate Action Plan, cities and municipalities of all sizes should incorporate their local public transportation agencies as an central player in sustainability.

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 special reference to TCRP Synthesis 130, "Battery Electric Buses – State of the Practice."

Propulsion Types and Emission Comparison

Diesel. Diesel, a fossil fuel refined from crude oil, has been the traditional propulsion type for the U.S. bus fleet. Significant progress has been made in utilizing more efficient engines that emit less nitrogen compounds (NOx) and particulate emissions, by running on ultra-low sulfur diesel fuel. Diesel buses have a range[1] of around 700 miles.

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 traditional 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. Biofuel buses have a range of approximately 700 miles.

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 strong greenhouse gas. CNG also requires significant investments in fueling infrastructure. CNG buses have a range of about 600 miles.

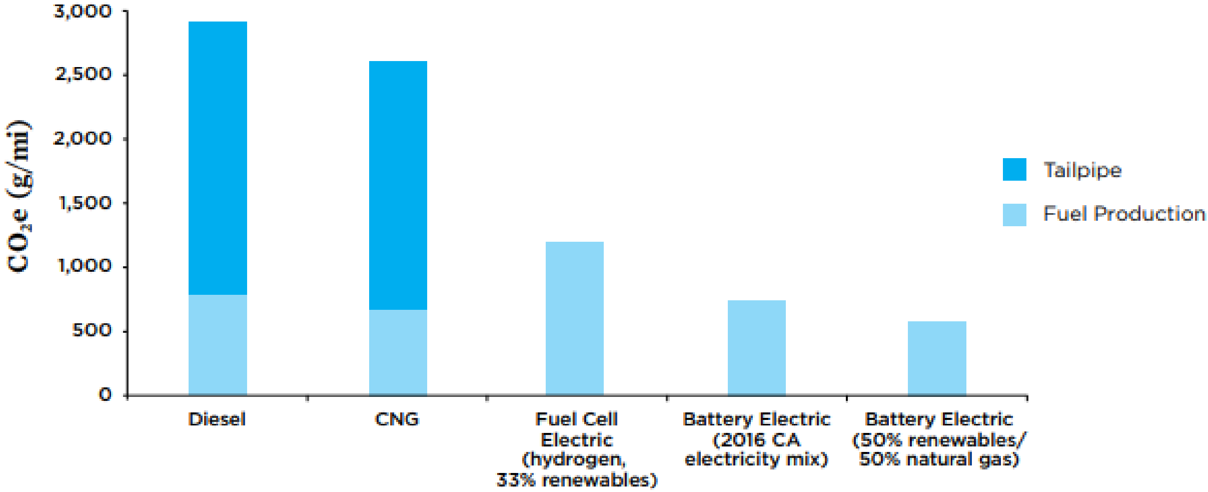
Hybrid. Hybrid-electric vehicles rely on a traditional combustion engine and an electric propulsion system. A fairly mature technology, hybrid-drive buses offer greater efficiency than traditional buses and have the advantage of requiring limited new infrastructure. Batteries recharge through regenerative braking [Ref. 2]. Hybrid-electric buses have a range of around 720 miles.

Battery electric. Battery electric buses (BEBs) are relatively new to commercialization, so continued advancement is expected. These vehicles run purely on battery electric power and have no tailpipe emissions. They do require significant investments in charging infrastructure and charging times can vary depending on the model. Vehicle ranges are improving, with an increasing number of buses able to travel over 200 miles per charge and some manufacturers advertising 350-mile ranges for new models. The range is affected by climate, topography, ridership loads and driving behavior [Ref. 3]. However, it has been shown that depending on the route, battery electric buses can be up to eight times more efficient than diesel and CNG buses [Ref. 4]. Battery electric buses also have lower exterior and interior noise levels than other buses.

Hydrogen fuel cell electric (FCE). FCE buses are electric vehicles powered by hydrogen fuel cells and an electric battery. Hydrogen must be processed (typically off-site) in an energy intensive process, contributing to substantial fueling infrastructure needs. They have no tailpipe emissions and have a higher fuel economy compared with diesel or CNG buses. FCE buses have a reported range around 300 miles.

The following chart [Ref. 5] details the life cycle emission comparison for different bus fuel options. While electric buses have no tailpipe emissions, they may have larger "upstream" impacts, meaning that the carbon emissions generated from making electricity can be greater than the emissions generated in formulating CNG or diesel fuel. For battery electric upstream emission calculations, two scenarios are presented, a 50-50 renewable/natural gas mix, and a 2016 California mix, which was 45 percent renewable, 36 percent natural gas and 19 percent other.

[1] Ranges are for 40-foot buses and are sourced from Tong, F., C. Hendrickson, A. Biehler, P. Jaramillo and S.M. Seki, Life Cycle Economic and Social Costs of Alternative Fuel Options for Transit Buses, 2016. https://www.cmu.edu/energy/education-outreach/public-outreach/17-104%20Policy%20Brief%20Buses_WEB.pdf

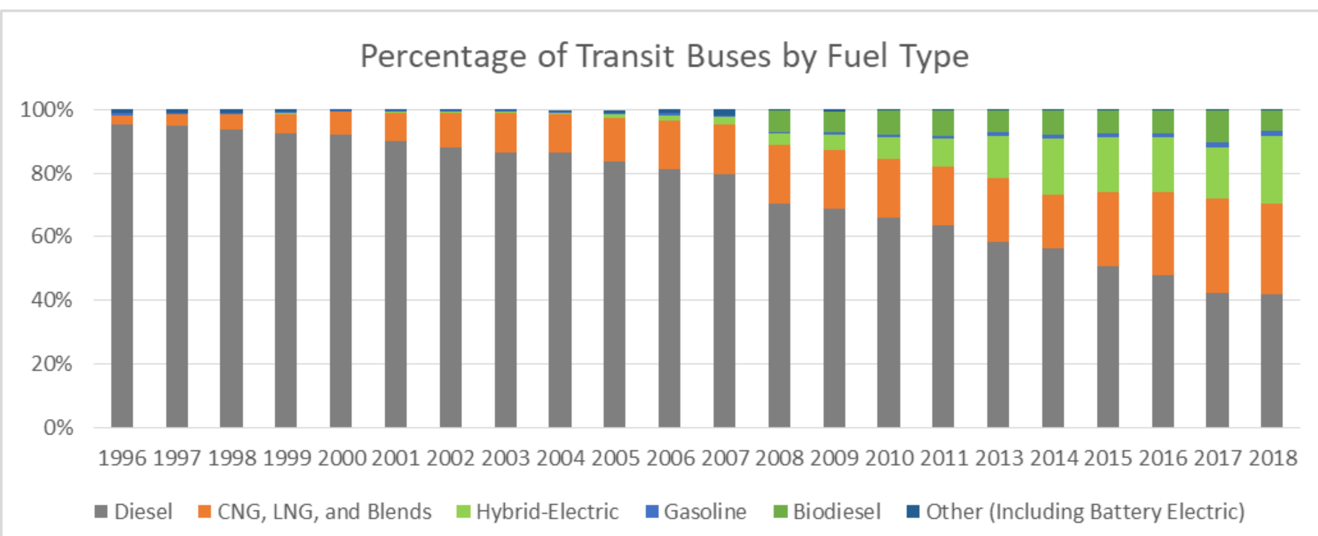


Source: Chandler et al.

Breakdown of the Existing Public Transit Bus Fleet

In the past two decades, we have witnessed a remarkable shift toward alternative fuels in the U.S. transit bus fleet. 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 electric-diesel hybrids and cleaner burning CNG buses have picked up significant market share. In 1998, just 5 percent of the bus fleet was estimated to be CNG-powered. Today, that figure exceeds 28 percent. Meanwhile, biodiesel buses have remained fairly stable in their share of around 7 percent.

In 2018, it was estimated that more than 21 percent of the bus fleet was either hybrid-electric (primarily diesel-electric) or entirely electric. This is more than 17 percentage points higher than in 2008 and is sizably larger than the 2 percent of automobiles that are hybrid or electric [Ref. 6]. APTA's 2018 Vehicle Database report recorded that there were 6,855 diesel electric hybrids and 169 battery electric buses in active service. External estimates report over 300 BEBs out of a 65,000 total U.S. bus fleet.

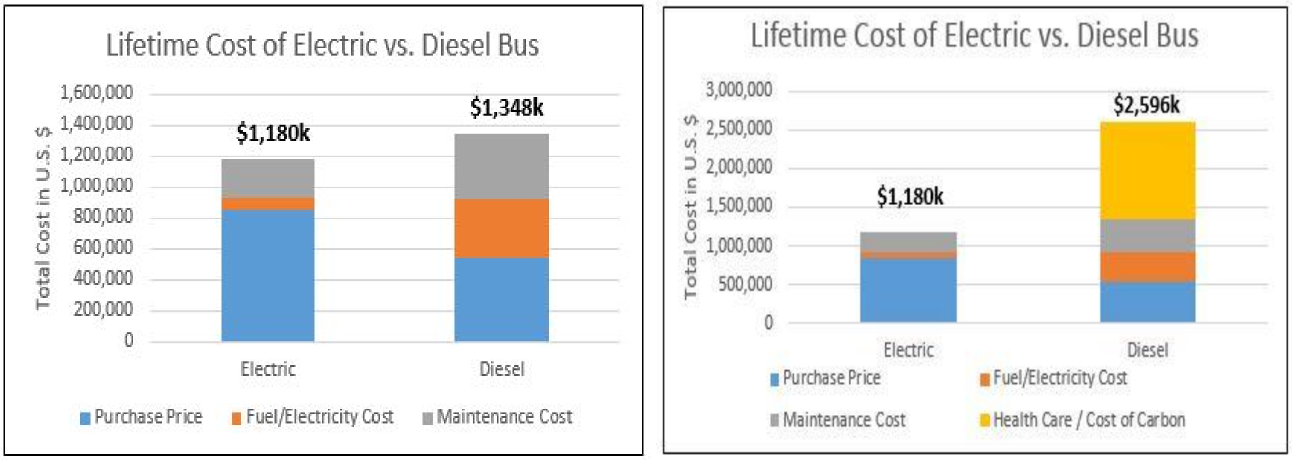


Source: APTA Fact Book Appendix A

The Economics of Battery Electric Buses

The economics of BEBs are shifting, attracting further interest from transit agencies and municipalities. A chart from a Columbia University analysis sponsored by New York City Transit on electric buses shows how the lifetime cost of electric buses provides a long-term cost incentive over diesel buses. When the estimated health benefits associated with decreased pollutants are included, such as decreased particulate emissions reducing heart and lung diseases, the gap further expands. This explains why many policy leaders are advocating for BEBs as better for transit agencies and communities. Early estimates such as these provide helpful information on potential cost incentives for adopting BEBs, though transit agencies are still evaluating lifetime costs in practice.

Capital and Infrastructure 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 New York City Transit, Columbia University, May 2016. http://www.columbia.edu/~ja3041/

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.

The upfront price point of electric buses is still a current barrier to widespread adoption, with reports noting 40 to 50 percent greater capital costs than diesel or CNG buses (around $200,000 to $300,000 more) [Ref. 7]. According to a survey of transit agencies with BEBs done by the National Academy of Sciences in 2017, the average capital costs were under $900,000, though since purchases took place over time, current costs would actually be lower. As more electric bus orders are placed, marginal costs should continue to decrease for manufacturers because of economies of scale, and lead to further price reductions. Foothill Transit noted that the capital costs of its electric bus orders fell by 21 percent from 2009 to 2015 [Ref. 7].

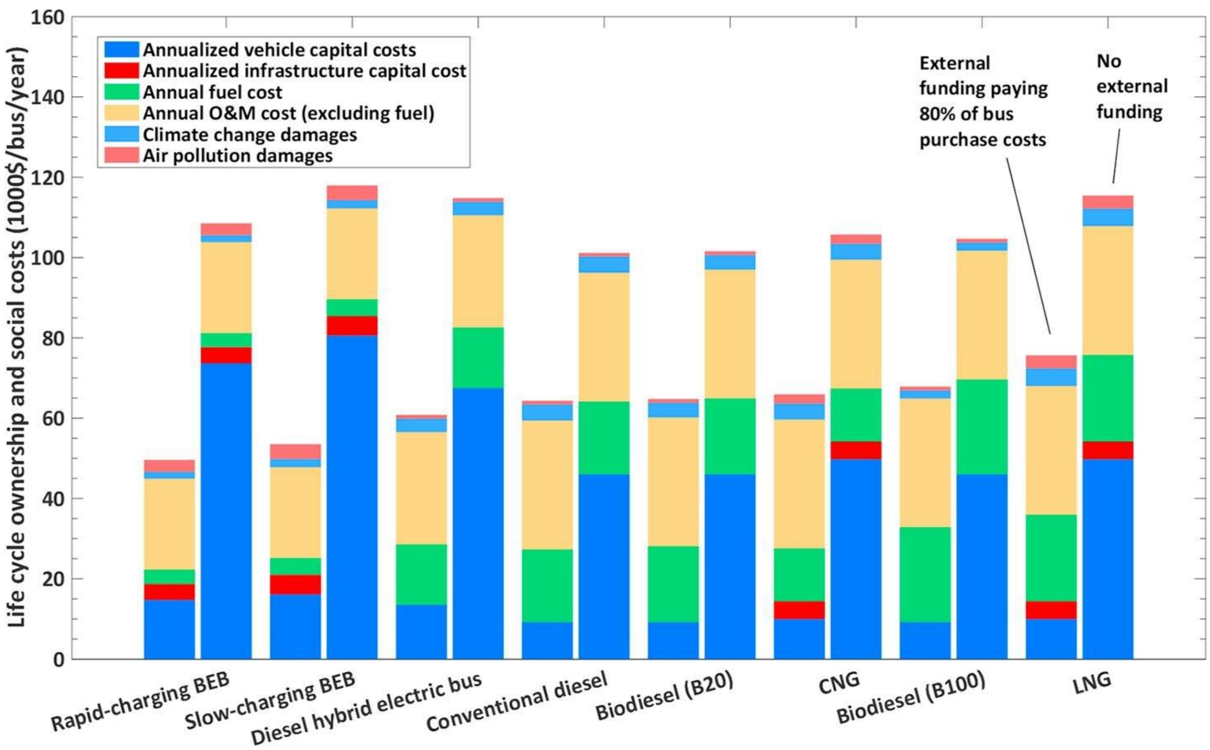
Another cost factor is the need to install depot plug-in charging stations or high-speed chargers that can be utilized on-route. High-speed chargers reportedly can cost up to $600,000 to install, and location restrictions can complicate implementation on certain routes [Ref. 8]. While depot charging is less expensive, charging is slower and can require overnight docking.

Fuel and Maintenance Costs for BEBs

P&S Market Research reports that an electric bus can save as much as $365,000 in fuel costs compared with a diesel bus over its life cycle ($225,000 compared with CNG buses) [Ref. 9]. Altoona-measured fuel economy testing confirms that the average electric bus fuel economy (20.5 miles per diesel gallon equivalent) is more than four times greater than the average CNG and diesel bus fuel economy.

A current electric bus manufacturer contends that the operating costs of electric buses are $0.65 less expensive per mile than diesel buses [Ref. 10]. Further maintenance savings can be realized with BEBs because they don't require oil changes, they don't have transmissions, and their brakes last longer. It is reported that BEBs can travel more than twice the distance of natural gas buses before needing to be serviced [Ref. 11]. It is also noted that the current limited supply chain for BEB parts limits these savings. Again, Foothill Transit is projecting a $135,000 reduction in maintenance costs and $225,000 in fuel savings over the course of the life of one BEB [Ref. 12].

Research done 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. 13]. Note that social costs such as air pollution and climate change damages are estimated for each fuel type and included in the analysis.



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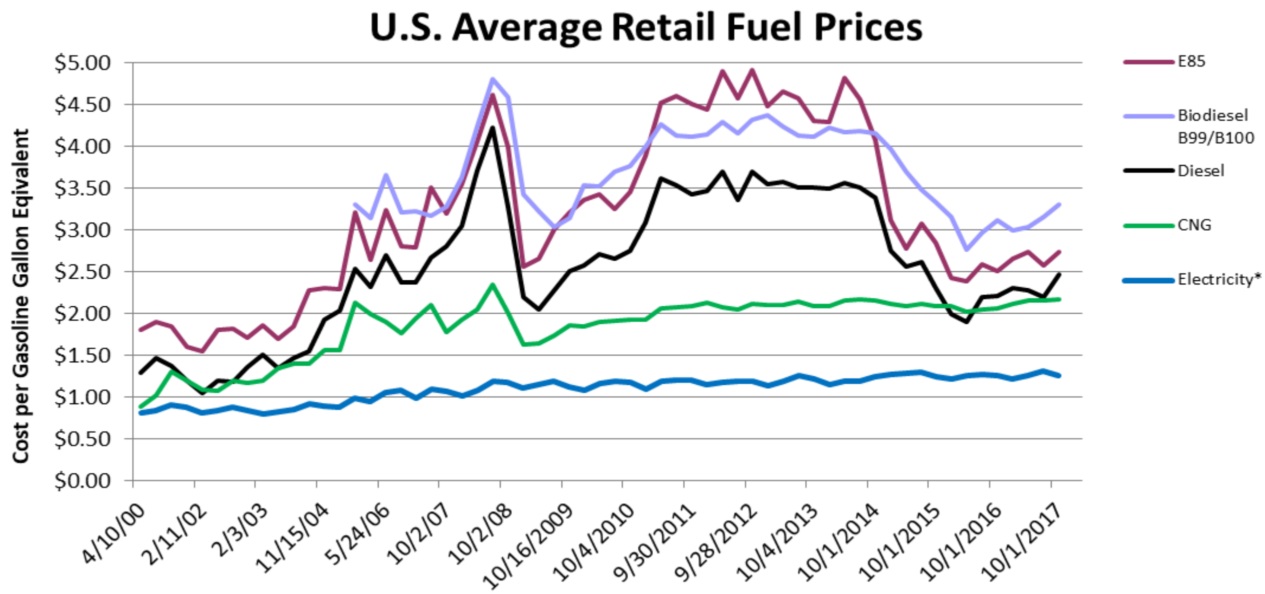
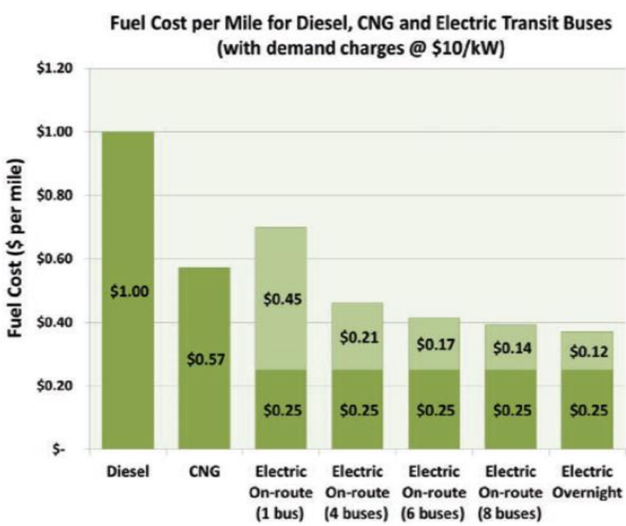
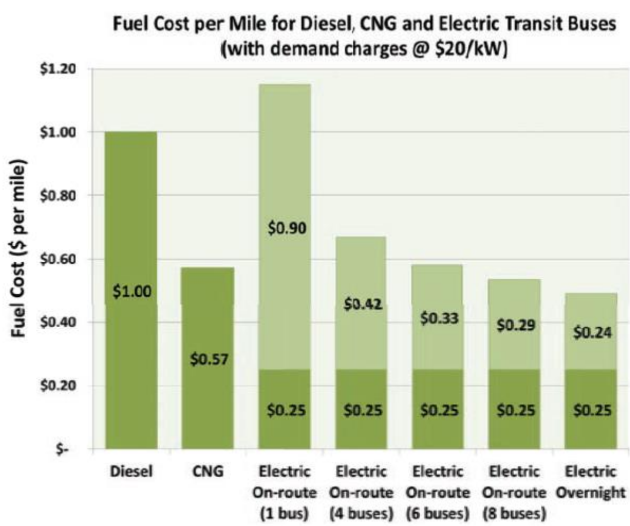


*Electricity prices are reduced by a factor of 3.4 because electric motors are approximately 3.4 times as efficient as internal combustion engines. Altoona testing of New Flyer electric buses confirms this.

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

Historical electricity prices are more stable than conventional fuels such as diesel, which can have significant spikes in short periods. This is appealing to transit agencies, which value cost stability. However, while electricity can be a less expensive source of fuel on a per-mile basis than diesel, electricity rates fluctuate depending on location, time of usage and demand charges (fees based on the rate of electricity drawn [kWh/h]). The following figure contains average per mile costs for different fueling options, and different demand charges for electricity, assuming a diesel price of $4 a gallon. According to a National Academy of Sciences survey, $0.36 was the average per-mile electricity cost experienced by agencies [Ref. 14].





Source: National Academies of Sciences, Engineering, and Medicine

Hydrogen FCE Technology Also Providing Sustainability Options for Agencies

While more expensive than BEBs, fuel-cell technology is also growing in the public transit industry. It is reported that fuel-cell bus prices average around $1.3 million, about $900,000 less than in 2008 [Ref. 15]. According to the National Renewable Energy Laboratory, there were 35 active fuel cell buses in 2018, with an additional 39 in planned development [Ref. 16]. The refueling process is fast for these buses, with reported times of 10 to 20 minutes. While there is no need for on-route charging infrastructure with FCE buses, they do require hydrogen refueling infrastructure. Having a transit agency make its own hydrogen fuel is recommended over buying on the open market, which is more expensive.

Policy Drivers

The 2009 American Reinvestment and Recovery Act provided funds through the TIGER grant program that jump-started clean energy technology for many cities. Since then, the central federal policy driver for clean transit technology has been the $55 million annual Low or No Emissions grant established under the FAST Act through FY 2020 [Ref. 17]. Under the FY 2018 Omnibus passed in March 2018, the program received an additional $29.45 million. 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 state and federal funding could enhance BEB research and testing to further facilitate the transition to a zero-emission bus fleet.

Several BRT projects that will utilize electric buses are making their way through the Capital Investment Grant (CIG) program as well. Indianapolis received a Small Starts Grant Agreement in 2018, and Pittsburgh and Spokane are both in the project development phase.

There are also many state programs that are encouraging the transition to cleaner power sources. For example, California's cap and trade program provides money to the California Air Resources Board, which has distributed grants to several transit agencies for zero-emission buses. In December 2018, the Air Resources Board unanimously approved a statewide mandate for transit agencies to transition to electric fleets by 2040 (over 12,000 buses) [Ref. 18]. After 2029, agencies will be prohibited from purchasing diesel- or gas-powered buses. 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. As mentioned in the next section, many California transit agencies have already made strong electrification pledges.

Volkswagen's 2016 settlement from violating the Clean Air Act is providing a $2.8 billion stimulus to states for diesel emissions reduction. States are already taking advantage of the funds by investing in electric transit buses. For example, Rhode Island will spend the majority of its $14.4 million on electric buses and charging stations [Ref. 19].

Notable Electric Bus Leaders and Significant Transition Announcements

This section is an overview of public transit agencies that have been particularly out front with regard to electric bus adoption and setting larger policy goals for fleet electrification. It should be noted that many of these agencies, such as Foothill Transit and LA Metro, have already made the transition from diesel to CNG for their fleets.

Alameda County Transit (AC Transit)

After an $8.5 million grant from the California Air Resources Board, AC Transit will add 10 FCE buses to its fleet, nearly doubling its FCE fleet size [Ref. 20]. The agency aims to have all zero-emission buses by 2040. AC Transit began testing FCE buses in 2006 and currently has 13. It recently recorded a record 25,000 hours of continuous operation of an FCE bus.

Chicago Transit Authority (CTA)

After experiencing success with two battery electric buses in 2014 and 2015 (funded by a $2.5 million FTA grant), CTA will be purchasing 20 additional electric buses by 2020, to be used on several high ridership routes [Ref. 21]. The $32 million investment also includes necessary charging infrastructure. CTA has noted that its two electric buses have saved CTA more than $54,000 annually in fuel and maintenance costs compared with diesel buses [Ref. 22].

Foothill Transit

In 2016, Foothill Transit committed to an all-electric bus fleet of over 300 by 2030 [Ref. 23]. The agency currently operates 30 electric buses, including quick-charge buses with a range of 35 miles and a recharging time of 10 minutes. It 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. 24]. Finally, the agency estimates a 2,616 ton reduction in greenhouse gas emission because of its BEBs.

IndyGo, Indianapolis

For its new BRT lines, IndyGo is buying 31 60-foot electric buses with ranges of 275 miles. It already has 21 in its fleet (facilitated by a $10 million U.S. DOT TIGER grant), with 130-mile ranges and operating costs one-fourth the amount of a traditional diesel bus [Ref. 25]. Its goal is to replace all diesel buses with electric by 2032.

King County Metro Transit

King County Metro was the first transit agency to adopt 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 up to $754,000 each [Ref. 26]. 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 the entire fleet to zero-emission vehicles by 2030. It announced contracts for the delivery of 95 electric buses within the next four years, and plans on spending $1 billion on new buses over the next decade [Ref. 27]. As a first step, the agency will purchase 35 articulated electric buses for $58.5 million, to be used on its Orange BRT Line, and has an approved contract for 60 new 40-foot BEBs [Ref. 28].

Metro Transit, Madison, Wisconsin

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 it purchase three electric buses by 2019 at a price of $667,000 each [Ref. 29].

NYC Transit (NYCT)

The NYCT president has announced that the agency is planning to have an all-electric fleet at least by 2040 [Ref. 30]. NYCT operates the largest bus fleet in the country (more than 5,700 buses), and currently has 10 all-electric buses (with plans for an order of 60 more by 2019).

San Francisco Municipal Transportation Agency (SFMTA)

SFMTA has announced that it will purchase only all-electric buses by 2025 in order to have a completely all-electric fleet by 2035 [Ref. 31]. Muni already operates the largest fleet (250) of zero-emissions electric trolley 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 electric-diesel hybrid buses has already reduced fuel consumption by 5.4 million gallons over 12 years.

Stark Area Regional Transit Authority (SARTA)

SARTA now has 13 hydrogen fuel cell buses in its fleet. Each bus cost around $1.4 million, which was covered by the federal grant program [Ref. 32]. The agency has recorded a 50 percent increase in fuel efficiency over diesel buses.

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

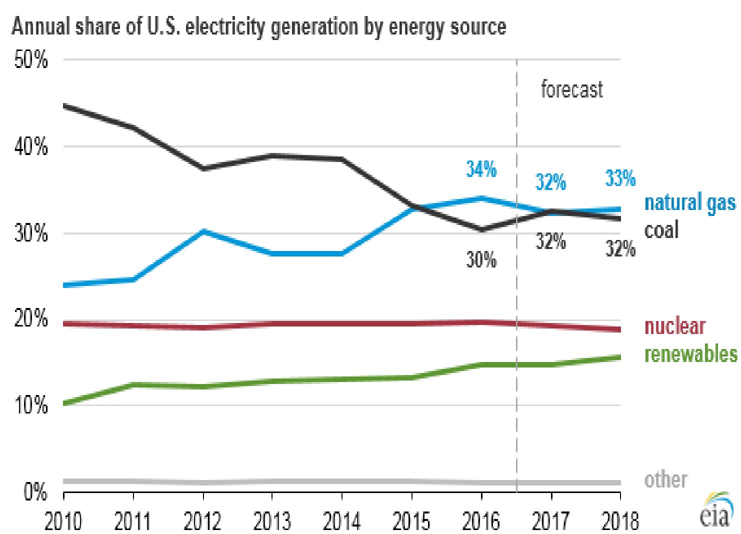
TARC operates 15 all-electric buses on downtown circulator routes and a branch of its busiest [Ref. 33] route. The electric buses constitute around 7 percent of its total fleet.

Electric Vehicle Industry Outlook: Transit Ahead of Automobile Industry

Forecasts for light-duty vehicles show electric vehicles growing in market share significantly (54 percent of new car sales are projected to be electric vehicles by 2040), though EVs currently make up around 1 percent of new vehicle sales. The decreasing price of batteries and the key elements they are made of (particularly cobalt), along with the proliferation of charging infrastructure, will be critical in making electric vehicles more competitive and accessible. Since 2010, the price of lithium-ion batteries has gone from $1,000/kWh to $200/kWh and is projected to further decrease to $70/kWh by 2030, which will further narrow the pricing gap with combustion engines [Ref. 34].

While the public transit industry will continue to benefit from innovations in the auto market, it is already ahead in terms of electric vehicle implementation. While current U.S. BEB sales are only 5 percent, forecasts for electric bus proliferation range from 27 percent of new U.S. sales[2] (Navigant Research) to 50 to 60 percent (CALSTART) by 2030 [Ref. 35]. A recent Bloomberg New Energy Finance report forecasts that 84 percent of global bus sales will be electric by 2030, reflecting the acquisition of BEBs in Asia [Ref. 36]. Electric bus manufacturers are even more optimistic, with one betting that all new bus sales will be electric by 2030. This bold transformation would result in an entirely electric bus fleet within the following decade (as a 12-year lifespan is typical for buses) and significantly reduced fossil fuel consumption. Existing fleet electrification commitments by transit agencies will lead to a substantial increase in BEB sales over the next 10 to 15 years. The promise of further technological innovations gives transit agencies confidence that BEBs will be ready for widespread fleet adoption in the coming years.

Conclusion



As the federal government takes the backseat in the climate change race, cities and municipalities are increasingly stepping up to take on this fight themselves. More than 36 U.S. mayors have now signed the Chicago Charter, an agreement that lays out each city's goals to reduce GHG emissions and monitor progress [Ref. 37]. 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. 39]. With the U.S.'s means of electricity production further transitioning to renewable sources, battery electric buses will become more environmentally friendly in the upstream cycle. Cities and transit agencies are natural allies in

[2] APTA's 2018 vehicle database recorded 2,025 transit buses built in 2017 for agencies and more than 2,068 ordered, 55 of which are BEBs.

the 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.

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APTA Vision Statement

APTA is the leading force in advancing public transportation.